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 # 3:

Our answers to the comments will be presented point by point (first answering the general comments marked by GC#: and answer by GA#: and then the specific comments marked by SC# and answer by SA#).

GC1: There is a need for verification of the IHM against surface rain measurements, at least from part of the sampled days. Rainfall data is available at least from Israel.

GA1: Ground validations studies for TRMM require lengthy analyses which justify a complete separate paper. However many previous studies did these kind of validations of TRMM PR for many other regions and they are referenced in the references in Sect. 2.1 of the revised manuscript: **"Many validation studies have been conducted for the 2A25 product. Validation results vary on spatial and seasonal temporal scales (Nicholson et al., 2003;Wolff et al., 2005), and are regionally dependent (Franchito et al., 2009). Like all TRMM level 2 products, 2A25 is outperformed in estimating accumulated rainfall by lower resolution, rain-gauge calibrated TRMM products such as the 3B42 (Kummerow et al., 2000;Adeyewa and Nakamura, 2003;Nicholson et al., 2003). Nevertheless, 2A25 product has successfully been able to capture diurnal precipitation and climatological trends (Shin et al., 2000;Yang and Smith, 2006), and is considered to be well calibrated compared to ground validation radars (Wang and Wolff, 2009;Liao and Meneghini, 2009;Fisher and Wolff, 2010)"**. Moreover, since the conclusions derived in this paper are based on intra-seasonal and diurnal trends, a constant/random TRMM bias compared to actual surface rainfall would not change much those conclusions.

GC2: There is a need to specify how many individual samples that occurred in rain days are included in the study. This is essential for the statistical significance of the results.

GA2: Thank you for the remark. The number of rain days was added to the results section for each sub-region, it is 941 days for Israel and 1545 days for Lebanon. Number of rain counts per grid pixel is presented now as a part of Fig. 4 in the revised manuscript.

Additionally, number of counts per sorting bin is added in all the figure captions (Fig. 6 – Fig. 11) for figures showing the mean IHM as a function of the distance from the nearest EM coastline and their time evolution.

GC3: There is a need to address the possibility that over land the sensors underestimate the rain rate. This can also explain the drop of rain rate across the coastline, in spite of the sharp orography, at least in Lebanon.

GA3: Thank you. Because of such issues, the revised manuscript is based on the new 2A25 version.7 product, which is considered superior over land. However the possibility of rain underestimation over land is addressed in the methods section: **" Moreover, some of the weaknesses in performance (i.e. underestimation of rain-rates and surface clutter) over land compared to over sea previously reported (Wolff and Fisher, 2008;Iguchi et al., 2009) are expected to improve considerably as surface reference resolution increased from 1^0 to 0.1^0 and Z-R relations over land were recalibrated (changes done in the new version 7 product used in this work)."** and in the conclusions**: "There was no notable effect to the Anti-Lebanon ridge (located in Lebanon sub-region, 60 km from the coast). This may be due to depletion of much of the water content (rain shadow effect) after passing the first ridge, the smaller height gradient between both ridges, and underestimation of rain-rates which can occur over certain land areas (see Sect.2.1)."**. A look at Fig. 9 in the revised manuscript, that presents the mean IHM as a function of the distance from the coastline in Lebanon, shows us that the sharp drop in IHM occurs mainly for liquid hydrometeors and not ice which remains constant till at least 20-30 km inland. This makes sense over high topography where the hydrometeor column is "squeezed" between a high level inversion and the high mountains (above the freezing level) and contains mostly ice hydrometeors.. Meaning, that the drop is not necessarily related to underestimation of rain-rates.

GC4: The IHM maximum you attributed to orography seems to be, at least partly, a coast-line effect. You should mention that in the "results" section.

GA4: As mentioned in the general remarks part, 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. In the revised results section we add more emphasis on the coastline effects and check their significance in different regions and times. The separation of orographic peaks is clearer in the new figures. See also answer to specific comment #15 below.

GC5: There is a need for further improvement of the language, especially in the last section (see several specific comments).

GA5: A language editing was done to the best of our ability in the revised version and we addressed all the specific comments below regarding langue inaccuracies.

SC1: Page 15662, line 4, **"i.e./ conditional instability"**. Omit. This it is not the definition for lower level inversion

SA1: The term "conditional instability" was omitted from the text.

SC2: Page 15663, line 3-6, Items *i* and *ii.* Add at least one reference

SA2: Items (i) and (ii) refer to the findings by Neumann,1950: **"Frequent nocturnal thunderstorms (Neumann, 1951) observed near the Eastern Mediterranean coastline were explained by: (i) the convergence of synoptic gradient winds with LB (ii) the convergent effect coastline curvature may play on low level winds, with**

concave coastlines favoring LB convergence and convex coastlines favoring SB convergence". They are not general statements. Other papers that find similar findings are listed in the same paragraph: **"Similar effects of cloud formation as a result of low level convergence were observed (Purdom, 1976) nearby other land-water interfaces such as rivers and lakes. Furthermore, breeze fronts were seen to interact with preexisting convection lines and thunderstorms, greatly intensifying the mesoscale convection. Radar observations of regions exhibiting LBs opposing gradient winds (Meyer, 1970;Schoenberger, 1984) showed frontal zones of nocturnal cumulus clouds which form nearby coastlines and propagate further offshore at a speed dependent on the temperature difference between the land and sea"**.

