Response to Referees

We have addressed all the referees' comments.

Our rebuttal for all referees is presented in separate documents as the format requests. A modified manuscript that addressed the referees' major suggestions was prepared. Finally, we would like to acknowledge all the referees and editors for spending their time and effort sharing their view and providing constructive comments.

NOTE:

- The blue font indicates the response given by us authors.
- ***Fig. x*** refers to figure number in the main manuscript
- ***Figure y*** refers to figure in this response letter but not in the main manuscript. Parts of figures included in the manuscript are indicated in parenthesis under each figure's caption.

Interactive comment on "Evaluation of surface properties and atmospheric disturbances caused by post-dam alterations of land-use/land-cover"

By A. T. Woldemichael et al. (HESS-2014-125)

Response to Anonymous Referee #1

Summary:

This paper evaluates the impact of land-use/land-cover change by dam construction and irrigation on the near-surface and boundary layer properties. The topic is interesting and fits into the scope of the journal. The paper is well written and the results are clearly presented. However, there are two major concerns.

MAJOR ISSUES

COMMENT 1: The first concern I have is that the simulated results have no validation. I also quickly went through the two papers from the same group (Woldemichael et al. 2012, 2013) and did not found validation of near-surface temperatures, winds, fluxes, boundary layer profiles, etc. The only validation that was carried out in these two papers is rainfall and runoff

***Our Response**: We would like to thank the referee for pointing out this essential component of the modeling experiment. As mentioned correctly, our calibration and validation was performed only for precipitation. There were two major reasons for this:*

1) The modeling experiment in RAMS calls for different cumulus and radiative parameterization schemes that have direct consequence for precipitation simulation. Since it is always a complicated experience to obtain a better simulation of precipitation, we chose the different RAMS cumulus parameterization schemes and selected the scheme that closely represented the measured precipitation by comparing it to PRISM and CDEC (in case of ARW) and GHCN (in case of ORW). We also anticipated that if the precipitation (which is a *derived or diagnostic parameter) is well-calibrated, then it was apparent that the prognostic variables responsible for the generation of precipitation are also implicitly calibrated,*

2) It is usually a difficult task to obtain accurate spatial measurement of the other parameters such as temperature, wind profiles, and boundary layer properties that dated back to the 1990's. As a result we opted for the precipitation as a calibration and validation parameter.

However, since it is clearly indicated by the referee that the other parametrs are also essential in the validation phase of the modeling experiment, we have tried to conduct validation of the RAMS simulations against the following datasets:

1. *PRISM generated monthly spatial averages of maximum, minimum and dew-point temperature: Parameter-Elevation Regressions on Independent Slope Model (PRISM) (available at http://prism.oregonstate.edu) uses point data, a digital elevation model (DEM) and other sets of spatial datasets to generate gridded monthly and annual precipitation, maximum and minimum temperature and dew-point temperature, on a 4 km spatial grid (Daly et al. 1994)*

[Daly, C., R. P. Neilson, and D. L. Phillips: A statistical-topographic model for mapping climatological precipitation over mountainous terrain, J. Appl. Meteorol., 33, 140–158, doi:10.1175/1520-0450(1994)033<0140:ASTMFM>2.0.CO;2, 1994]

2. *Radiosonde archives from the NOAA Earth System Research Laboratory (ESRL) Global System Division (GSD) for certain locations in the ARW and ORW for the period of 1996-97*

***Table-1**: Summary of the selected cumulus and radiative parameterization schemes for each watershed (as of Woldemichael et al., 2012, 2013):*

Watershed	*Monthly spin-off period*	*Cumulus parameterization (after calibration)*	*Radiative scheme (after calibration)*
American River Watershed (ARW)	*Dec. 1996*	*Kuo*	*Harrington*
Owyhee River Watershed (ORW)	*Dec. 1996*	*Kain-Fritsch (KF)*	*Harrington*

The comparison between the PRISM generated monthly averaged minimum, maximum temperatures (^{o}c) and dew point temperature (^{o}c) and the RAMS simulated values are shown on Figure-1 for ORW and Figure-2 for ARW. The RAMS simulations, in most cases, follow the spatial patterns generated by PRISM especially in the northeastern locations. The RAMS simulated values for ORW, however, are widely spread than the PRISM values that are more detailed. These could be due to the scale variation between the RAMS (10km) and PRISM (4km).In case of ARW, since the scales of the PRISM and RAMS at the calibration runs was

4km and 3km respectively, there is a better spatial similarity in the simulated and observed temperature vales between the two (Figure-2).

