We thank the reviewer for his/her insightful and constructive comments. We reply to his/ her suggestions below.

1) Page 5, para 2: Please explain this "climatological mid-level minimum" that is being referred to. Certainly, the moist tropical sounding of the North Atlantic doesn't have such a minimum. Please clarify.

We think the usual meaning of a 'climatological state' implies temporal averaging over some time period and spatial region. The Jordan Caribbean sounding certainly fits this common definition of a 'climatological state' for the Caribbean region during hurricane season. The notion that the water vapor mixing ratio decreases with height and potential temperature increases makes it plausible why a minimum of theta_e would be expected generally in such a circumstance. For example, Frank and Ritchie (2001) use the McBride and Zehr (1981) pre-storm sounding for their idealized TC experiments. The McBride and Zehr sounding represents a composite sounding within developing cloud clusters taken from the Northwest Pacific. This sounding exhibits a broad minimum of theta_e between 800 and 550 hPa (see Fig. 7 in Frank and Ritchie 2001). In a simulation of a real Hurricane case in the Atlantic basin (Bonnie, 1998, see Fig. 4c in Cram et al 2007) a minimum of theta_e was found also between 3 km and 7 km. Because tropical cyclones do not always reside in the moist tropical sounding of Dunion and Marron (2008) (see also response to item 3) we think that our wording "the minimum of theta_e is usually located at" mid-levels (page 5) is defensible. We now use the same wording also in the caption of our Fig. 1.

2) Page 6, para 2: Re: parcels with reduced theta e rising in the eyewall. What about the mid-level low theta e air that created those low theta e BL parcels? That too could be an inhibitor if it's near the updraft region: first it's dry and second, it's creating localized downdrafts that could disrupt the engine.

We do not fully understand the reviewer's point here. In the introduction, we propose that the low theta_e air is brought into the BL by downdrafts. Figure 1 indicates clearly that this low theta_e air comes from the midlevels. To our knowledge, no previously published study has suggested observationally or theoretically that downdrafts and the associated transport of low theta_e-air play a significant role in the intensity evolution of TCs *interacting with vertical shear*. We chose not to discuss the details of the downdraft formation in the introduction.

Rather, we dedicated a significant part of the manuscript to describing the formation of downdrafts and the corresponding patterns of downward flux of theta_e.

Based on comment 3 by John Molinari, we have revised our description of the downdraft formation in section 5. We hope that this revision clarifies the nature of the downdrafts that arguably lead to a significant intensity decrease.

3) Page 11, para 1: Re: the use of the Jordan sounding: a few recent studies have suggested that the Jordan sounding may be too dry and not adequately represent what the moist tropical sounding really looks like. Mid-level moisture in Jordan's sounding may be ~15-20% too dry compared to what the moist tropical Atlantic really looks like. See Dunion and Marron (2008);

We are unaware of any study showing that tropical cyclones generally reside in the moist tropical sounding of Dunion and Marron (2008). During their lifecycle, TCs often encounter drier environments; one possible example (Omar) is provided by the reviewer under his/her item 11. The bimodal distribution found in Dunion and Marron (2008) complicates the standard practice of using one representative mean state. The purpose of this study was not to examine shear interaction in 'moist' and 'dry' environments, but rather to re-examine the fundamental processes of TC – shear interaction. The Jordan sounding is used merely to create some generic tropical environment comparable to previous studies and as a first step in a more comprehensive study. In this paper, we have not precisely mimicked NATL conditions.

We concur with the reviewer that the environmental sounding, in particular the midlevel humidity, is most probably an important variable when trying to assess the extent to that a TC is affected by environmental shear. In the conclusions of our manuscript we emphasize the likely importance of the environmental sounding.

4) Page 12, para 1: the authors explain the use of 12 km at the height of max wind (~200 hPa), but it is unclear from the text how the ~850 hPa level was selected;

In our initial vertical profile of environmental shear, the vertical shear between the surface and 12 km altitude approximately matches the commonly used 850 - 200 hPa shear metric. When we consider the shear evolution in more detail in section 6, we calculate the shear between 1.5 km and 12 km as a proxy for 850 – 200 hPa shear. This information is given in section 6 when the vertical shear is calculated.

