Review of "The climate impact of aerosols on lightning: Is it detectable from long-term aerosol and meteorological data?" by Q. Wang, Z. Li, J. Guo, C. Zhao, and M. Cribb

This paper is an excellent contribution to the literature on the effects of thermodynamics and aerosol on lightning activity, and gets high marks for its efforts to study simultaneously the roles of multiple variables. Only in this way can aerosol and thermodynamic effects get disentangled. Figure 7 is a remarkable result in showing a consistent optimal AOD value (=0.3) for effect of aerosol on lightning, on the basis of climatological datasets alone as I understand it. The two areas in greatest need of attention are the procedures used in the paper to organize the data sets and make specific plots, and the discussion and interpretation of same plots. Further details are provided below through an emphasis on Substantive Issues. This discussion is followed by a detailed editing of the manuscript.

Summary recommendation: Publish after appropriate revision

Substantive Issues:

(1) Data sampling

Coming back to Figure 7, the most important single result in the paper, some comments are in order about data sets and sampling. Maybe the most remarkable aspect of Figure 7 is that it shows consistent behavior with AOD for two regions with very different aerosol characteristics. And somewhere it needs to be stated clearly that the data points in that plot do not represent simultaneous lightning and aerosol measurements on the same storm or in the same grid square, but instead points drawn from two independent climatologies developed over many years of observations, one for lightning and one for aerosol. But still I am confused about the last sentence in the Figure 7 caption which attempts to explain how this figure was created. More details are needed here. For example, are the 10 samples mentioned drawn from only the AOD data set or both the LIS and AOD data sets? And since both lightning and AOD data sets have samples through all the seasons (though with resolution degraded from monthly), are all seasons represented in this plot (and other plots, see below)?

(2) Meteorology versus aerosol

This study is comparing the effects of meteorology (including six meteorological variables) and aerosol on lightning rate. However, to any physical meteorologist, aerosol is a subset of meteorology. Shouldn't the authors be pitting aerosol effects versus thermodynamic effects? I guess then we have a problem because SLP is a variable outside the thermodynamic realm. Please consider.

(3) The lightning quantity is a rate

Lightning is often referred to in this work but the real metric for lightning is a flash rate obtained from the LIS. Hence the suggestion for a slight modification of the paper's title.

(4) "Severe storm" terminology

In a couple of places (lines 59, 162), the severe storm usage appears. The problem here is that a severe storm in USA meteorology is a storm in which very specific thresholds are exceeded: surface wind speed, hailstone size, and the occurrence of a tornado on the ground. The great majority of storms studied here will not be in the severe storm category.

(5) Linking AOD with CCN concentration in per cc

Figure 7 is one of the highlights of this work in showing maximum values of AOD near 0.3 for the impact of aerosol on lightning rate. The value of these results could be extended by linking with CCN, a parameter more closely allied with the cloud microphysics pertaining to lightning and now getting increased attention by virtue of Rosenfeld's satellite method to measure CCN at cloud base height. Towards this end, the work by Andreae et al. (2009, Atmos. Chem. Phys.) should be cited. According to the least squares fit in Figure 1, for an AOT of 0.3, the corresponding CCN value is a little less than 2000 per cc. These values are close to what Hu et al. (2018, manuscript in preparation) are finding for optimal values in the lightning context.

(6) AOD boundaries, defining regimes

Given the central importance of the AOD=0.3 value in Figure 7 (that the reader does not learn about when AOD boundaries are first discussed in lines 201-205), and the linkage to CCN in Figure 1 of Andreae et al. (2009), more care should be given to explaining, justifying and bounding the three regions (clean, intermediate?, and polluted) that are used in this work. All three regions should be named, and possibly illustrated in Figure 7 where the full range of AOD is shown, and with early notice about the special transitional value taken from Figure 7. I am confused in returning to this important Figure because there you show equations for just two AOD intervals (AOD< 0.3 and AOD>0.3) rather than the three given mention in the text. It seems to this reviewer that all ambiguities on this topic can be resolved by appropriate modification of the AOD range in this figure.

My recollection is that Altaratz et al. (2017) did something similar with the AOD scale in their work. This paper on the same topic (lightning and AOD-measured aerosol) should also be consulted and cited.