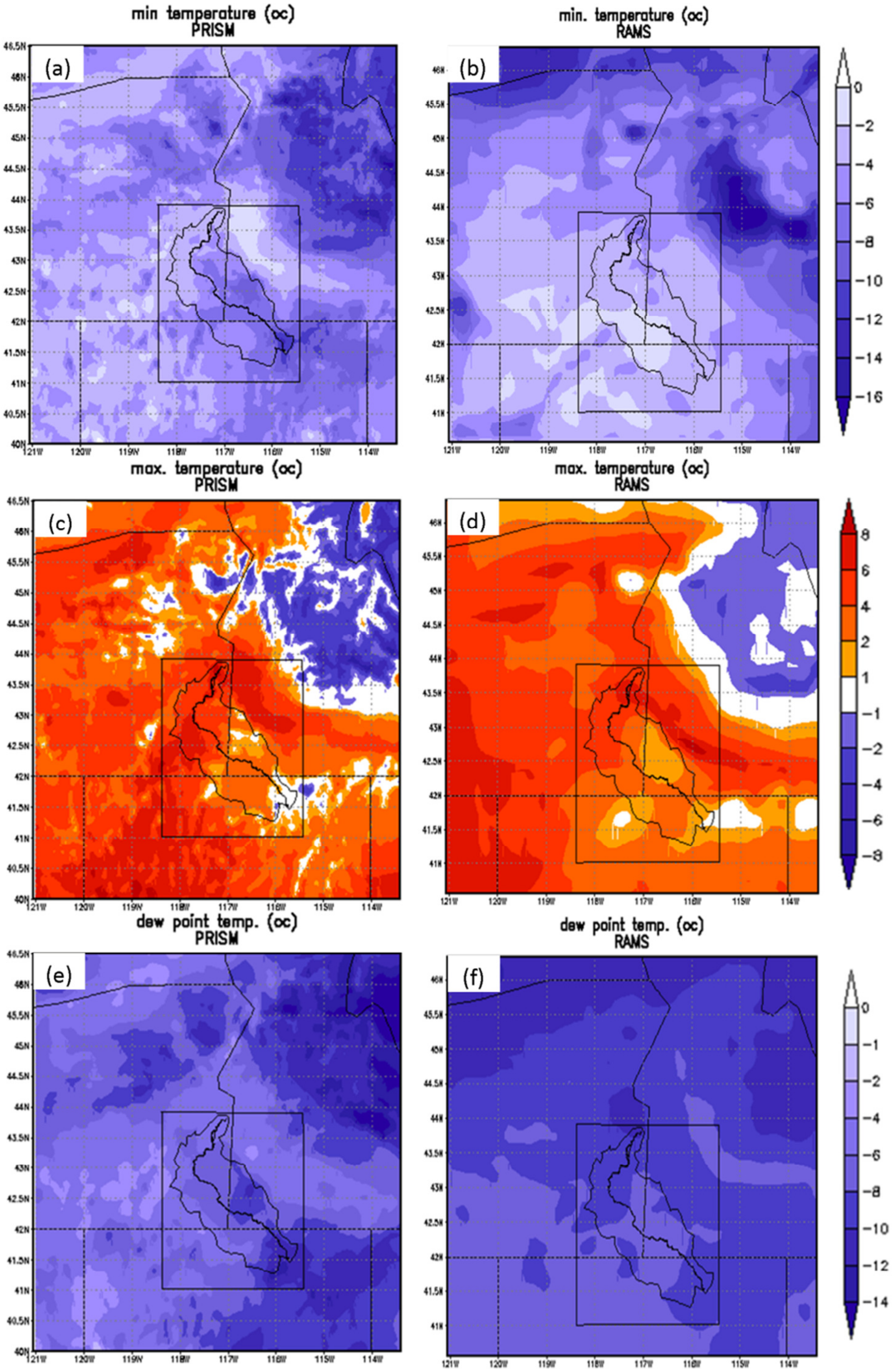

***Figure-1**: PRISM generated (left) and RAMS simulated (right) minimum (a & b), maximum (c & d) and dew point (e & f) temperature (^{o}c) for ORW. Note that values are monthly averaged for Dec-1996.(<u>Also included in the modified manuscript</u>)*

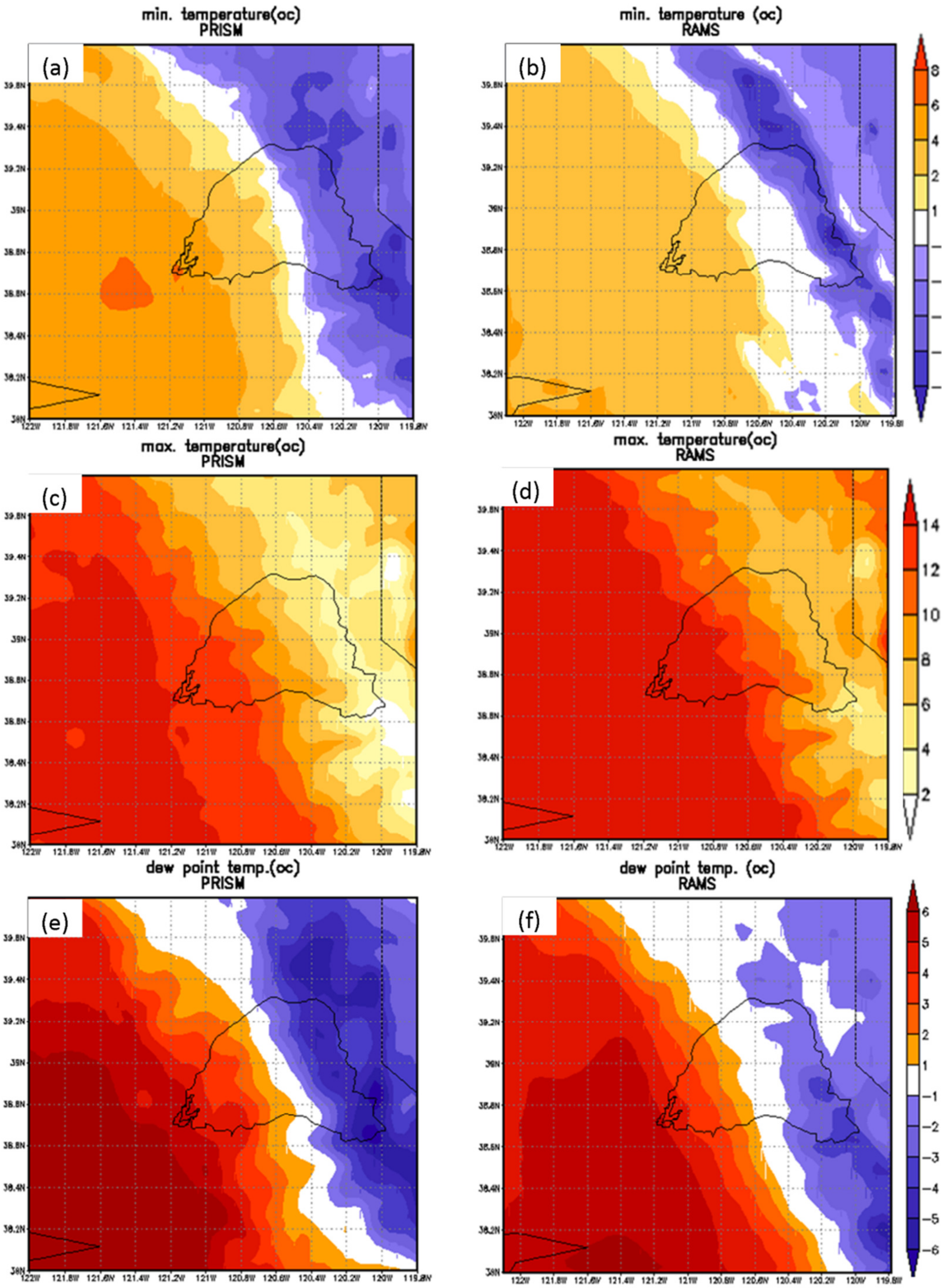

__Figure-2__: PRISM generated (left) and RAMS simulated (right) minimum (a & b), maximum (c & d) and dew point (e & f) temperature (^{o}c) for ARW. Note that values are monthly averaged for Dec-1996. (Also included in the modified manuscript).

The radiosondes soundings paint a clear picture of the existing atmospheric processes. We also tried to adopt these soundings as part of the validation procedure at specific locations that coincide in our ARW and ORW's RAMS simulations domain. The locations of the archived soundings and the watershed in which they are contained are shown in Table-2.

For the purpose of the validation, we selected three days (12/31/96 to 01/02/97 at 12:00 UTC). These were the periods when greater amounts of precipitation were recorded at both watersheds.

Table-2*: the names, locations and elevations of archived soundings and the watershed where they belong to (shown in brackets). Note that these locations are included in Fig.1 of the modified manuscript.*

Radiosonde station Name (watershed)	*latitude*	*longitude*	*Elevation(m)*
Oakland(ARW)	*37.75*	*-122.22*	*6.0*
Reno (ARW)	*39.57*	*-119.8*	*1516.0*
Elko(ORW)	*40.87*	*-115.73*	*1608.0*
Boise(ORW)	*43.57*	*-116.22*	*871.0*

At the Oakland location (Figure-3) since the elevation was only 6m above sea level the observed and simulated pressures at the lowest point is approximatley 1000mb at all times. The wind vectors showed similar direction with higher magnitudes recorded from the observations than the simulaions. There were abrupt decreasees in temperature readings at the about 750mb, 250mb and 450mb of the observations which were not present in the simulation, resectively for Figures-3 a, b and c. Temperature inversions occurred at about 200mb for the observations while the RAMS simulations showed temperature inversions at about 250mb levels.