5) Page 12, para 1: Consider adding a 2Um value (or two) in between 0 and -10 m/s. 10 m/s of vertical wind shear is moderate to high and certainly the 15 and 20 m/s shear values are extremely high. Since the average shear in a basin like the NATL is ~15 kt, it might be valuable to include shear values of 5 and 7.5 m/s as well. Since the Jordan sounding was used (and that's a NATL mean sounding), it makes sense to mimic NATL conditions as much as possible;

We have performed an experiment with "5 m/s" shear also. None of the characteristic structure changes found in the 10 – 20mps cases is found in this experiment. The difference between the intensity evolution in the 5mps and the no_shear case is within an envelope of intensity that one can expect in light of the TC intensification ensemble experiments in the quiescent environment of Nguyen et al 2008 (QJRMS). In our modeling study, the TC intensity is about 69 m/s when the shear is introduced and without this vertical shear the vortex continues to intensify to over 95 m/s. It is thus reasonable that such an intense storm is hardly affected by moderately weak shear. It is hypothesized that our results scale in proportion to the ratio of storm intensity/ shear magnitude, i.e. they qualitatively hold for less intense storms in weaker shear. Ongoing work is dedicated to examine this hypothesis.

We have added a footnote in section 2.5 that reflects the paragraph above.

6) Page 12, para 1: It is unclear why the authors chose to impose easterly shear on their system, even though W or WNW shear is the most common shear direction in the NATL. Of course, westerly shear could be realized in two ways: strong westerlies aloft or strong easterlies near 850 hPa. The former is more typical, but the latter can often occur in the tropical NATL in association with the African easterly jet and Saharan Air Layer;

As our idealized experiment is on an f-plane the direction of the shear is moot. We have deliberately chosen a wind profile with no surface wind initially to keep surface fluxes in the environment to a minimum. Minimizing these fluxes delays the onset of environmental convection. A comprehensive examination of the impact of different shear profiles poses an interesting question for future studies.

7) Page 14, para 2: Re: the storm movement: I may have missed this, but is there no environmental steering flow that the vortex is embedded in? Please explain what is meant by “the vertical shear profile implies a steering flow for the TC”. Since TCs are largely under the influence of the deep layer mean steering flow, it’s not quite clear what is meant here;

No environmental steering flow is present before imposing the shear profile. As the “deep layer mean” of the shear profile is not zero, the shear profile constitutes not just a shear flow but a steering flow also. Consequently, the storm begins to move after the shear is imposed. We have changed “imply” to “constitute” in the text in an attempt to make this point clearer.

8) Page 16, para 2: at this point, the reader may be wondering where the “considerably reduced BL theta e” is coming from. Clearly, it’s being advected into the TC circulation (e.g. Fig 7), but some of those values (particularly the <347 K values) are extremely low. Is that low theta e air the result of a downdraft or is it simply being advected from the outer environment? Of course, this is addressed later, but a teaser may be a nice addition here;

The theta_e values between 351-355 K appear indeed to be advected from the environment inwards. The local minima, however, cannot be formed by horizontal(!) advection (theta_e being conserved along a particle path in the absence of interaction with the underlying surface or precipitative flux). We have added a comment to this end in section 4.1.1, paragraph 1.

We mention in the introduction to section 4 that we will show that downdrafts play the dominant role in forming the theta_e depression. Thus we believe that another 'teaser' here would be repetitive.

Based on some preliminary results of a recent analysis of the quasi-steady flow topology of the TC-shear flow we offer the following explanation for the interplay of horizontal and vertical advection. Figure 1 shows the theta_e distribution and distinct streamlines of the quasi-steady flow above the BL at 2 km height. The contours in Fig. 1a depict upward motion and the contours in Fig. 1b depict downdrafts. Environmental air at low-level above the boundary layer can approach the storm centre by horizontal advection alone(!) most closely in the downshear-left quadrant. In this region the environmental air encounters strong and persistent downdrafts and is brought into the inflow layer. This flushing of the BL with low theta_e-air occurs close to the core and is thus a very efficient way to disrupt the TC power machine.

