We thank Reviewer 2 for his/her insightful comments and suggestions. Below is our point-by-point responses to the provided comments.

Reviewer Summary: This manuscript presents an assessment of modelled rainfall patterns and amounts for an extreme rainfall event in UAE derived from two modelling systems, namely, the standalone WRF and the coupled WRF/Hydro system. The evaluation of model results is based on a comparison with weather stations' data (i.e. gauge rainfall data, temperature, radiation) and satellite products (i.e. the Global Precipitation Measurement (GPM) rainfall, the MODIS cloud fraction, and ASMR2 soil moisture). In the manuscript, analysed variables are limited to these hydrometeorological variables, i.e. precipitation, cloud cover, global radiation, air temperature, and soil moisture. Statistical output of the evaluation shows that the coupled WRF/Hydro is better than the standalone WRF. However, no further effort is made to diagnose the processes and mechanisms controlling the water cycle that can be better captured by the coupled WRF/Hydro system than the standalone WRF. Thus I recommend that revision should be made for the following key points:

In line with the reviewer's suggestion, we have carried out two additional analyses to diagnose the processes and mechanisms controlling the improved precipitation fields in the coupled model. First, we analyze the impact of lateral flow on the propagation of soil moisture captured by WRF-Hydro during the event. Second, we compare the simulated surface energy balance (SEB) and planetary boundary layer (PBL) heights at the four stations considered in the study. The outcomes of the additional analysis corroborate our initial findings and demonstrate how soil moisture and atmospheric water vapor alter the distribution of fluxes and affect the PBL height. We added new figures and the supporting analysis (included in our following responses).

Comment 1 (C1): Literature review of the manuscript stated that numerous studies in the past have already shown the advantages of the coupled WRF/Hydro over the standalone WRF. If this study is a same kind but just a case study for another geographical location, what would be its unique contributions to knowledge?

Author's response to C1: Hydrological processes in hyper-arid regions are different from those in mid latitude regions. In desert regions, high soil porosity and hydraulic conductivity of the prevailing sandy soil implies rapid infiltration and runoff drainage. This suggests that the impact on latent heat and, therefore, on the surface radiation budget would be minimal. This study, with the additional analyses during the revision, demonstrates that even in desert regions the surface feedback to the atmosphere is still considerable and important to account for. We state on Page 3 (Lines 31 – 33) that "such coupling has never been assessed in hyper-arid environments like the one observed in the UAE, where hydrological and atmospheric processes are specific and different from other study domains where similar coupling was evaluated".

We explain that the gentle topography in the study area, with a slope favoring water drainage from the east to the west, does not drain water rapidly. Furthermore, precipitation largely contributes to soil physical crust formation in desert environments as shown by Fang et al. (2007). Precipitation compacts fine particulate and fills the porosities of the top soil layer, forming a hard shell. Dust is also washed out of the atmosphere by precipitation over desert environments which increases amounts of finer particulate at the surface layer to further accelerate crust formation process. This translates to less vertical infiltration and more lateral flow processes. These mechanisms are specific to arid regions and corroborate the importance of accounting for lateral flow and surface feedback in the coupled WRF/WRF-Hydro model to correctly capture the atmospheric and hydrological process.

In their Global Land Atmosphere Coupling Experiment (GLACE), Koster et al. (2004) identified regional hot spots for coupling strengths, including moderate coupling strengths over the Arabian Peninsula. A follow-on study from Seneviratne et al. (2006) followed the same methodology as GLACE, but with higher resolution model runs, found high coupling strengths over Europe which were not previously reported by GLACE. Consequently, the present study represents the first local assessment of coupling over the UAE for short-term (48 hours) and high-resolution (100-meter) prediction of an extreme event, and quantifies the added value of coupling for the accuracy of precipitation forecasts.

Author's Changes in manuscript: The above reasoning will be added to the revised manuscript.