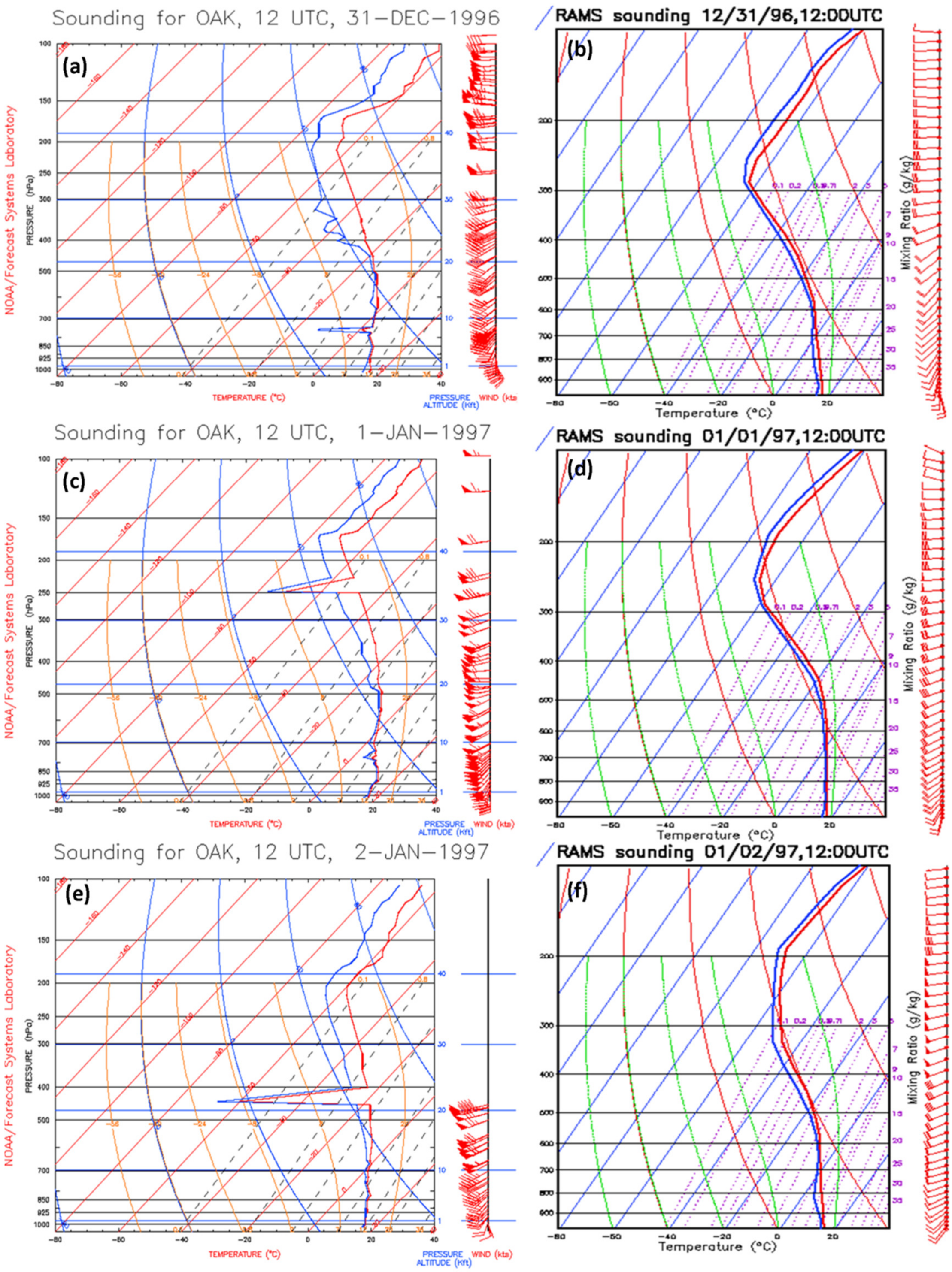

***Figure-3**: temperature sounding (red) and dew-point sounding (blue) from NOAA radiosonde observations taken at 12UTC Dec31, 1996 , Jan01, 1997 and Jan02, 1997(left) and generated from RAMS simulations for the same time period(right) at Oakland, CA (ARW). (Jan 1st sounding included in the modified manuscript).*

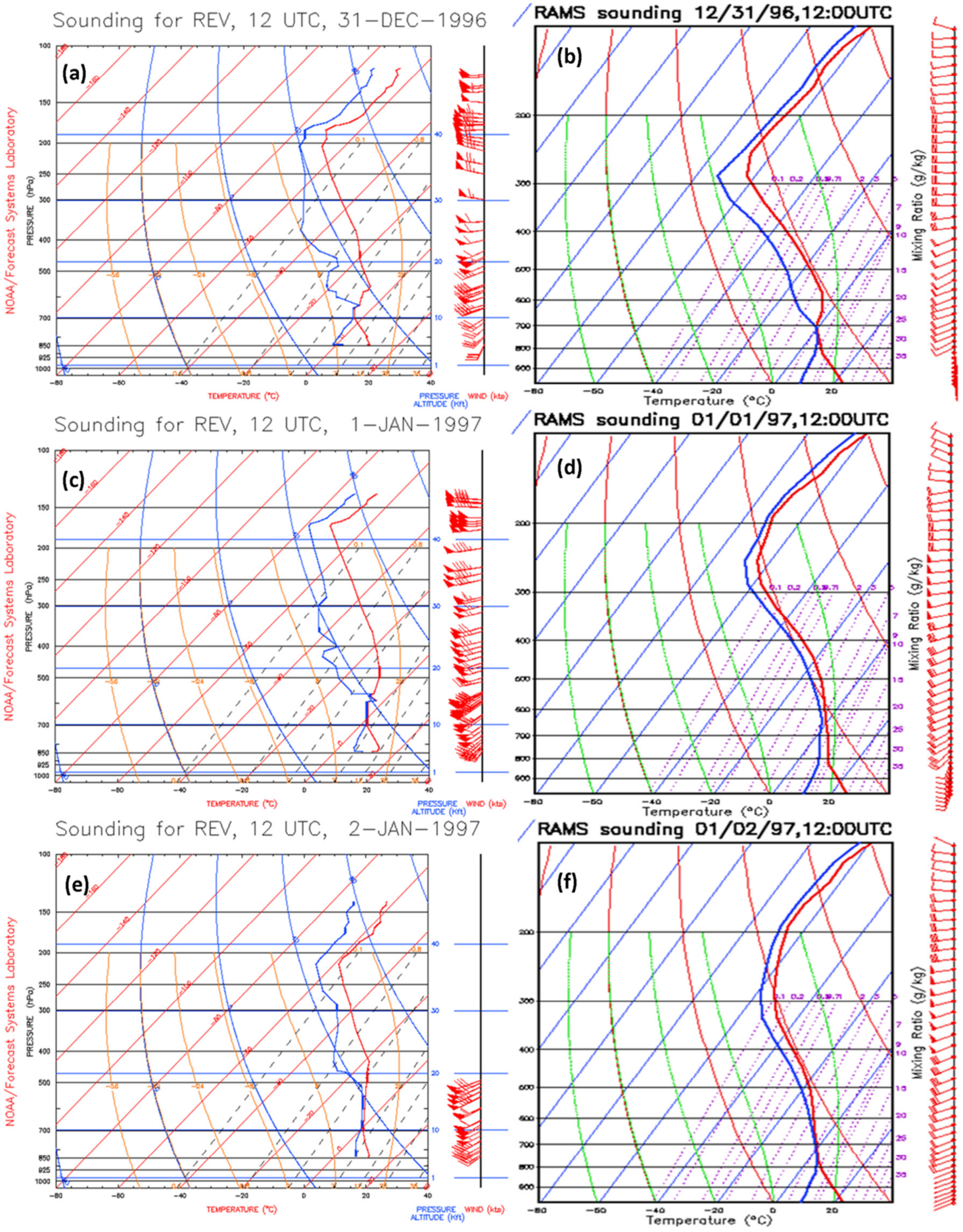

Figure-4*: temperature sounding (red) and dew-point sounding (blue) from NOAA radiosonde observations taken at 12UTC Dec31, 1996 , Jan01, 1997 and Jan02, 1997(left) and generated from RAMS simulations for the same time period(right) at Reno, NV (ARW). (Jan 1st sounding included in the modified manuscript).*

