Reply to the Reviewers:

As a first note, we would like to express our gratitude for the efforts and work done by the reviewers. The comments we received helped us revise the manuscript and improve it significantly. The major revisions done, based on the main comments will be summarized first and then will be followed by specific point by point answers to all the comments.

General Comments:

In this manuscript we use rain-rate vertical profiles from the TRMM satellite for examination of the spatial and temporal distribution of clouds hydrometeor mass as a function of the distance from coastlines. Based on the reviewers comments we did further analysis of TRMM data and of winds data and we present the results in the revised version. We think the manuscript presents now a more complete picture with smaller uncertainties in the analysis and more evidences to support our hypothesis about the physical mechanisms behind the observed trends.

The main changes done in the revised manuscript:

1) **Substitution of TRMM Product**: Due to the comment that raised the issue of uncertainties attributed to microwave sensors in coastal areas and suspected artifacts in the data, we did further analysis and choose to present in the revised manuscript the results based on the TRMM 2A25 product (based only on the Precipitation Radar) instead of the TRMM 2B31 product (Precipitation Radar + Microwave Imager) that was used in the previous version. To our knowledge, this product serves as the best remote sensing option of rain in coastal areas and is insensitive to sea-land transitions compared to microwave based products. This way we reduced significantly the likelihood for artifacts in the data in coastal regions. Moreover, in the revised version we use the new TRMM 2A25 version 7 product that was recently released as a replacement for version 6. The new version is considered superior over land areas compared to the previous versions.

2) **Addition of Wind Data**: To further support our hypothesis that some of the observed trends in rain rates near coasts are indeed due to mesoscale breezes, we added low-level

wind data from Israeli Meteorological Service radiosondes, for the rain events. Bet Dagan station is located about 10 km from the coast and gives a good indication to the prevailing winds in the region. It gives direct evidence for the frequency of occurrence of land breeze during winter rain events. Additional analysis is done by sorting the rain mass spatial distribution in each event by the winds. Moreover we have added a new analysis using the QuikSCAT wind data to demonstrate convergent and divergent effects over the sea near the coast. Please see the comments below for more details on those new analysis results added to the manuscript.

3) **Frictional Convergence** (FC): In the revised version, we took into consideration the Frictional Convergence effect that occurs near the coast as a result of the change in the roughness of the surface. This effect is considered now in the manuscript as an equally important mechanism for coastline convergence as the land breeze and orographic forcing effects. Evidences are presented for the impact of this effect and its relative importance compared to the other effects, all influencing together on the rain distribution around coastal regions.

Reply to Reviewer # 2:

Our answers to the comments will be presented point by point (first answering the main comment and then specific comments marked by C#: and answer by A#:)

Main C: This manuscript uses TRMM satellite derived products to investigate the formation of coastal winter-time clouds in the Eastern Mediterranean. This manuscript uses 13 years of satellite observations to analyze the mean and diurnal spatial distribution of the "Integrated Hydrometeor Mass" (IHM). The manuscript hypotheses that the land breeze is interacting with the synoptic wind to determine the location of the IHM. But, the manuscript does not present any temperature or wind data to support or document this conclusion. Without any other supporting data, it is not possible to isolate whether the observed distribution of IHM is due to orographic forcing or the interaction of the land breeze with the synoptic wind. Therefore, this manuscript documents the location of mean and diurnal variations of IHM using satellite observations, but does not quantify how or why those variations exist.
This manuscript would be more beneficial to the literature if either wind or temperature data are analyzed in a similar fashion as the satellite data to determine if there is any correlation between forcings and IHM. I encourage the authors to add the analysis of wind or temperature data to this manuscript.

Main A: To address this comment, and to give further support to our explanations regarding the physical mechanisms behind the observed trends in rain mass, we added the revised manuscript an analysis of wind data. The zonal wind values were taken from Beit Dagan radiosondes for rain days only, representing the wind field during rain events in Israel, not far from the coast (see Fig. 5 in revised manuscript). It demonstrates the prevailing winds during those weather events, as written in the revised manuscript: **"Another type of meteorological data used in this study is the radiosonde wind and temperature data from the Beit-Dagan Israeli Meteorological Service station (Beit-Dagan is located in central Israel, approximately 10 km inland. See Fig. 3). The data was collected for rain days in Israel sub-region. The station provides two soundings**

per day, one at 00 UTC (02:00 LT) which represents the nighttime conditions, and the other at 12 UTC (14:00 LT) which represents the early afternoon."

