Earth Syst. Dynam. Discuss.,
https://doi.org/10.5194/esd-2018-32-SC1, 2018

Interactive comment on "On the origin of moisture related to synoptic-scale rainfall events for the North American Monsoon System" *by* Paulina Ordoñez et al.

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Received and published: 10 July 2018

Review of Ordoñez et al. 2018 David K. Adams (dave.k.adams@gmail.com)

I commend the authors, several of whom are my colleagues, efforts to attack this important problem, a problem that goes way beyond the scope of the North American Monsoon region. However, there are some fundamental problems with this paper that need to be addressed before publication. It is clear the study is fundamentally flawed by the conclusion that the Pacific Ocean off the coast of California is a moisture source for the monsoon. This is patently absurd given the water temperatures (10 to 20C) of the Pacific Ocean (see typical sounding Figure 2 below), no need to even consider the

stable Subtropical Pacific High and nearly impassable mountains of California. So, just for this reason alone, all other results from this study should be called into question. However, the indication that the Sonoran and Mojave Desert could be a major moisture source through also stretches the limits of credibility– one of the driest, warmest regions on Earth that receives scares, very localized rainfall during the Monsoon becoming an important local source. These results are surely a result of the FLEXPART modeling employed which is apparently inadequate for the task at hand.

These radical, game-changing conclusions that the authors arrive at, contradicting nearly 4 decades of the vast majority of studies (both observational and modeling), need to provide extraordinary evidence (particularly direct observational support, not modeled products of water vapor or precipitation products over Mexico) for their conclusions.

Below I outline basic points that should be addressed in order to validate their conclusions.

(1) From simple thermodynamic arguments (the water vapor scale height is only about 2km), mid-level cannot be responsible for for the in the NAM region west of the elevated terrain (SMO, Continental Divide, etc). This is shown by Adams and Souza (2009), Maddox et al. 1995, Mazon et al. 2016, Rogers et al. 2017 and many, many others. Low-level water vapor (below 800mb) is required for generating convective instability over the valleys and low deserts. Elevated water vapor sources (above $\sim$ 700mb) can help with initiation over elevated regions (e.g. SMO or Four-Corners region) but this convection cannot migrate towards lower regions without the support of low-level moisture. Entrainment of dry air is too detrimental. Gulf of Mexico can certainly contribute to NAM convective precipitation, but can not "cause" or be "responsible" for a sizeable portion of it, west of the SMO/Continental Divide regions. No low-level moisture, no deep convective precipitation in low-lying zones. Likewise, no strong surface heating, no deep convection (higher level moisture can actually be detrimental to the later, soundings can be too moist (see Adams and Souza 2009))

(2) The Model. The authors will have to provide more evidence as to how their extremely simplistic model (FLEXPART) which cannot account for vertical transport in convective updrafts, (scale 100s of meters to kms on the high end of organized convection, and order minutes to an hour), nor for entrainment/mixing in a realistic manner, and no need to mention the proper formation of hydrometeors and precipitation processes. Even assuming FLEXPART is a valid model for doing the impossible, consider also the arguments of Ana Maria Quesada. The evaporation/precipitation relationship is entirely space/time resolution dependent (See our figure 3 below, local surface fluxes have little relationship with total column, precipitable water vapor).

(3) Data. ERA-Interim data is not adequate. Reanalysis data, in general, is inadequate because model-generated values depend on convective and microphysical parameterizations. Pressure, geopotential heights and winds, can be dynamically constrained, the water vapor distribution cannot. This poorly measured quantity is extremely difficult to replicate in the NAM region (see Radhakrishna et al. 2016 and many others) (Also, See attached figure 3 for ERA-Interim vs GPS Precipitable water vapor data below). ERA-5 is still bad, but much better than ERA-Interim or NARR. Given the radically different nature of surface evaporation of the oceanic (e.g., different surface wind speeds and temperatures) zones and more critically over the complex topography of Mexico and the Southwest U.S., how is the evaporation determined at the necessary spatial/temporal resolution.