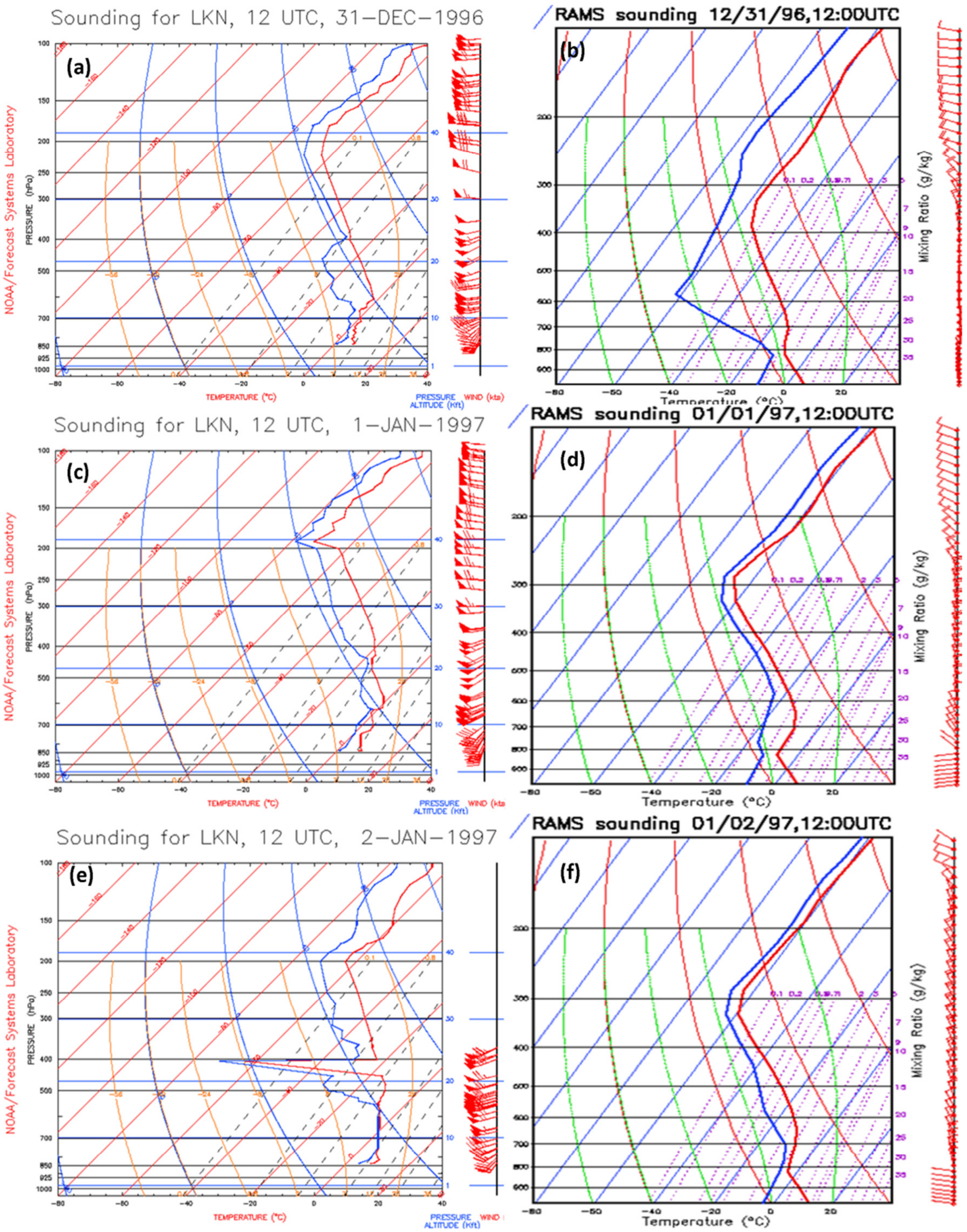

***Figure-5**: temperature sounding (red) and dew-point sounding (blue) from NOAA radiosonde observations taken at 12UTC Dec31, 1996 , Jan01, 1997 and Jan02, 1997(left) and generated from RAMS simulations for the same time period(right) at Elko (ORW). (Jan 1^st^ sounding included in the modified manuscript).*