(7) Selection of variables

The authors choose meteorological variables to investigate, but the physical meaning/justification for this selection gets short shrift. Furthermore, other studies have considered different (but more physically relevant to the questions at hand) variables (CBH and warm cloud depth) that the authors chose to bypass without explanation. It should also be noted that certain variables will work better in Africa than elsewhere (RH is one), and others will work poorly in Africa (potential temperature). The linkage between lightning and shear has been considered in previous studies (Fan et al., 2009; Yoshida et al. (2009, have relevant data but do not address it directly) and Bang and Zipser (who have a positive relationship but overlook it). These findings are mixed and so new looks (like this one) are most welcome.

(8) RH as a favored variable in Africa

I did not grasp immediately that you were considering the RH in mid-troposphere, rather than the surface RH. Please clarify this wherever appropriate. If it is the RH in mid-troposphere that is selected, some physical interpretation of the importance of this variable should be discussed, and especially how that can influence the erosion of moist convection by entrainment. I do not see any discussion on the entrainment issue at all in the present version.

The text below on this RH topic was prepared when I was still under the impression that the authors were using surface RH. I think I will leave this text in, just for further consideration of the important thermodynamic side of this challenging problem. When one considers the full meteorological dynamic range of this variable, it's limitations as a correlate to lightning rate should be clear. The largest values during lightning episodes are ~80% and this is a prevalent value over tropical oceans where lightning is least likely. The contrast between weak lightning activity in the high RH tropical monsoon and in the strong lightning activity of the low RH pre-monsoon/break period is also widely recognized (Williams et al., 1992; Rutledge et al., 1992). The reason RH works as a positive correlate with lightning in Africa is because RH is low and CBH is already high. See for example Williams and Satori (2004) and follow up work by Venevsky et al. (2014) that are not now cited.

Venevsky, S., Importance of aerosols for annual lightning production at global scale, Atmos. Chem. Phys. Discuss., 14, 4303-4325, 2014.

Williams, E.R. and G. Sátori, Lightning, thermodynamic and hydrological comparison of the two tropical continental chimneys, J. Atmos. Sol. Terr. Phys., 66, 1213-1231, 2004.

(9) Potential temperature

Potential temperature is selected as another variable, presumably as a test of earlier work that considered global lightning/temperature relationships and not just Africa. Here is the problem with the use of this quantity for Africa. The linkage between lightning rate and thermodynamics clearly involves moist processes. In much of the African continent, there is insufficient moisture to allow ANY condensation, much less deep moist convection of the kind productive of lightning. Accordingly, elevated potential temperature is not serving to enhance moist processes. A second (but related) problem with the use of potential temperature is that in elevated terrain, the air temperature can be high by virtue of sensible heat flux, but because the boundary layer height (containing the rich water vapor) is comparable, the air is still moisture starved and so little lightning producing convection can occur. A good example is the Rocky Mountains west of Denver. The positive correlation between lightning and theta in the Sahara Desert (Figure 5) is puzzling to me and deserves additional explanation.

Wet bulb potential temperature includes both temperature and moisture. We ought to be measuring global warming in that quantity rather than dry bulb temperature. Why isn't this variable being considered in the present context?

(10)Figure 2 backup

Figure 2 is a useful contribution to this work but more attention is needed to justify it when it is first introduced and more details are needed for how the curves computed from the observations in the

clean and polluted conditions. An additional sentence or two should suffice here. This also links with the Substantive Issue on AOD boundaries. It also seems that no attention is given to thermodynamic variations on either the diurnal or the seasonal times scale here, so how are the authors disentangling the two contributions. Also some justification is needed for the selection of the wind parameter and the elevation of 850 mb.

As a general remark, the figures in this paper are full of information but are deserving of greater discussion either in the text or in the respective captions.

(11) Figures 3 and 4

Sufficient details should be included in the text and/or figure captions for Figures 3 and 4 to enable anyone to replicate the plots. At present, I could not do it. For example, are data from all seasons used to make these plots, or only the respective lightning seasons? Were data points taken from every grid square in the two selected regions of interest?

(12) Figure 5 discussion and interpretation

Only four sentences appear in the text to describe what one finds over Africa in the six panels of Figure 5. Some unaddressed questions: why is the correlation with SLP positive only in a narrow range of latitude? Why is lightning positively correlated with over wide areas of the Sahara where there is little lightning, and where hotter conditions are often accompanied by less moisture? Why is there a narrow belt of zero correlation in the RH plot? What is the significance of the blue spot in central Africa for the CAPE plot? Why is the correlation with wind shear positive in much of extratropical Africa but positive in the equatorial region? What is the nature of the blue zone in the map involving divergence?