(4) Moisture recycling Just a point of logic, if local moisture recycling is important then (1) how does the monsoon precipitation begin? Vegetation green up occurs at the end of July into August (2) Why does precipitation decrease, become for more variable around the second week of August (see for example Kursinski et al. 2008) in Northwestern Mexico and Arizona even though vegetation is green and surface moister, in general? Also, wet surfaces can actually be detrimental to deep convection, as convective temperatures cannot be reached for this region (see Kirsten Findell's 2011 article among others). Our results from the GPS Hydromet Network show that at the sub-

diurnal scale, local water vapor fluxes and precipitable water vapor have small correlations, lagged or not. So at least locally, it is not apparent that moisture recycling (see figure 3 below) plays any important role in column water vapor. Boundary layers are extremely deep and well-mixed over much of the region, so very local surface evaporation would be mixed out quickly, not providing sufficient "density" to either contribute to increasing convective instability, nor precipitation efficiency. Only large-scale advection could account for generating the necessary water vapor fluxes to produce the instability necessary to generate convective activity.

5) And probably most important and what makes this a very difficult problem to separate sources easily is the mixing over the SMO due to deep convective activity. Moist air to the east of Arizona and the SMO, in general, may result from deep convective mixing further south and then transported northward along the high terrain with or without precipitation.

Minor Comments

"Later studies claimed" is not the correct word, better "indicated" or something of the like. The vast majority of studies over the last several decades have shown that the time mean as well as transient flow are dominated by the EPac and GoC.

"While compelling, these results are based on observations from a limited field campaign" These are a least real-world data and not model dependent as are ERA-Interim.

"IVs, as well as improved models of the flow over complex terrain like that of the NAM region are both needed to better understand the role of IVs in supporting convective outbreaks across the monsoon region." This is sort of a throwaway statement. Our understanding of IV is fairly good and there dynamic effects (increased shear) appears to be responsible for convective organization. Water vapor transport plays no role, nor its advection, as these features are found at 300 or 200mb. (See Finch and Johnson 2010).

IVs seem to help the moist air to bypass the Sierra Madre westward accompanied by organized convection and upward vertical velocity over the NAM region. You need to back this claim up. As shown by Finch and Johnson (2010). windshear in organizing convection is important, adiabatic lifting is weak. From our examination of Marty Ralph and Tom Galarneau′s results (using lightning data as a proxy) Invited Manuscript for Atmospheric Research there is little evidence of low-level water vapor transport from the Gulf of Mexico on strong convective days. Strong shear can certainly be important in the easterly winds, but we should not convolve dynamics and water vapor transport.

"This wind reversal is not of sufficient magnitude and scale to meet the criteria of Ramage (1971) for a monsoon (Hoell et al. 2016)." You need more the two citations to make the claim that it is not a monsoon circulation.

"Bosilovich et al. (2003) found the dominant sources of monsoon precipitation to be the local evaporation and transport from the tropical Atlantic Ocean (including the GOM and Caribbean Sea)." As Bosilovich et al. (2003) note in their study "It is also worthwhile to reiterate that the model does not resolve the Gulf of California, which should influence the sources of water." Always critical to consider space/time resolution of large-scale models.

Our work with Chris Castro and others demonstrates the need for Convective Resolving Models in order to capture mesoscale convective systems (order kms resolution), which are responsible for a large portion of precipitation particularly in NW Mexico. Results from low resolution models 1degree x 1 degree should be critically assessed given their inability to produce these systems correctly. (see Lamhers et al. 2016, Luong et al. 2017, Moker et al in press JAMC)

Figure 1. (Figures 1,2,3 in comments) Percent error between ERA-Interim PWV and collocated GPS PWV from NAM GPS Transect Experiment 2013 (See Serra et al. 2016). Errors for most of the 10 GPSmet sites can exceed 20%.

Figure 2) (Figure 4 in comments) Typically July sounding for Oakland and San Diego.

Low Moist Static Energy at surface could simply not provide sufficient convective instability and could, under no conditions, break through the extreme inversion always present over the Pacific Ocean from July to mid-September.

Figure 3. (Figure 5 and 6 in comments) Latent Heat Flux vs GPS PWV for Rayón Sonora (top) during active Monsoon period.(Bottom) Correlation of above LH flux vs PWV figure smooth for 3 hours. Correlations with different smoothing are typically 0.3 or less on diurnal to sub-diurnal timescales. Data from NAM GPS Hydromet Experiment 2017.