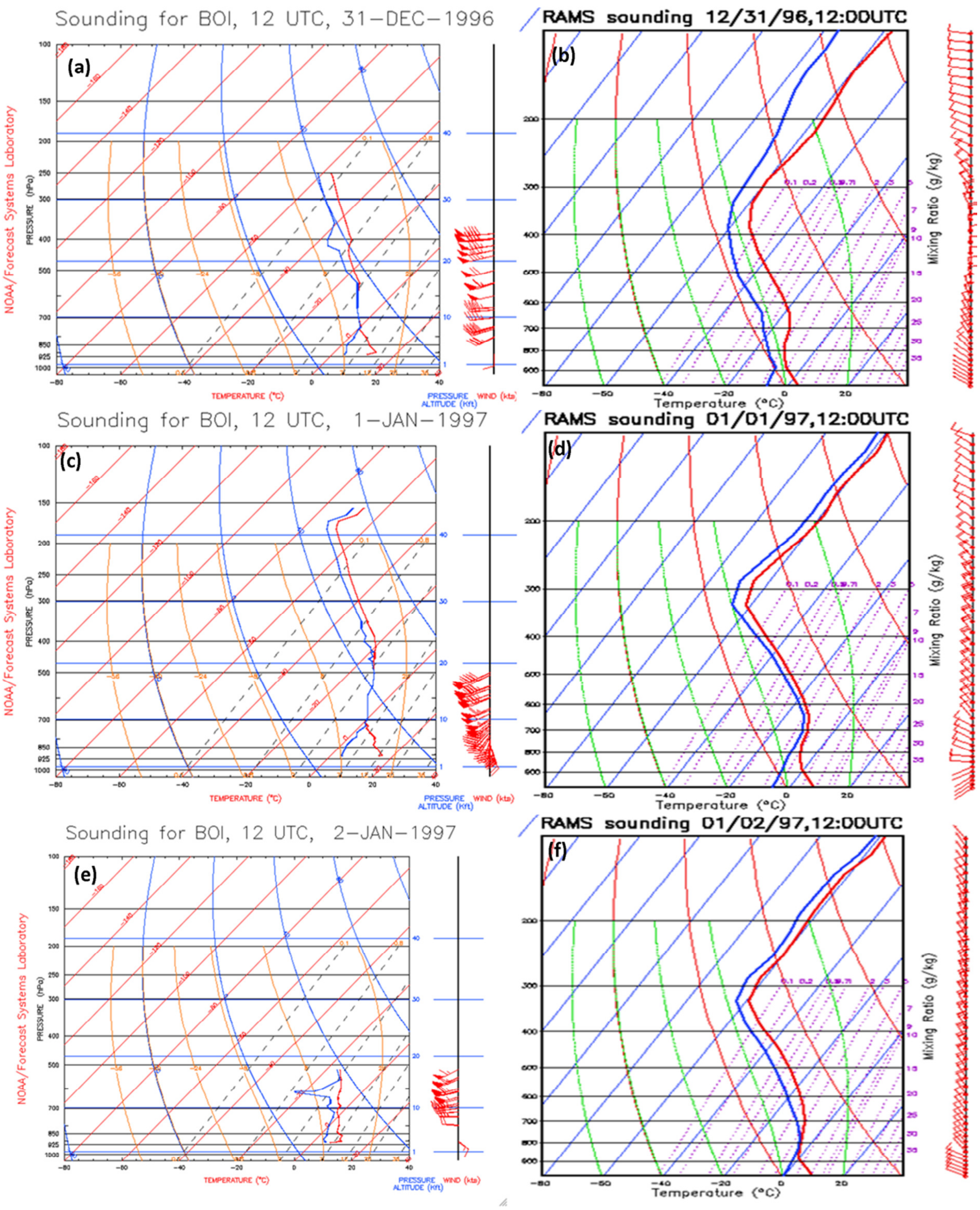

***Figure-6**: temperature sounding (red) and dew-point sounding (blue) from NOAA radiosonde observations taken at 12UTC Dec31, 1996 , Jan01, 1997 and Jan02, 1997(left) and generated from RAMS simulations for the same time period(right) at Boise, ID(ORW). (Jan 1st sounding included in the modified manuscript).*

Figure-4 shows the sounding for the Reno, NV, station in ARW. The temperature inversions and other vertical profile characteristics are quite similar for the observation and the simulated soundings. At about 700mb level of 31st Dec 1996 and 1st Jan 1997 (Figures 4 a & b, and c & d), the temperature and dew-points soundings become equal indicating saturation. Figure-5 shows the soundings for the Elko station in ORW. At 31st Dec, 1996, there are levels (at about 600mb) of abrupt decrease in the dew-point temperature of the RAMS simulation (Figure 5b). At 1st Jan 199, the observations indicate saturation at 600mb level which was not captured by the simulated soundings (Figure 5c). At 2nd Jan 1997, the temperature and dew-points abruptly decrease at about 400mb (Figure 5d). The wind barbs for both the observations and simulations indicate same direction. However, wind magnitudes are much higher through all levels of the observations.

Figure-6 shows the soundings for Boise, ID station in ORW. The wind barbs show the same pattern as the Elko stations. For 31st Dec 1996, the observations sounding assumes saturation between 600mb and 700mb (Figure-6 a). However, saturation was not observed for the simulated soundings. Similar characteristics also prevail for the 1st of Jan 1997 (Figure-6 c). At 2nd Jan 1997, saturation were attained at about 550mb for the observation and at about 800mb for the simulated soundings, respectively (Figure6 e and f). In summary, from Figures 3 to 6, it can be deduced that all the important vertical profile characteristics are captured adequately well by the RAMS simulations.

COMMENT 2: The second concern is that the paper is simply a follow-up paper based on the same simulations in Woldemichael et al. (2012, 2013). It does not appear to me that this paper contributes much more as compared to Woldemichael et al. (2012, 2013). In fact I like the previous 2 papers much more than this one. The results of this paper are superficial in some sense if we consider the fact that the authors have already analyzed the impact of land use/land-cover change on precipitation using the same simulations, as the impact on precipitation is certainly through the impact of near-surface properties and boundary layer properties. Thus it is unclear to me what the novelty of this paper is.

***Our Response**: We appreciate the referee for going the distance to review our previous papers and sharing his assessment of this third paper. We elaborate below our difference in opinion and explain how our new paper makes a fundamental contribution to the body of knowledge:*

1. *The overall objective of the former papers was how precipitation and moisture-maximized extreme precipitation gets modified from the point of view of dam-induced changes in land-use/land-cover (LULC). The underlying important atmospheric parameters that could also have experienced modification were not considered. However, in this paper, we included these important parameters such as near-surface temperatures, winds, fluxes, boundary layer profiles that the referee deemed essential. By including these essential parameters, we not only fill the gaps left in the previous papers that only targeted precipitation, but also add value to the overall effort of*

addressing the effect of LULC change on the modification of the overall hydrometeorology of an impounded river basin.

2. *We also addressed this concern in the manuscript starting from page-5, line-27 to page-6, line-10. We specifically mentioned that "… Findings of the present study allow for the comparisons of the role of localized mesoscale circulations against the changes observed in extreme precipitation… In this paper, particular emphasis is made on the actual storm patterns which have little to do with extremes. We also addressed the behavior of storm dynamics and how the behavior is affected in a changing LULC situation." Hence, we believe that the present paper can stand alone as a full-fledged and complete paper with its own broader impact and objectives quite different from the previous two papers.*

Other comments:

1. Fig. 5, Fig. 6, Fig. 7 and others: are these period-averaged values, daily averaged values or what values are you plotting?

Our Response*: the parameters plotted in the respective figures Fig. 5, Fig. 6 and Fig. 7 are daily averaged values for the simulation period (i.e. six-day period of 29th Dec-1996 to 3rd Jan-1997). Hence, in the analysis only the days are considered and averaged for six days when the heavy storm episode was observed.*

2. Fig. 6: the changes in sensible and latent heat fluxes at the ARW location clearly show some patterns, which are not discussed at all. For example, the authors simply report a decrease in the sensible heat flux on the order of 15W m-2 or greater. This is rather superficial and does not seem to explain much of the pattern observed in Fig. 6.

Our Response: *we thank the referee for the comment. We fully agree that the explanation needed further reinforcement. As a result, we have included the following underlined statements in section 4.1 of the modified manuscript:*

"In ARW, the exact location were the previously irrigated land was converted to nearest land-use pattern (i.e. woody savanna) in the control – non-irrigation case, showed a decrease in the sensible heat flux on the order of 15 W/m2 or greater. The decrease in sensible heat flux can be due to the hypothetical replacement of the woody savanna in the non-irrigation scenario with the existing cropland in the control. Crops transpire more due to their lower stomatal resistance and increased evapotranspiration. This intern cooled the surface as shown in Fig. 5 and hence reducing the outgoing radiation in the form of sensible heat flux."

3. Fig. 7: how do you quantify the significance when you say 'a more significant transformation was observed in the change between the non-irrigation to control compared to the pre-dam to control results due to its less difference in land use change'? (Line 20, page 5050) by eye?