SC3: Page 15663, 15-16, Fig. 1. Additional image from later on the same day, showing decay of the cloudiness, would help.

SA3: Additional three radar images, in 2 hours intervals (6 Jan 2011, from 5:00 to 11:00 local time) showing cloudiness decay were added to Fig. 1 (See here below as well).

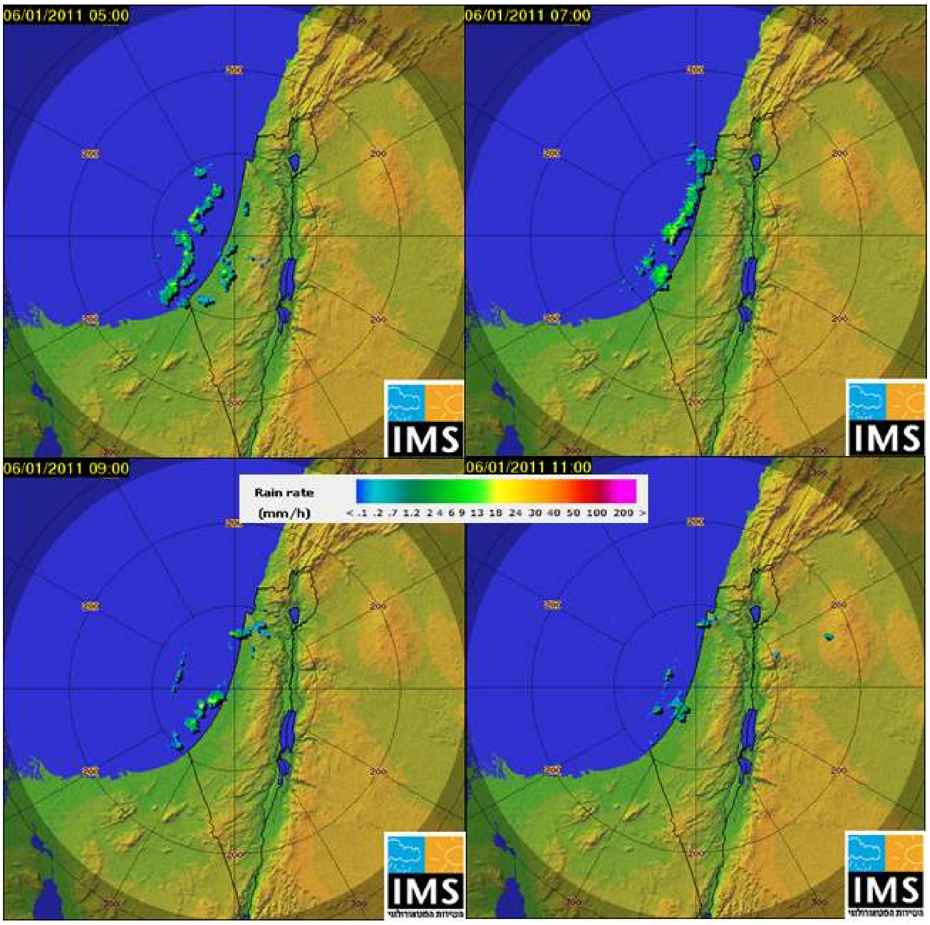

Figure 1. Radar image evolution of rain clouds off the coast of Israel, 6 Jan 2011, from 5:00 to 11:00 local time, at two hour intervals. The rain clouds started dissipating after sunrise. The image serves as an example of an almost stationary precipitation line formed offshore, and is likely attributed to an offshore LB front. Image taken from the Israeli Meteorological Service (IMS) website, at http://www.ims.gov.il.

SC4: Page 15663, line 26, **"Java"**. It is not in the SE Pacific. Please, correct.

SA4: Corrected to South East Asia: **" Java Island in South East Asia is an extreme case...".**

SC5: Page 15664, line 7, **"cold air above"**. Change to "cold air to its north". The upper cold air does not imply baroclinic instability.

SA5: Proposed word exchange was carried out: **"These systems may further intensify through processes of low-level baroclinic instability i.e. large thermal contrast between the sea and cold air to its north and lee cyclogenesis near southern Turkey."**.

SC6: Page 15664, line 12, "**95%"**. This has not been found by Goldreich (2003). I suggest you should quote Saaroni et al. (2010)*, who really examine the contribution of Cyprus lows to Israel rainfall.