Moreover, we used the radiosonde wind data to compare IHM spatial trends for different wind regimes (Fig. 7 in the revised manuscript): **" More insight on the possible causes for the IHM spatial distributions can be obtained by sorting the IHM data according to the observed low-level zonal winds (see Fig. 5). The results are presented in Fig. 7. For each sub-season, the rain events detected by TRMM were classified here as day (8:00 LT to 20:00 LT) or night (20:00 LT to 8:00 LT) events. The median wind velocity was then calculated for day and night separately using the Bet Dagan sounding data. Half of the total soundings that represent days and nights with easterly and weak westerly winds were classified as WW (Weak Wind) events, and the other half that represent days and nights with medium to strong westerly winds as SW (Strong Wind) events."**

, which enable us to conclude about the significant effect in each case in the conclusions section of the revised manuscript: **" Land Breeze tagged peaks are more prominent during days with weak westerly and easterly winds, especially during November-December. Frictional convergence tagged peaks are clearly seen on days with strong westerly winds, especially during January-March"**.

An additional analysis was done using wind data from the QuikSCAT satellite. The results are presented in Fig. 1 (see below). The resolution is 25 km and represent an area over the sea from about 25 km offshore. Figure 1 shows us near surface wind divergence (positive values) and convergence (negative values) for early morning (6:00 LST) and late afternoon (18:00 LST) in the Eastern Mediterranean (EM). We can see that in the early morning when the strongest land breeze is expected, surface winds nearby EM coastlines show a convergent effect. During the late afternoon when we expect the weakest land breeze or no breeze at all, the winds show a divergent effect. This trend is true for both November-December and January-March sub-seasons. The results of this analysis are mentioned in the manuscript but we choose not to add this figure since we didn't want to make the manuscript too long: **"Additional wind analysis was performed (results not displayed here) using SeaWinds aboard QuikSCAT (Quick**

Scatterometer) mission (Graf et al., 1998). QuikSCAT obtains near surface wind vectors with a spatial resolution of 25 km x 25 km and passes over the same terrain twice every day, at 6:00 (early morning) and 18:00 (late afternoon) LST. The instrument is limited to marine surfaces reaching to about 25 km offshore the coastlines. Using the wind vector data, we calculated wind divergence for the EM region during rain events and reached two main conclusions: i) Offshore coastal areas (excluding Cyprus island) up to 100 km offshore experience near surface negative (positive) wind divergence during the early morning (late afternoon) hours. ii) Far offshore areas show no wind divergence in the morning and slight positive divergence in the afternoon. These conclusions are valid for both sub-seasons, and serve as another indication that mesoscale convergence occurs nearby coastlines during the night and early morning when LBs more frequently occur".

For more wind and temperature climatological data, we kindly refer the reader to the references in the text, such as: Neumann, 1951; Khain et al., 1993;Goldreich, 2003;Levy et al., 2008 (references attached at the end of this document as well): **"During the rainy months studied here (November-March), EM Sea Surface temperatures are usually warmer than the adjacent land by 2-10 °C, making LB a common phenomena during the winter (Neumann, 1951;Goldreich, 2003;Levy et al., 2008). The LB magnitude varies both diurnally: maximum (minimum) Land-Sea Temperature Difference (LSTD) at sunrise (afternoon), and seasonally: maximum (minimum) LSTD during December (March)."**.