Comment 2 (C2): As claimed in the manuscript, the main objective of the study is to investigate the added value of coupled land surface-atmospheric modeling (WRF-Hydro) over the hyper-arid environment of the UAE. In fact, the coupled WRF-Hydro system captures the dynamics of the water and energy cycles, linking the upper atmosphere to the unsaturated and saturated zones on the land surface. In order to take the full advantage of the WRF-Hydro system, diagnoses of the feedback processes/mechanisms controlling the regional scale water cycle (e.g. runoff, penetration, evaporative fraction, water vapour flux) should be conducted. Such diagnoses may lead to valuable generic outcome that could benefit the research community. In fact, the discussion in the manuscript has cited many publications for such processes/mechanisms for the purpose of interpreting the modelled output, but none of these has been further diagnosed in this study. It is strongly recommended that these diagnoses should be explored.

Author's response to C2: We fully agree with the reviewer on the need to diagnose the mentioned processes in more depth. The scarcity of in situ data for runoff and flux measurements is a major challenge in the study region (Ghebreyesus et al. 2016, Wehbe et al. 2017). Nevertheless, we have carried out additional analyses based on the comparison of simulated surface energy balance (SEB) and planetary boundary layer (PBL) heights between the two models at the four stations considered in the study.

Following the methodology used by Niu et al. (2011) to evaluate the performance of the Noah-MP hydrological processes at the local scale, the surface energy balance is investigated as follows:

$$\text{SW net} + \text{LW net} + (\text{Qh} + \text{Qe} + \text{Qg}) \pm \text{RES} = 0$$

, where the net shortwave (SW net) and longwave radiation (LW net) are given as the sum of the positive (outward) component and the negative (downward) components. The Qs, Ql, Qg and RES terms represent the sensible, latent, ground, and residual heat fluxes of the energy balance, respectively. The residual term arises from processes not applicable to the study domain, including energy consumed by snowmelt and rain freezing at the surface.

The Bowen ratio (β), initially proposed by Bowen (1926), gives an indication of the relative partitioning of net radiation in a region and can be expressed as:

$$\beta = \frac{Qs}{Ql}$$

Fig. 1 shows the SEB time series and the time-averaged Bowen ratio at each of the four studied stations.