SA6: Suggested reference added. The amount of total precipitation attributed to Cyrpus lows was changed to 90%: **"...yielding about 90% of the rainfall in the central and northern parts of Israel (Goldreich, 2003;Saaroni et al., 2010)."**.

SC7: Page 15667, line 10-17, Sampling. You should specify how many individual samples of rain days are included. This is essential for the statistical significance of the results.

SA7: See GA2 above.

SC8: Page 15670, line 17, **"The wind average increases during the winter"**. Such a statement should not based on long term mean data, but only on the average for the sampled rain days .

SA8: The averages are based on sampled rain days. We added: **"…which correspond to the rain events during the study time span."**

SC9: Page 15672, line 21, **"−9±7 (37)"** .Since the std is written (37), what does ±7 mean?

SA9: The Gaussian mean location and standard deviation is not used as an analysis tool in new revised results section.

SC10: Page 15673, line 1, **"decoupled"**. Replace by "separated".

SA10: The sentence referred to was removed from revised **"**results**"** section.

SC11: Page 15673, line 4-17, The rapid drop of IHM downwind the mountain. It seems suspicious. You should address the possibility that over land (or over mountains) the sensors underestimate the rain rate (this may explains also the drop of rain rate across the coastline, in spite of the sharp orography, at least in Lebanon.

SA11: See GA3 above. The rapid decrease only occurs after the ridge and not in transition between sea and land. Hence, it does seem to be due to PR underestimation.

SC12: Page 15673, line 18, **"before"**. Replace by "downwind".

SA12: Replaced to "upwind". **"We tag the peak at -23±7 km as related to LB effect, and the other at the coastline (about 20 km upwind the ridge's max elevation) as related to OF and FC effect."**.

SC13: Page 15674, line 5, **"and consistent"**. Change to "and is consistent".

SA13: The sentence referred to was removed from revised **“**results**”** section.

SC14: Page 15674, line 24, **"extent"**. Change to "distance".

SA14: Thank you. The proposed word exchange was carried out: **"Moreover, the distribution spreads offshore to its largest distance during daytime and not nighttime as expected."**.

SC15: Page 15674, line 25-29, The orographic effect. The gap between the location of the IHM peak and the ridge suggests that the coastline (roughness contrast) contributes there. I suggest you refer to it here.

SA15: We address this issue at the beginning of Lebanon sub-region analysis: **“The high Mount Lebanon ridge dominates the coastal plain and serves as a barrier for the flow, therefore we classify the peaks as a combined OF+FC peak, and a LB induced peak.”** OF=Orographic Forcing. FC=Frictional Convergence.

SC16: Page 15675, line 21, **"before"**. Change to "upwind".

SA16: Thank you. The proposed word exchange was carried out. See quote in SA17.

SC17: Page 15675, line 21-22, **"height gradients"**. Change to "slope".

SA17: Thank you. The proposed exchange was carried out: **"The OF peaks are located around 20 km and 40 km upwind the Judea, Jordan mountain ridges' peak**

elevations, and seem to correspond to the location with the largest slopes (see the green curve in Fig 6).".

SC18: Page 15677, line 13, **"before"**. Change to "upwind".

SA18: Thank you. The proposed exchange was carried out:

SC19: Page 15677, line 17, **"to"**. Change to "of".

SA19: The word "to" does not appear in that line.

SC20: Page 15677, line 21, **"means"**. Change to "maxima" or "peaks".

SA20: The sentence referred to was removed from revised **"**results**"** section.

SC21: Page 15678, line 16, **"11Km"**. Where? Offshore?.

SA21: The sentence referred to was removed from revised **"**results**"** section.

SC22: Page 15678, line 21, **"by"**. Change to "as".

SA22: Thank you. The proposed word exchange was carried out: **"During the whole winter season in Israel (with the exception of the afternoon hours in November-December), the average diurnal variation can be described as a see-saw pattern."**.

SC23: Page 15679, line 12, **"stronger winds in Lebanon (closer to the low pressure vortex)"**. This is problematic, since within the cyclone core (~500Km from the center for Cyprus lows) the winds decrease toward the center down to zero, and Lebanon is rather close to the cyclones centers.

SA23: Rephrased sentence to: **"The main differences between Israel and Lebanon sub-regions are the location and magnitude of their topographic obstacles, combined with Lebanon's closer position to the Cyprus low vortices centers.”**.

SC24: Page 15680, line 5-7, Precipitable water. I suggest to use values rather than partly values and partly percents.

SA24: We try to explain intra-seasonal reduction in IHM by looking at intra-seasonal reduction of Precipitable Water. In this case the absolute values are less helpful than the percentage of change for each variable. The values are added in parentheses: **"Average Precipitable Water values for the Israel region decrease ~22% (from 18.60 kg/m^2 to 14.52 kg/m^2), and Lebanon region values decrease ~20% (18.52 kg/m^2 to14.67 kg/m^2)."**.