Detailed edits and comments on the text:

Major editing is needed for this manuscript. The important and innovative scientific content of the paper has justified a detailed editing as the authors are not English-speakers, but in the future they should make a more concerted effort to clean their manuscript text prior to submission. Errors abound.

Title: Given that lightning rate rather than lightning is the key observable, shouldn't the title be: "The climate impact of aerosols and lightning rate: Is it detectable from long-term aerosol and meteorological data?"

Page 2

Abstract

Line 34 "based on the 11-year dataset of lightning

Line 35 "from the Moderate Resolution…"

Line 38 Why wasn't CBH or warm cloud depth selected, given earlier published results of Williams et al. (2005) and Stolz et al (2017)?

Lines 48-49 Why is this so?

Page 3

Line 51 Need to check this special value of AOD = 0.3 in the context of the Andreae et al. study linking AOD and CCN.

Line 51 "lightning flash rate increases monotonically…"

Line 54 "enhance and suppress" without further explanation is confusing here

Page 4

Introduction

Line 59 "accompanied with a concomitant" is redundant; be careful about use of "severe". This has a well-defined formal meaning in meteorology, and by those definitions the great majority of thunderstorms investigated here will not be in the severe category. Suggest not to use this term.

Line 60 Just a comment on this pairing: For many physical meteorologists, aerosol is part of meteorology. These are not two distinct categories.

Line 63 There was also pioneering work on aerosol effects on lightning in the 1990s by the cloud microphyscis group in Guadeloupe. See for example the following reference:

Michalon, N, A. Nassif, T. Saouri, J.F. Royer and C. Pontikis, Contribution to the climatological study of lightning, Geophys. Res. Lett., 26, 3097-3100, 1999.

Line 73 I don't understand "constrained" in this context.

Line 76 Better if authors can quantify "conspicuous"

Page 5

Line 80 "and a simple parcel calculation" stops short. What is the authors' intended meaning here. Most readers will not understand.

Line 83 "rainfall in southern China and drought in northern China"

Line 88 Here and elsewhere in the paper: "lightning activity"

Line 89 ", prompting us to perform…"

Line 91 Markson (BAMS, 2007) also considered temperature sensitivity of lightning in global circuit context.

Line 94 Bang and Zipser also considered influence of shear in a recent paper. Yoshida et al. (2009) has indirect evidence for positive shear effects on lightning flash rate.

Line 96 Given these physically-based connections with aerosol, why don't the present authors also consider these same variables?

Page 6

Lines 99-100 A reference would be valuable here.

Line 100 "forming in relatively dry conditions"

Lines 103-104 Authors are non-committal about the SIGN of the effect of shear. That is appropriate given different results in the literature, but given that, this situation should be clarified.

Line 104 "from the invigoration effect"

Line 106 Williams et al. (2005) found the same effect but in CBH rather than in warm could depth. They are closely related.

But it is in this line that I was left with the impression that you were looking at SURFACE RH rather than mid-tropospheric RH. Please make this clear in the text, everywhere.

Lines 108-109 See earlier comments on "meteorology and aerosol"

Page 7

Line 118 "onboard the Tropical Rainfall…"

Line 119 "(TRMM) satellite which was designed…"

Line 120 "and span all longitudes"

Line 127 "with the same spatial resolution"

Lines 130-143 Somewhere the full time period of the AOD data set should be given, for comparison with the eleven year period provided for the LIS lightning data

Line 131 "onboard the Aqua satellite…"

Line 133 "based on a dark target-deep…"

Line 136 "data from 1979 till present"

Line 139 "into the Aerosol Robotic…"

Line 140 "…(AERONET)-calibrated…"

Page 8

Line 142 Is the particle size aspect used in this paper? If not, why bring this up?

Line 148 “Convective Available Potential Energy”, given the acronym in CAPS.

Line 151 Ditto

Line 151 The “most commonly used thermodynamic parameter” for what purpose? Be specific. For climate studies, ordinary temperature is much more commonly used than CAPE.

Line 153 “of the atmosphere”

Line 154 “the more unstable is the atmosphere”; “and more likely is strong vertical air motion”

Line 156 Williams et al., JGR, 2002 or Williams, 2012, AGU Franklin Lecture are better references.

Lines 157-158 Suggest rewording to “Unfortunately, reliable updraft measurements are lacking toward illuminating this role in the present study.”