Our Response: *We appreciate the referee for this insight. At first, observation was used to deduce that more transformation was apparent in the case of non-irrigation to control as* *compared to pre-dam to control. However, in order to reinforce this assertion, we present here, for the sake of clarifying the response, quantitative differences observed between the two. The results are shown in Figure 7 below:*

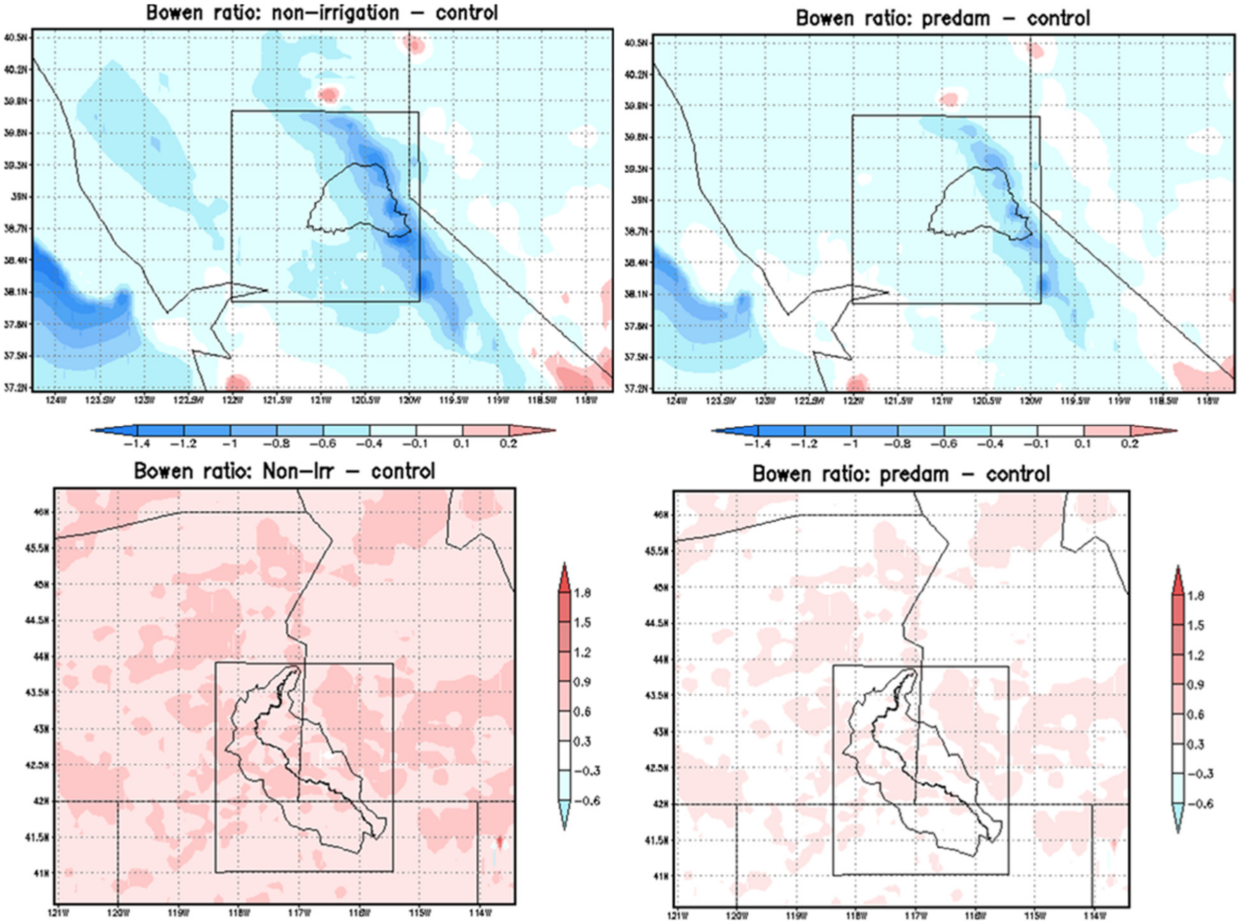

Figure-7*: Bowen ratio difference among different scenarios for ARW and ORW.*

4. Fig. 9: the results are not discussed except one sentence explaining the difference between the two locations (line 1-4, page 5052). Why not show the difference between different runs?

Our Response: *We appreciate the comment. In Fig. 9, the only reason the Planetary Boundary Layer (PBL) figures are displayed was to support the wind magnitude and direction discussion that followed. We also would like to emphasis that from the very objective why this figures were presented, it was not essential to display the difference between different runs.*

5. Line 14, page 5052: 'This documents that the circulations due to LULC changes can transport moisture and heat higher into the atmosphere as discussed below". I didn't see any discussions that could corroborate this argument. The only sentence that is sort of relevant is 'both scenarios showed well developed vertical motion that was responsible in

transporting moisture from the surface to higher altitudes'. However, this did not explain the difference between scenarios.

Our Response: *We thank the reviewer for the comment. We also believe that the paragraph needs more detailed discussion on the vertical water vapor mixing ratio results observed between the different scenarios. Accordingly, we have included the following statements for the paragraph immediately following line 14:*

"For the control - non-irrigation, in particular, the 121W to 122.5W longitudes where the low-level wind convergence was observed (Fig. 8a); the circulation cells were a maximum for the lower half of the PBL. However, as convergence zone disappears as shown in Figure 10a, there is a discontinuity in the vertical circulation cells. The control – pre-dam scenario, on the other hand, manifested a different pattern where there was no discontinuity throughout the whole depth of the PBL. Figure 11c & 11b showed vertical cells for control – non-irrigation and control – pre-dam respectively. At longitudes of 116W to 117W, the convergence zones were fully established all the way through the top of the PBL. Correspondingly, the vertical water vapor mixing cells traversed from the ground up to top of PBL for both cases. In this case the moisture was transported much deeper than the PBL indicating a much stronger vertical motion established in ORW than ARW. In both regions, the dense area of moisture transport corresponded to the location where wind convergence occurred."

6. Fig. 12 and 13: why is the CAPE result only shown for the control case? Then how you do quantify the impacts of land-use/land-cover change on the CAPE? If you don't quantify the impacts, what is the point of showing these 2 figures and what do you mean by 'there is also the important question as to how LULC affects this synoptically driven winter time systems'? Am I missing something? And why 'since positive CAPE is recognized as a major factor that is altered by LULC'?

Our Response: *We thank the referee for the comment. As accurately pointed out by the referee, Fig. 12 and 13 can further be expanded with more emphasis to the difference analysis between different scenarios rather than just the control. We also believed that scenario based comparison represents the discussion clearer than just the six day values of for control of each scenario. Hence, we have replaced Fig. 12 and 13 with the following figures in the manuscripts and the follow-up discussion is expanded accordingly. The underlined statements are included in the improved manuscript:*

"Finally, to understand the availability of potential energy and convective contribution for precipitation formation, a Convective Available potential Energy (CAPE) analysis, was performed. <u>Fig. 12 indicates the amounts of CAPE in the atmosphere for ARW and ORW respectively during the time of maximum CAPE (Jan 3rd 1997) out of the considered 6-days of analysis.</u> <u>Although the CAPE values were not large enough to warrant a convective initiation in the regions, there was a progressive increase in CAPE value from the pre-dam to the non-irrigation and to the control, mostly in the ARW.</u> In all cases, the observed

increase in CAPE originated from the increase in the latent heat flux in much of the northwest in ARW and eastern parts of ORW. There is also the important question as to how LULC affects these synoptically driven winter time systems. Since positive CAPE is recognized as a major factor that is altered by LULC, yet, during most days in the winter in the study regions, there is no CAPE, the general impression is that LULC effects on precipitation cannot work in these situations.