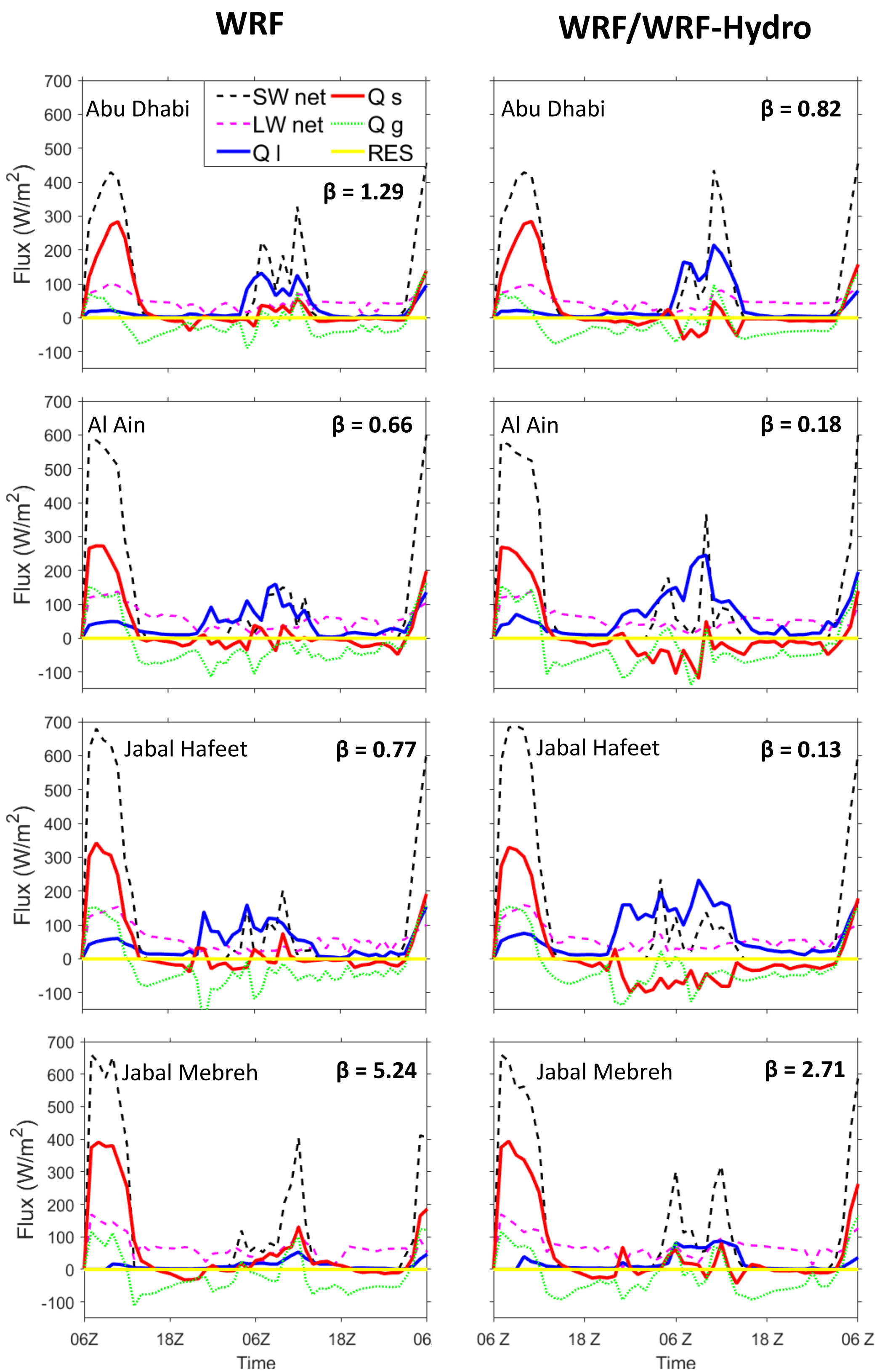

Figure 1. Surface energy budget time series from WRF and WRF/WRF-Hydro simulations at each of the four stations and their corresponding Bowen ratios (β).

The major differences between the SEB from both model configurations are shown midway through the simulation period between 06 and 18 Z. The coupled WRF/WRF-Hydro simulation shows higher (and lower) latent (and sensible) heat fluxes, as well as slightly higher net shortwave radiation, compared to the standalone WRF simulation. The coupled model is also associated with lower Bowen ratios compared to standalone WRF. The results are in line with the soil moisture-rainfall feedback mechanisms explained by Eltahir (1998). An increase in water content of the top soil layer decreases both the surface albedo and the Bowen ratio. A lower surface albedo dictates more absorbance of net radiation, while lower Bowen ratios are a result of higher water vapor content in the boundary layer and more downwards flux of terrestrial radiation at the surface due to the water vapor greenhouse effect. This dual effect amounts to a larger total flux of heat from the surface into the boundary layer.

Furthermore, the cooling of surface temperature accompanied by the moisture should be associated with a reduced sensible heat flux and a smaller PBL height. Fig. 2 shows the PBL heights from both simulations with larger collapses resolved from the WRF/WRF-Hydro. The timings of the reduced PBL heights in Fig. 2 coincide with those of the SEB discrepancies in Fig. 1 between 06 Z and 18 Z, which corroborates the occurrence of the chain of events considered thus far. According to Zheng and Eltahir (1998), the increase of the boundary layer moist static energy is expected to result in additional rainfall from the increase of local convection.