Page 9

Line 162 Ditto on use of “severe weather”. Please check formal definition of this term.

Line 166 Markson (BAMS, 2007) should be added here for his investigation of the UT diurnal dependence of the DC global circuit on temperature

Line 168 “temperature systematically declines with altitude”

Line 172

Use of RH as a parameter for lightning rate can bring confusion. When lightning contrast between monsoon and break period convection is considered, increased RH is associated with dramatically reduced lightning activity. In Africa, which is moisture started, increased RH is associated with increased lightning activity.

Line 176 Consider including the same references you had before in lines 99-101 here.

Page 10

Line 181-182 I experience same confusion here as in the Abstract. Please elaborate here.

Line 187 Add space before “Mapes”

Line 191 “In addition, the Bowen ratio (BR) is calculated from the SHF and the LHF to describe a surface property”; on completion of the reading of the paper, it appears that these variables are never discussed again. If that was the intention, why not delete this information?

Line 195 “three-month smoothed average is chosen in this study”; I am confused about “three-month” period when an 11 year period was mentioned earlier.

Lines 195-196 Suggest rewording: “allow the LIS to progress twice twice through the diurnal cycle at a given location”

Line 196 “and to show”

Line 199 If the gridding of the basic data is 2.5 x 2.5 deg, why does the sampling in Figures 5 and 6 appear to be finer than this? (Please be careful on procedure throughout this document. Sampling info should go into the captions of every figure for which this is appropriate.)

Page 11

Line 199 “taking a 3-month running mean and resampling to…”

Line 200 change “climatic” to “climatological”

Line 202 Justify the choice here.

Line 203 “top third of the AOD range”; “and the bottom (lowest) third”

Line 207 “to measure the strength of a relationship between lightning flash rate and individual predictors”

Line 208 Need reference for ‘Pearson correlation’

Line 211 “test at the 0.05 level”

Line 213 “use a multiple-linear regression method following previous studies”

Line 214 “and establish a standardized regression…”

Line 215 At this stage of the paper, we do not yet understand the importance of 0.3 so perhaps some foreshadowing is needed; “reduce the nonlinear effect”

Line 216 how does this sorting relate to the three categories of AOD noted above (lines 202-203)?

Page 12

Lines 228 to 229 Wording and meaning are unclear to me here.

Section 3 Shouldn’t it be “Regions of Interest (ROI)”?

Line 231 “Northern and southern Africa have high…”

Line 234 “It has been estimated that about…”

Line 235 Shouldn’t “globally” be “annually”?

Line 238 “accounting for roughly 30 to 50 %”

Page 13

Line 244 “onboard the Aqua satellite”

Lines 246-247 “at a spatial resolution of 0.625^{o} x 0.5^{o}”

Line 249 “have excessive uncertainties over land. The African continent stands out…”; quantify “very large”

Line 251 “Africa dominated by smoke”

Line 252 change “they….” to “these two regions ROI_1 and ROI_2 have been selected for study”

Line 255 “to study multiple aerosol effects on lightning rate”

Line 257 The use of “long-term” here suggests you will study time series and trends, but I think you are focused only on climatology; suggest new section title: “Climatological behavior of lightning rate and aerosol optical depth”

Line 258 Discussion of details of Figure 2a begins abruptly. Some introductory sentences are needed to show reader where you are headed with this Figure.

Page 14

Line 259 “over Africa”; “neighboring”; “over the red rectangle shown in Fig.1”

Line 260 delete one “the”

Line 262 “over the dust-dominant region”; “aerosol-dominant region”

Line 266 Williams (2000, JAM) is relevant here.

Line 270 “simulations by Lee et al. (2016)”

Line 274 “shows a pronounced seasonal variation with a huge…”

Line 275-276 The basis for this claim is not entirely clear to me.

Lines 277-278 Need to be more specific about what features you are calling attention to.

Line 278 “the impact is much weaker than for smoky conditions”

Page 15

Line 280 “dominating the region”

Line 280 “A key factor…” Authors are not giving the physical basis here for the importance of relative humidity. See also earlier Substantive Comments

Line 283 A reference that could be added here pertains to oceanic conditions where RH is greatest—Thornton et al. (GRL, 2017)

Line 284 “is located in the vicinity…”

Line 285 “is located in the ITCZ”

Line 286 “and leads to differences in wind shear and instability between the two regions”

Line 287 Aerosol is a part of meteorology

Line 288 “Thermodynamic conditions are considered to play the main role in the diurnal and seasonal variation of lightning”

Line 290 “which are characterized”; Add CBH or warm cloud depth, or say why they have not been included.