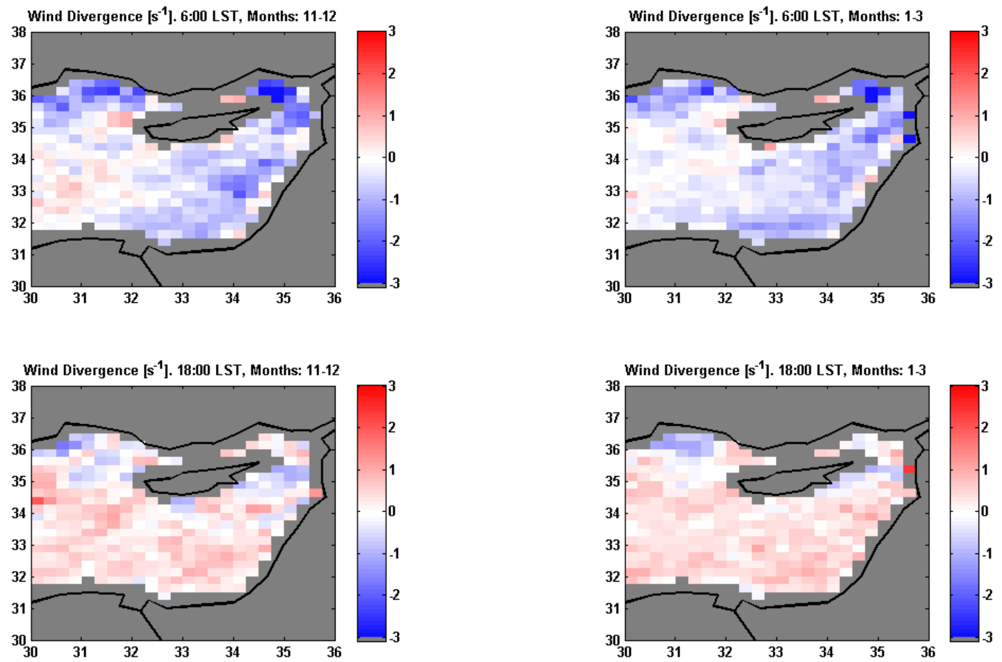

Figure 1. QuikSCAT near surface wind divergence [s^{-1}] in the Eastern Mediterranean. Left (Right) panels correspond to November-December (January-March) months. Top (Bottom) panels correspond to 6:00 LST (18:00 LST). Pixel resolution is 25 km. Positive values (red shades) indicate divergence, and negative values (blue shades) indicate convergence.

C1: Title, "Coastal precipitation formation and discharge based on TRMM observations". This manuscript does not address the "formation" of precipitation. It addresses the location of the precipitation as observed by TRMM observations. What is "discharge"? This word is only used in the title and the abstract. Please determine a more appropriate title.

A1: We changed the title to: **"Coastal Precipitation as Immerges from TRMM observations".**

C2: Abstract, page 15660, line2 13-15. "The intra-seasonal and diurnal changes in the distribution of hydrometeor mass indicate that the land breeze is most likely the main responsible mechanism behind our results." The manuscript does not present any land breeze data or any data that can be considered a proxy for a land breeze. Therefore, this conclusion stated in the abstract is not supported in the body of the manuscript.

A2: As mentioned above in the main answer, a new analysis of wind data was added to the manuscript for description of prevailing winds during rain events that can indicate the presence of land breeze. Moreover we show an additional analysis based on sorting of the IHM data according to the low-level zonal winds enabling more insight on the possible causes for the IHM spatial distributions. Another new analysis was done using the QuikSCAT wind data to demonstrate convergent and divergent effects over the sea near the coast. We rephrased the statement to: **"The intra-seasonal and diurnal changes in the distribution of hydrometeor mass indicate that the land breeze may likely be the main responsible mechanism behind our results."** The new wind data analysis does support our conclusion that land breeze is likely to be a main contributor to the observed IHM spatial patterns.

C3: Page 15663, lines 17-24. Are the convergences in the Eastern Mediterranean (EM) during the winter-time comparable in magnitude to the convergences observed and modeled over the summer-time Florida Peninsula? Please explain to the reader that EM convergences are less than those modeled and observed in Florida.

A3: The section discussing breezes over the Florida peninsula was removed from the revised manuscript (lines 17-24 on page 15663).

C4: Page 15666, paragraph starting on line 16. This paragraph defines the hypothesis that the interaction of synoptic wind and the land breeze (LB) determines the location of the precipitation. But no wind data is presented in this study to test this hypothesis. This raises many questions, for example, if the LB is driven by a temperature difference between the sea and the land, what is the temperature difference when clouds are present? What is the wind strength and direction of low level wind along the coast during synoptic weather events? What is the correlation between wind strength and direction with IHM, both in the mean and at the diurnal temporal scale? Plus many more questions that could be addressed with some wind data.