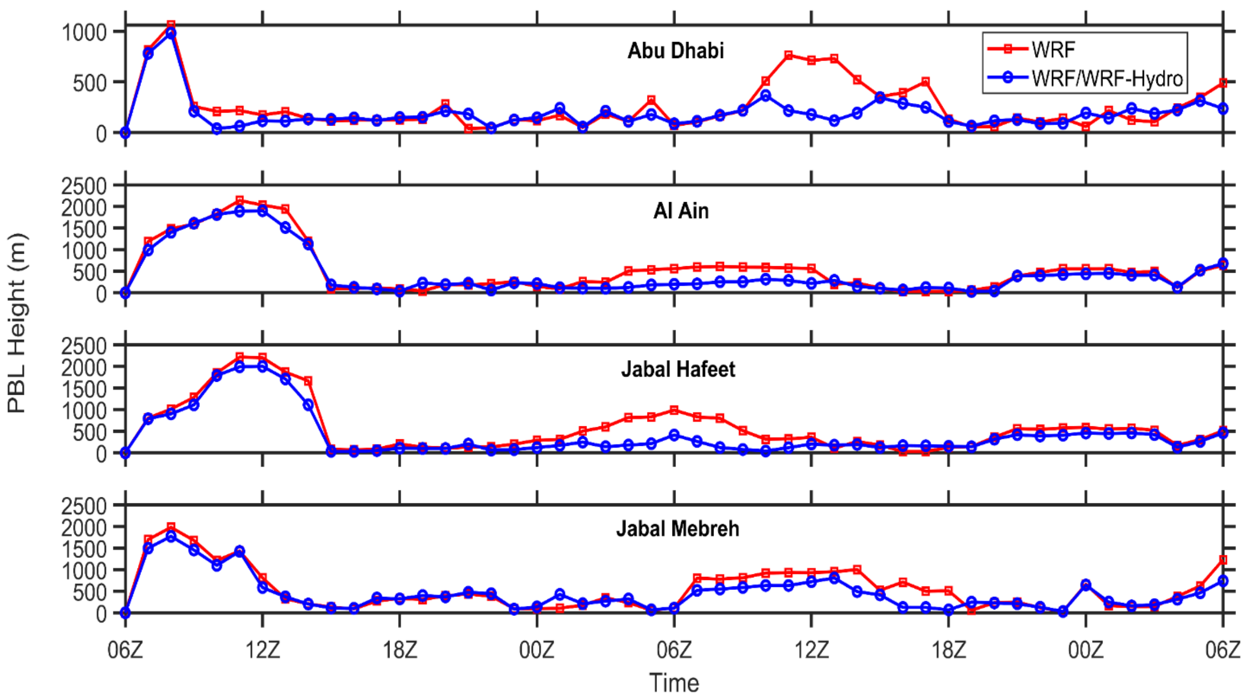

Figure 2. Planetary Boundary Layer (PBL) heights from WRF and WRF/WRF-Hydro simulations at each of the four stations

Author's Changes in manuscript: The above analyses will be added to the revised version of the manuscript.

Comment 3 (C3): Several speculative arguments (e.g. lines 31-33 of p.10 about the processes linking rainfall to soil moisture and to 2m air temperature, lines 5-6 of p.11 about the effect of soil moisture on surface emissivity/temperature, lines 11-15 of p. 12 about resolved scale vs subgrid scale cumulus, lines 13-15 of p.12 about underestimation of cloud by MODIS, and lines 19-20 of p. 12 about spin-up time) may be further analyzed in order to show in-depth processes.

Author's response to C3: Following Comment 2, we thank the reviewer and fully agree on the need for further analyses of in-depth processes, particularly the hydrological processes. In the below, we pursue the verification of soil moisture propagation due to lateral flow resolved by WRF-Hydro.

For a specific area, an individual sensor dedicated to soil moisture measurement fails to capture any change during a short time span in the order of days. The Soil Moisture Operational Products System (SMOPS), provided by the National Oceanic and Atmospheric Administration (NOAA), merges soil moisture retrievals from multi-satellites/sensors to generate a global product at higher spatial and temporal coverage (Liu et al. 2016). Relevant to the current study period, SMOPS now incorporates near-real time SMAP data and includes soil moisture retrievals from the GPM Microwave Imager (GMI). The 6-hourly product mapped at 0.25° x 0.25° spatial resolution is used here to assess the accuracy of the simulated soil moisture.

A comparison of soil moisture evolution at the upstream and downstream of a wadi within the study domain is expected to verify whether soil moisture transport occurs over the storm timescale. A wadi within the coverage of the Saih Al Salem station (24 49 39 N, 55 18 43 E) was selected to conduct this test. Fig. 3 shows the time series of simulated soil moisture from WRF/WRF-Hydro at two locations upstream and downstream of the wadi. SMOPS retrievals are overlaid as data points, along with the hyetograph recorded at the corresponding Saih Al Salem station at the top. Given the short distance (less than 1km) separating the two locations, a lag time of less than 1 hour is observed between the two soil moisture patterns. The first rain of approximately 22 mm at 22 Z 08/03/16 triggers an immediate increase in soil moisture from 0.18 to 0.25 m^3/m^3. The subsequent rainfall then elevates the moisture further to around 0.34 m^3/m^3, with a slight increase in the peak of downstream soil moisture compared to that of the upstream. However, at 18Z 09/03/16 the downstream soil moisture rises again to a sustained peak at around 0.32 m^3/m^3, while the upstream soil moisture continues to dissipate through infiltration and evaporation. In the absence of additional rainfall, this sustained peak in downstream soil moisture is the result of lateral surface flow from the upstream which is resolved by WRF-Hydro and fed back to the soil moisture fields. Despite the SMOPS data gaps during the event, the merged retrievals consistently increase during the event with reasonable accuracy compared to the simulated soil moisture fields.