Line 291 “The violin plot…”

Line 292 “of distributions”

Line 296 Authors mean to say “linear correlations” rather than “linear relationships”. (The relationships themselves can be non-linear.”

Line 298 “lightning flash rates”

Line 298 Not in the ocean regime. If RH is too high, warm rain will kill the lightning activity. The authors need to consider the full dynamic range of the variables they select, and the limitations for regimes outside of the dry African continent.

Page 16

Line 300 I don’t understand “variable density shape”

Line 303 “characterizes”

Line 305 What can one expect, with author’s use of potential temperature variable?

Line 306 “that the variables cannot be considered correlated”

Line 307 Yes, “linear correlation” is correct, not “linear relationship”

Line 313 “which is also the case”

Line 314 “lightning”

Lines 314-315 This statement is ignoring the physics.

Line 316 “and cannot imply causal relationships”

Line 318 “To provide a visual comparison…”

Figure 5 has altogether too little discussion. (It is getting just four sentences.)

Page 17

Lines 321-322 What is meant here?

Line 323 “activity”

Line 324 “lightning”

Line 325 “lightning activity by participating in …”

Line 328 “the peak times for lightning”; Please note that thermodynamics will also change here.

Lines 329-330 Why?

Line 331 “condition the lightning response to AOD shows an…”

Line 332 “dust- and smoke aerosol-dominant regions”

Line 333 “the data are divided”

Line 334 “performing correlation and regression”

Line 35 “lightning flash rate increases monotonically”

Line 337 “lightning flash rate is strongly…”

Line 338 “implying that under large…”

Line 339 “lightning rate is mainly influenced”

Line 339 At large aerosol loading, the cloud microphysics changes. See modelling efforts in Mansell and Ziegler (2013?)

Line 340 quantify “under smoky conditions” in AOD.

Page 18

Line 341 “significant” is repeated; I don’t understand the rest of this line. Please clarify.

Line 343 If I am not mistaken, the Farias studies would pertain to smoke rather than dust aerosol, as they were carried out in South America.

Line 344 “we can easily find”: This claim is unclear. Did the authors find it? Are you able to find it.

Line 345 “a smoke aerosol-dominant region that is located in the ITCZ”

Line 346 “the dust-dominant region sis much drier and so is not so easy…”

Line 354 “lightning flash rate increase”

Line 356 change “around” to “near”

Line 358 You mean to say that half the CAPE values are < 100 J/kg?

Line 359 How do you know that the effect is entirely thermodynamic?

Line 360 “the lightning flash rate response to RH in different ways…”

Page 19

Line 361 “In the dust-dominant region, flashes increase monotonically…”

Line 363 “constraint on lightning activity”

Line 364 “for the smoke aerosol-dominant region, large lightning flash rates appear…”

Line 365 “response of lightning rate to…”

Line 367 “…remain high.”; “The data distribute…”

Line 368 Best to remind the reviewer that you are talking about mid-level RH rather than surface RH.

Line 371 “are still conducive to …”; “but data variance is larger, suggesting…”

Line 372 “is not as high”; “the restriction on RH…”

Line 374 “also contribute to different climate conditions”: the meaning here is unclear to this reviewer

Line 378-379 “Generally, the lightning rates are greater for all these…”

Line 380 “lightning” (typo)

Line 381 “is highly significant (>99%), based on the Student’s test.”

Page 20

Line 383 “In addition, we note that, when SLP decreases and mid-level RH increases, the differences in lightning rate…”

Line 384 “conducive conditions”

Line 385 “participate in the cloud microphysics and convective development, and thus to modulate…”

Line 388 “response of lightning rate”

Line 389 “impacting aerosol loadings”

Line 392 “the aerosol-meteorological variables” and add “the turning point (AOD=0.3, Figure 7)”

Line 393 Start new sentence: “The results are shown in…”

Line 394 “For clean conditions”

Line 401 Excellent to constrain all the others.

Page 21

Line 402 “regression equation, the coefficients of this equation represent…”

Line 405 “anymore”; “envisaged”?

Line 406 “lightning activity through the modulation of meteorological variables…” Not clear what is the physical meaning here.