However, during these synoptically driven rain events, CAPE is often quite positive. Severe thunderstorms [with documented strong convective instability] and even tornadoes occur during these events [e.g. Hanstrum et al 2002, Kingsmill et al 2006]. [see also https://ams.confex.com/ams/pdfpapers/115125.pdf]. Our results indicated that during these precipitation events, a significant fraction involves deep cumulus clouds, and thus changes in CAPE, and other thermodynamic aspects of the atmosphere by LULC result in alterations in precipitation from what otherwise would have occurred.

In order to see how the CAPE varies among the different scenarios, CAPE differences between control and non-irrigation as well as control and pre-dam are shown in Fig. 13. Fig. 13 represents the six day daytime average differences in CAPE. According to Pielke (2001), a larger fraction of energy partitioned to latent heat flux results in greater CAPE and added moisture to facilitate deep convection provided that suitable conditions exist. Looking at Fig. 13 it is apparent that in both regions a larger CAPE is observed for the control as compared to the non-irrigation and pre-dam. These larger CAPE values are especially prominent at location where irrigation was intensified. In non-irrigated regions, there is larger sensible heat flux that doesn't favor CAPE than the latent heat flux. On the contrary, irrigation will add significant latent heat flux resulting from transpiration of water vapor. For larger irrigated areas, there is a possibility of development of mesoscale circulation. However, as discussed previously in such synoptically driven regions as ARW and ORW, the possibility of CAPE being a factor for generating a storm is minimal."

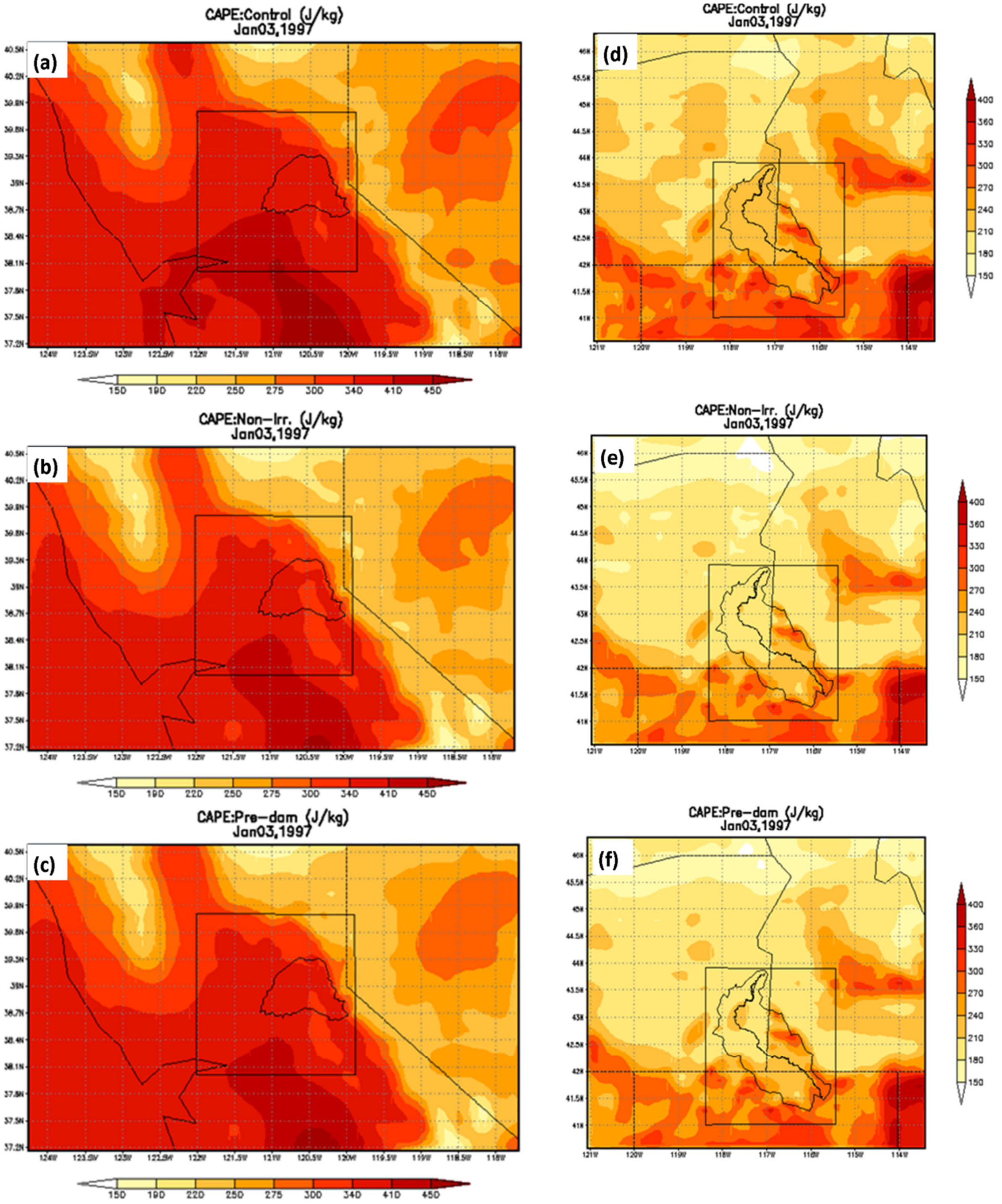

Fig. 12: Daytime average Convective Available Potential Energy (CAPE, J kg^{-1}) for the 3rd of Jan 1997 for ARW control, non-irrigation and pre-dam(a, b &c) and ORW control, non-irrigation and pre-dam (d, e & f).