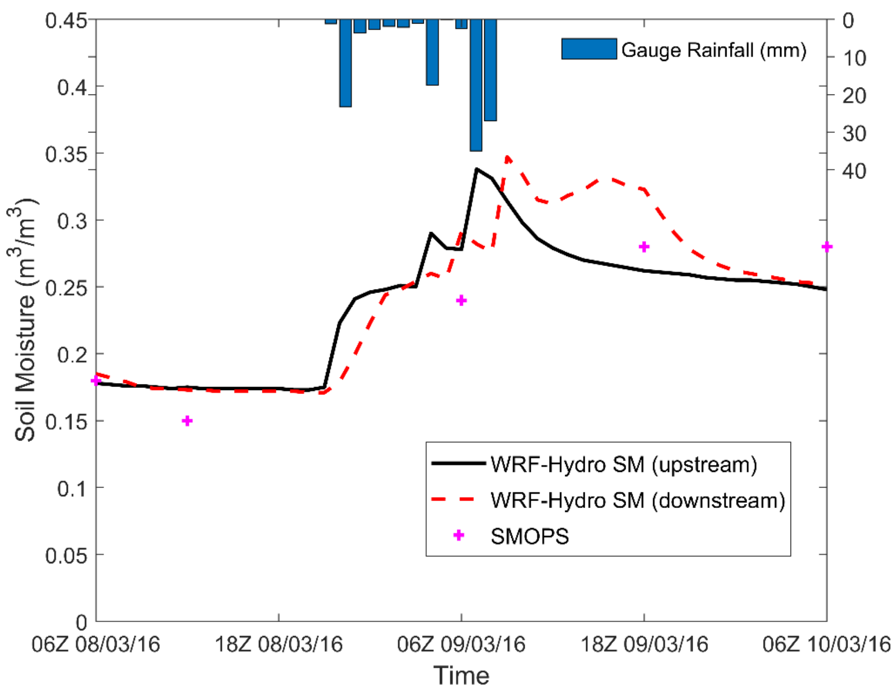

Figure 3. Time series of simulated soil moisture from WRF/WRF-Hydro at the wadi upstream and downstream locations, along with collocated SMOPS retrievals. Hyetograph recorded at the Saih Al Salem station is shown on top.

We mention the need for ensemble simulations and the issue of internal atmospheric variability (Page 15 Lines 29 – 33) that requires attention. The aim of the paper was a first trial of WRF-Hydro coupling over the UAE for a single extreme event. A more comprehensive detailed analysis with ensemble simulations covering multiple events are reserved for future work to isolate the processes with more in situ data, including eddy covariance observations.

Author's Changes in manuscript: The above analyses will be added to the revised version of the manuscript.

Comment 4 (C4): Figure 3 (c) & (d) and Figure 10's soil moisture plots from WRF all have shown weird stripe structure of modelled accumulated rainfall and soil moisture, respectively. This adds doubts to model settings or post-processing and must be investigated thoroughly and the reasons should be fully explained. Once the errors are identified, all analyses should be re-done and all results should be updated.

Author's response to C4: We thank the reviewer for capturing this anomaly in the mentioned figures. We revisited the raw WRF output files and found the problem arising from the post-processing, particularly the interpolation fields.

The Gaussian-weighted interpolation routine was initially used during the post-processing. We have repeated the post-processing for both figures using the Cressman-weighted interpolation, which conducts successive corrections using a decreasing radius of influence. This method required more computational time but the results retained more of the mesoscale structure. New figures will be added in the revised version.

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