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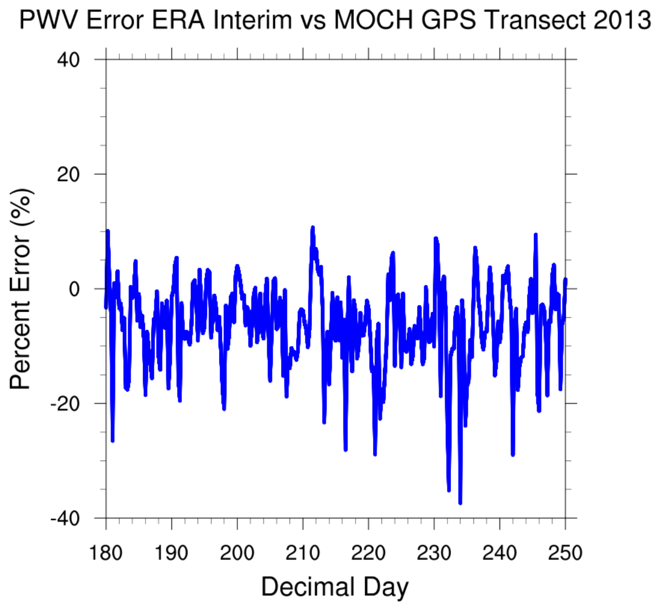
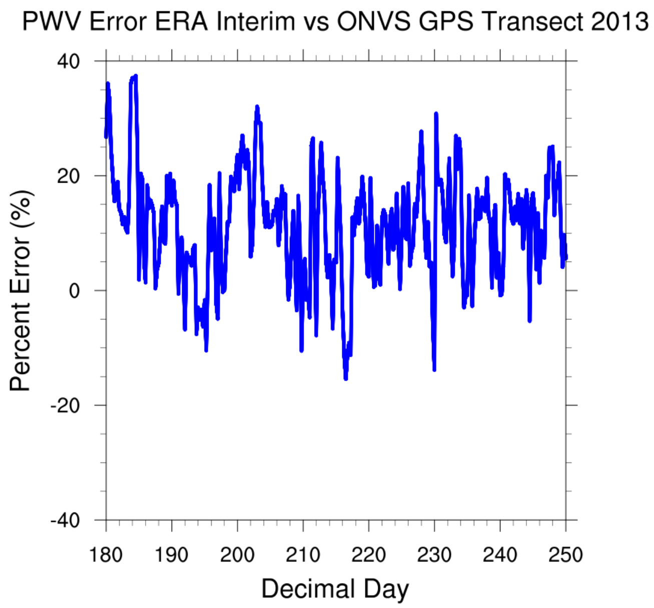


PWV Error ERA Interim vs MOCH GPS Transect 2013
40
20
0
-20
-40
Percent Error (%)
180
190
200
210
220
230
240
250
Decimal Day

Fig. 1.



PWV Error ERA Interim vs ONVS GPS Transect 2013
40
20
0
-20
-40
Percent Error (%)
180
190
200
210
220
230
240
250
Decimal Day

Fig. 2.