A4: Please see the detailed answers related to winds above (main A and A2), describing the new analysis of wind data during rain events (using Bet Dagan sounding and QuikSCAT data), that was added to the manuscript.

C5: Page 15673, lines 8-9. “one most likely related to the convergence of LB and gradient winds (LB peak), and the other related to orographic lifting (orographic peak).” How were the two peaks objectively identified as being related to land breezes (LB) and orographic lifting in the satellite data? What data supports this “most likely” result?

A5: Our classification to LB, FC and Orographic peaks are based on the expected locations based on the physical mechanisms involved and on indirect evidences. The wind data proves that land breezes do exist, and the nearly constant location of IHM peaks on the upslope of mountain ridges (see revised manuscript) imply the connection to orographic forcing. Nevertheless, we removed the “most likely” statements and rephrased to more restrained statements. The following sentence was added to results sections: **”According to our basic assumptions, we classify IHM peaks slightly offshore as convergence between synoptic winds and LB, peaks slightly onshore as FC (Frictional Convergence), and peaks nearby topographic obstacles as OF (Orographic Forcing)”.**

C6: Page 15674, paragraph starting on line 20 and Figures 7 and 9. In the IHM diurnal analysis plots shown in Figures 7 and 9, do the peaks at different distances occur at the same time or do they occur in different storms? The composite of 13 years of observations could show two peaks, but there may only be one IHM peak during each synoptic event. If I understand the manuscript, increased LB causes an increase in wind flow away from the shore. This would decrease the amount of on-shore flow and decrease the amount of orographic uplift. A cross-spectral analysis would reveal if the two peaks occur simultaneously.

A6: Thank you for a very good comment. Indeed, it was not clear in the original manuscript if the diurnal patterns represent a typical rain event evolution or is it a combination of effects of different types of rain regimes in storms. Our deep acquaintance with the data (based on analysis of many different months separately) proves it is a combination of effects and not a typical day. Therefore, the following sentence was added: **"We stress the point that diurnal IHM variations in this work do not necessarily reflect a typical diurnal variation per winter storm, but rather the diurnal preferences for precipitation in a climatological view. The satellite data used gives us only fragments of storms and instantaneous snapshots, therefore the existence of two different peaks at the same hour can be due to the combination of several different events or just one event with multiple effects taking place."**

C7: Page 15678, lines 22-23. "Evening to morning hours exhibit an offshore transition of the IHM peak, while late morning to evening hours exhibit a transition of the IHM peak towards inland." Patterns in the diurnal plots do not indicate that the peak moves from one 'time zone' to another 'time zone' within the same event. Please re-phrase this sentence.

A7: Sentence was rephrased: **"Evening to morning hours exhibit a preference for high offshore IHM values, while late morning to evening hours exhibit a preference for high coastal and inland IHM values."**

C8: Page 15678, lines 26-29. “It is apparent however, that the offshore LB Gaussian during November-December is highly affected from the intense afternoon offshore peak (see Fig. 9), a fact which opposes our current proposed theory.” This unexplained peak is the largest magnitude peak in Figure 9. Some observed wind or temperature data would enable the hypothesis to be tested.

A8: The afternoon peak was tested using the additional wind and temperature data from Beit-Dagan soundings. However, the synoptic factors during afternoon peak events are to the most consistent with the average synoptic factors during November-December. We therefore note that additional analysis must be performed in order to reach conclusions regarding the afternoon peak: **"Preliminary analysis of synoptic factors reveals no consistent reasons to why the afternoon peak exists. Therefore, a following work is planned to look into this diurnal feature".**

References

Goldreich, Y.: The Climate of Israel: Observation, Research and Application, Kluwer Academic/Plenum Publishers, 2003.

Khain, A. P., Rosenveld, D., and Sednev, I.: Coastal effects in the Eastern Mediterranean as seen from experiments using a cloud ensemble model with detailed description of warm and ice microphysical processes, Atmospheric Research|Atmospheric Research, 30, 295-319, 1993.

Levy, I., Dayan, U., and Mahrer, Y.: A five-year study of coastal recirculation and its effect on air pollutants over the East Mediterranean region, Journal of Geophysical Research, 113, D16121, 2008.

Neumann, J.: Land Breezes and Nocturnal Thunderstorms, Journal of Meteorology, 8, 60-67, 1951.