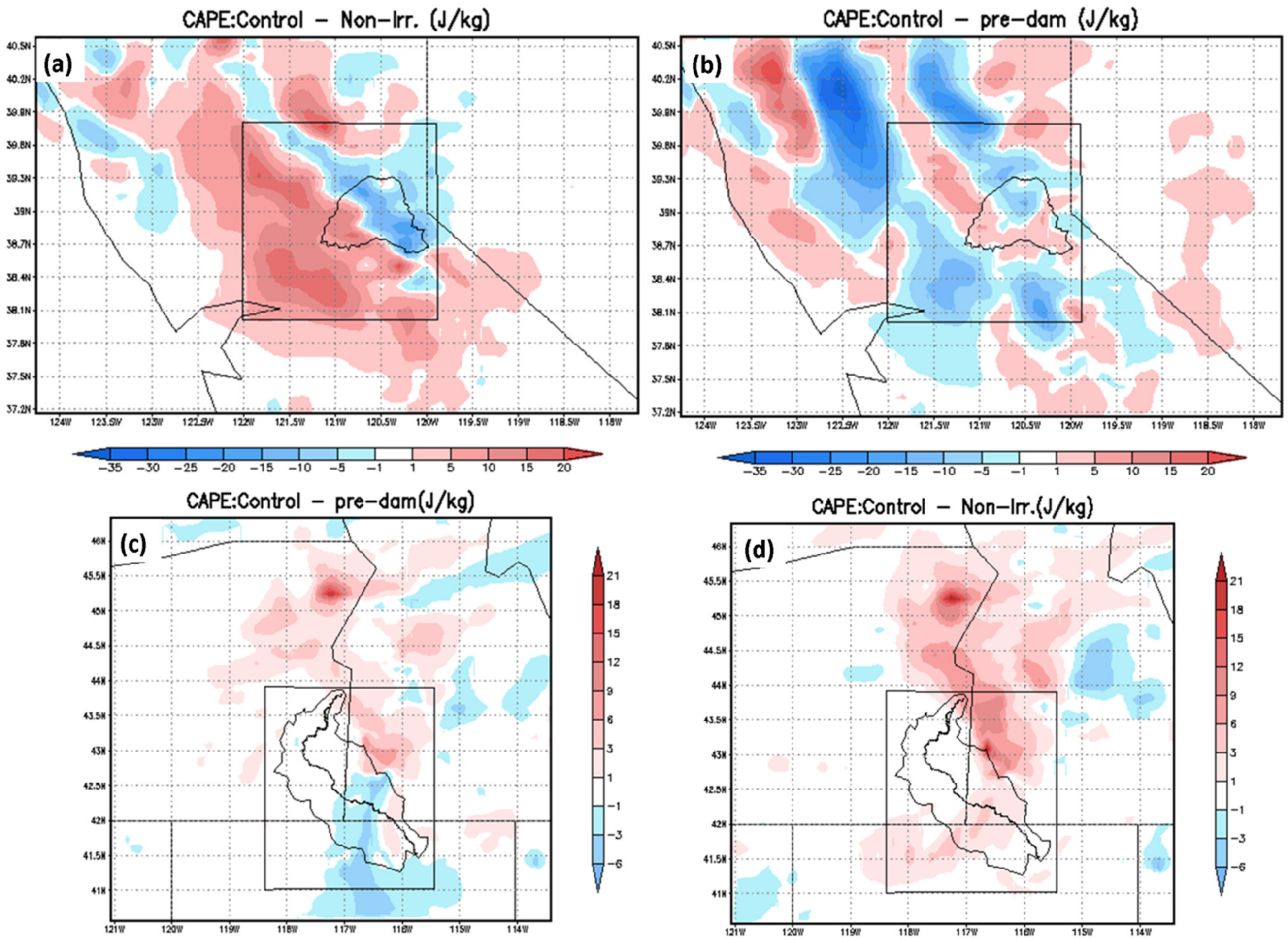

Fig. 13: Differences in Convective Available Potential Energy (CAPE, J kg^{-1})for ARW and ORW control – non-irrigation (a &d)and ARW and ORW control – pre-dam (b &c). note that values are six day daytime averaged for Dec 29th 1996 to Jan 3rd 1997.

7. Conclusions, "(4) there were well developed ...' please show the co-location between these well-developed motions and the precipitation difference.

Our Response: *We thank the reviewer for the comment. In Figure-8 below, we tried to locate the exact locations between the precipitation maximums and well-developed circulations cells both for ARW (Figure 8a, b, c & d) and ORW (Figure 8e, f, g & h). At relatively similar locations where the maximum vertical mixing ratios were located, the precipitation differences were also a maximum.*

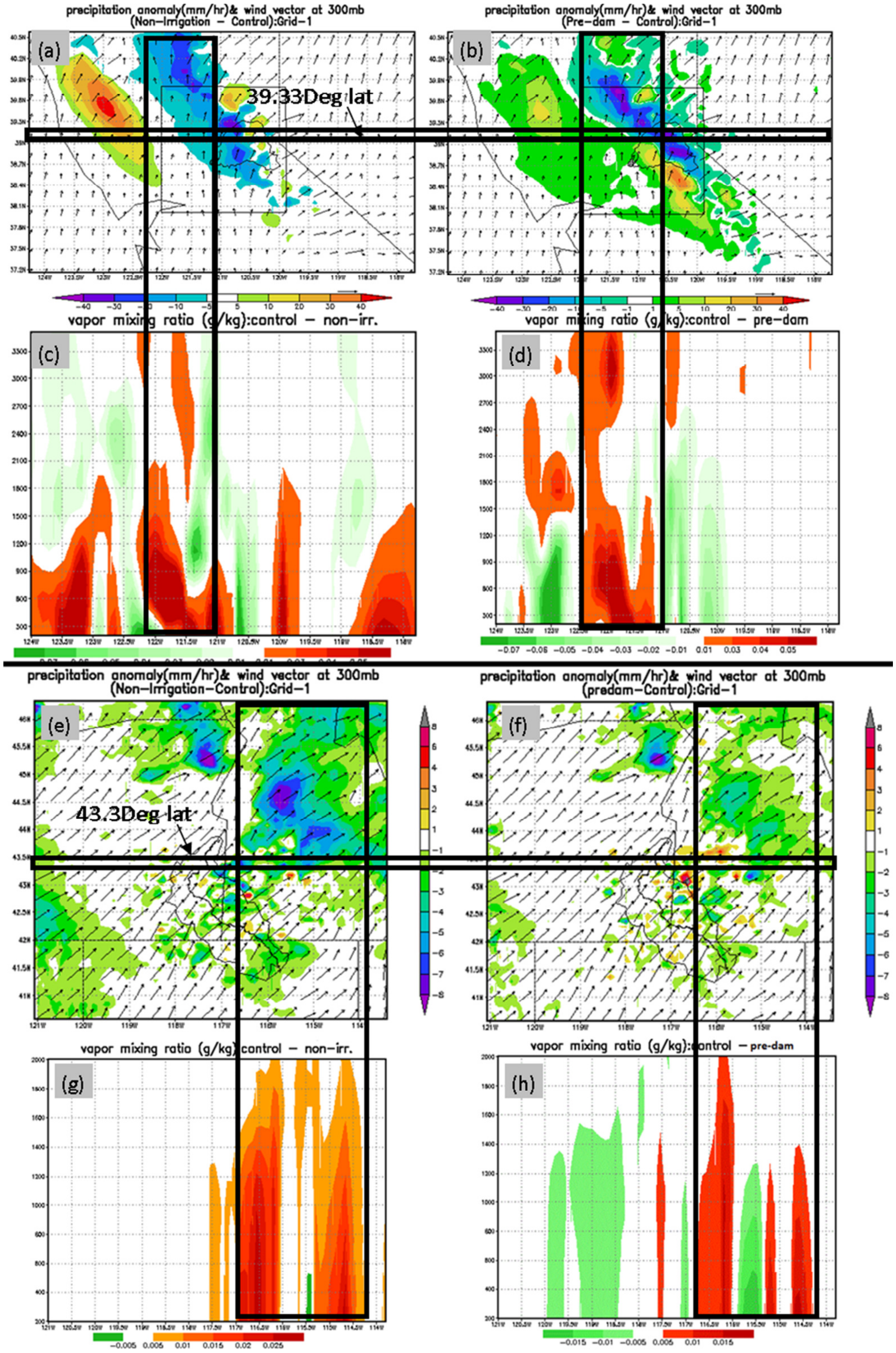

***Figure-8**: co-locations between the vertical circulation cell maximums and precipitation maximums for ARW and ORW. Note that the differences in precipitation are for non-irrigation - control and pre-dam – control (reverse) of the vertical profile differences.*