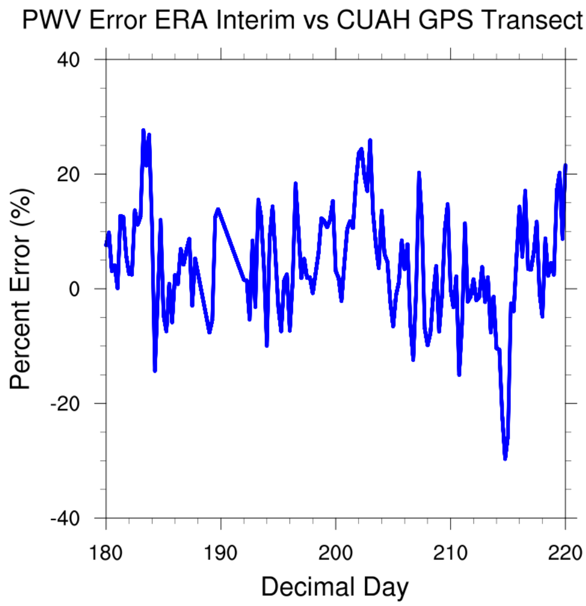
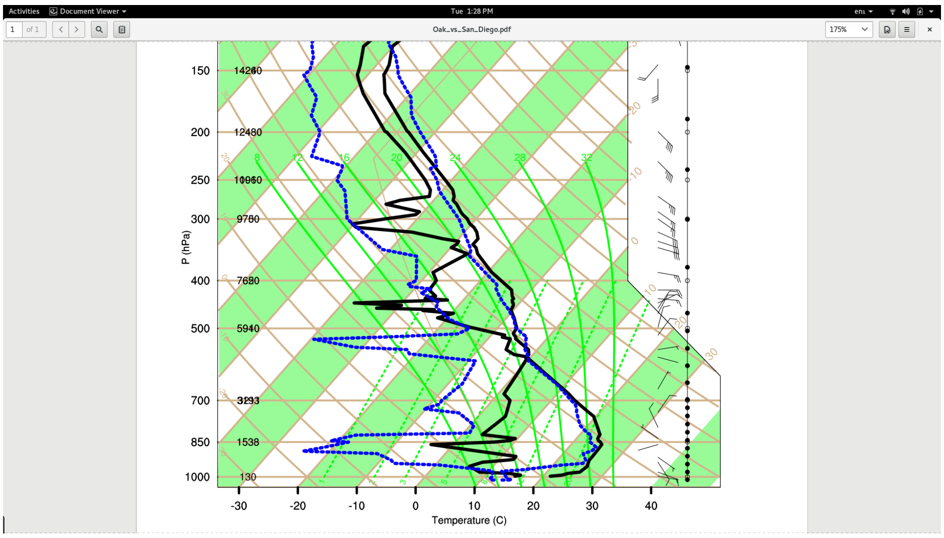

PWV Error ERA Interim vs CUAH GPS Transect 2013
Percent Error (%)
Decimal Day
40
20
0
-20
-40
180
190
200
210
220

Fig. 3.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P (hPa)
Temperature (C)

Fig. 4.

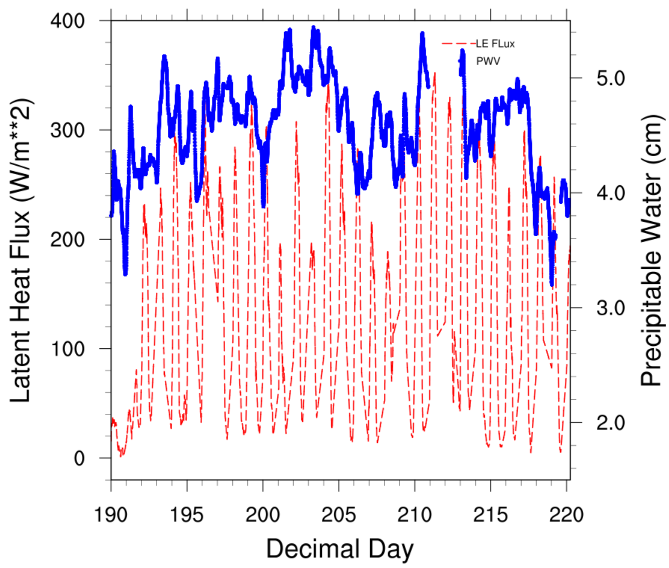
LE FLux
PWV
Latent Heat Flux (W/m**2)
Precipitable Water (cm)
Decimal Day
400
300
200
100
0
5.0
4.0
3.0
2.0
190
195
200
205
210
215
220

Fig. 5.

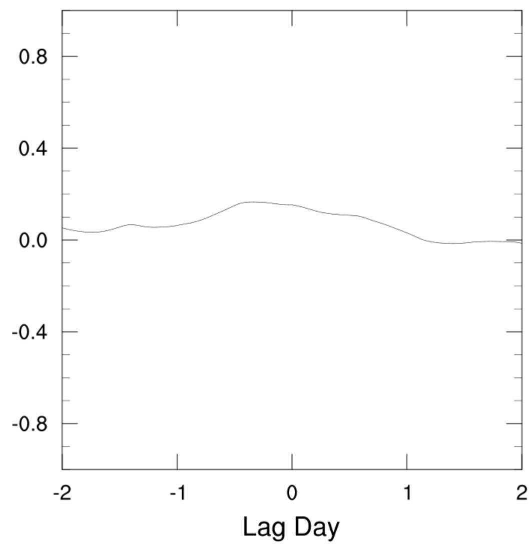
0.8
0.4
0.0
-0.4
-0.8
-2
-1
0
1
2
Lag Day

Fig. 6.