Line 408 “for the dust-dominant region”

Line 411 “The main interplay is between AOD and…”

Line 412 “and the coefficients”

Line 413 “The standardized multiple regression equation reveal the top three factors…”

Line 414 “as the top restraint factor in the dust-dominant region…”

Line 415 “In addition, AOD becomes more important…”

Line 416 “meteorology” (typo); What is the meaning here? Correlate well with what meteorology?

Line 417 I am not sure what the tight cluster distribution is in Figure 9. Please clarify.

Line 417-418 CAPE and moist static energy are not the same, so CAPE does not measure it.

Line 422 “more latent heat”

Page 22

Line 423 “conducive to convective development”

Line 426 “meteorology” (typo)

Line 427 “is weakened”; “meteorology” (typo)

Line 430 I think you have the causality turned around: a dry environment enables dust aerosol.

Line 431 “and the atmosphere more stable through the aerosol radiative effect”

Line 433-434 “in making the environment drier”

Line 434-435 This finding is surprising to me, but is also what Stolz et al. (2017) concluded.

Line 439 “convection-induced”; “case-based”

Page 23

Line 445 “dust- and smoke-dominant regions”

Line 447 “from the ECMWF…”

Line 448 “features of the diurnal…”; “show the peak in …”

Line 449 “role of thermodynamics”

Line 452 “lightning flash rates are larger”; “than under clean ones”

Line 453 “increase much more than when the SLP…” Clarify where this is shown in the paper.

Line 456 “show a boomerang shape”

Line 457 “in an attempt…”

Line 458 “and to quantify”

Line 459 “Under relatively clean conditions”

Line 461 “two top determinants”; “in the dust-dominant region”

Line 462 “in the smoke aerosol-dominant region”

Line 463 “on lightning activity”

Page 24

Line 464 “through a cloud microphysical effect which may modulate the meteorological …”

Line 465 “lightning rate shows a more dispersed…”

Line 466 “of a competition between the aerosol microphysical effect and the radiative…”

Line 469 “cools the surface”

Line 470 “warms the mid-level atmosphere”

Line 471 “dusty conditions”

Line 472 “the aerosol radiative effect”

Line 473 “to a stable atmosphere”; “lightning” (typo)

Lines 474-475 How do you know this?

Line 475 "for the dust-dominant region"; "and high CAPE"

Line 476 "help to intensify…"; "For the smoke-dominant region…"

Line 477-478 You could list the state variables and the transient variables here.

Line 479 "cannot totally filter them out"

Line 482 "model simulations"

Page 25

Line 487 "lightning flash information"

References

Suggest adding:

Altaratz O., B. Kucienska, A. Kostinski, G. B. Raga, and I. Koren, Global association of aerosol with flash density of intense lightning, Env. Res. Lett., 114037, 2017.

Andreae (2009) relating AOD and CCN

Fan et al. (Science, 2018) is relevant, even though the Amazon is the main target rather than Africa.

Williams et al. (JAM, 2000), Williams et al. (JGR, 2002), Williams and Satori (2004)

Venevsky (cited above)

Figures

Figure 1

Line 574 "from the MERRA dataset"

Line 758 "from the MERRAAero data set"

Caption needs to clarify whether pictures are seasonally integrated. And what is "BC+OC"?

Figure 2

2nd line of caption: "neighboring"

5th line of caption: "enables"

7th line of caption: "calculated" (typo)

8th line of caption: "in the dust-dominant region"; "smoke-dominant region"

Last line: “Cecil et al., …”

Figures 3 and 4 The caption should tell what time frame is examined and how the monthly sampling is handled. Why are the CAPE values so low here?

Figure 5 The caption should explain exactly how the plots were made. See also other questions about details of each sub-figure.

Figure 7 You have excellent opportunity here to show your three ranges of AOD, including the “clean” and “polluted” range, and the one in between. Also important to explain exactly what a single point represents on these important plots. The last sentence of the caption I do not completely understand. First of all, what is one “sample”?

Figure 8 What exactly is one “cell” here relative to the climatological maps you are taking data from? (This gets at the criticism on Procedure again.) Why is CAPE so small?

Figure 9 This is an impressive result, with all differences (no exception) taking on a positive sign. Still confused about “the top third of AOD”. Is that the top third of a full range of 0.9 (0.6 to 0.9), or the top third of a full range of 1.0 (0.66 to 1.0)?

Figure 10 is too complicated for me to understand.

End of Review

Earle Williams

May 11, 2018