The role of the vertical shear is therefore twofold. First, vertical shear forces the convective asymmetry outside of the eyewall by the tilt of the outer vortex (as described in more detail in our manuscript). Secondly, the low-level storm-relative

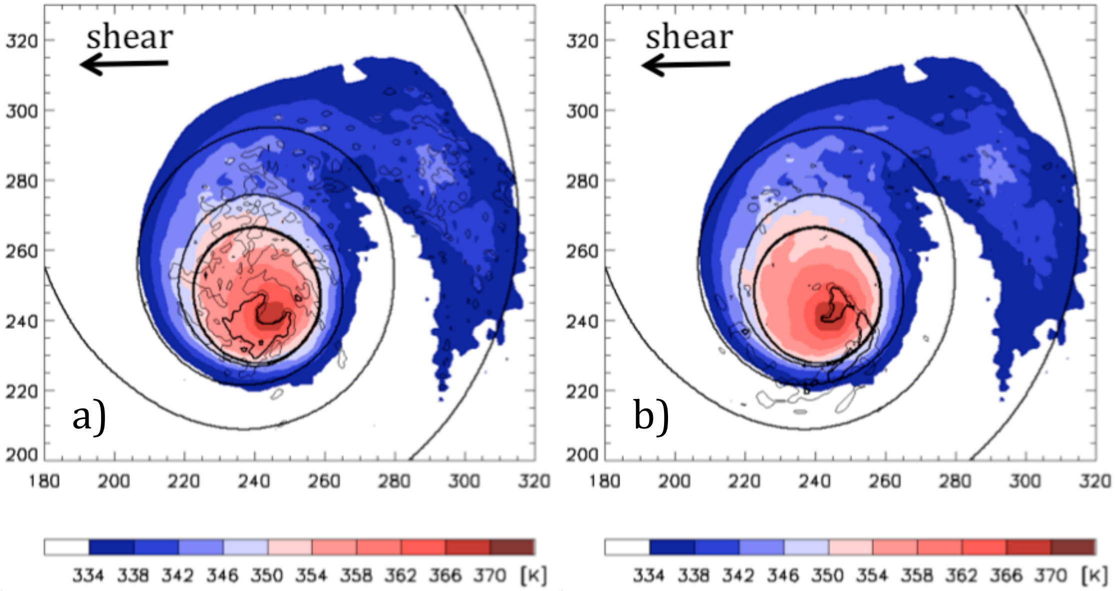

Fig. 1: Distinct streamlines (black curves) formed by the interaction of the vortex flow and the storm-relative environmental flow at 2 km height. The shear vector is indicated by the arrow. Colors denote theta_e, the contours show 0.2 m/s (thin) and 1m/s (thick) updrafts in a) and downdrafts of 0.2 m/s (thin) and 0.5 m/s (thick) in b), all at 2 km height. The horizontal scale is in grid points with a grid scale of 5 km.

flow above the BL associated with the vertical wind shear allows environmental low theta_e-air to approach the storm closely. This dry environmental air invigorates downdraft formation associated with the swirling asymmetric convection. These downdrafts then flush the BL with low theta_e-air close to the eyewall.

9) Page 16, para 2: It would be helpful to see the temperature and mixing ratio values for these plots (Fig. 7), so that the reader could get a better sense of the relative contributions of temp and moisture to these depressed theta e values;

This is a very good point. Figure 2 shows the mixing ratio and potential temperature for the no_shear, 15mps, and 20mps run at 5 h, the same time as in Fig. 7 of our manuscript. The depression in mixing ratio is about 4-5 g/kg and in potential temperature ~ 2-3 K. Other times look qualitatively very similar. While dry air appears to be wrapped into the circulation from the NW, the more pronounced decrease in theta_e to the S (downshear left) apparently cannot be explained by advection but due to the downward flux of low theta_e as shown in Figs. 10 and 11. From the decrease of theta along the descending path it can be inferred that evaporative cooling is an important mechanism in the downdraft formation.
Within the framework of the Carnot cycle theory, however, it is really just the moist entropy of the air that matters and thus we have minimized an emphasis on the

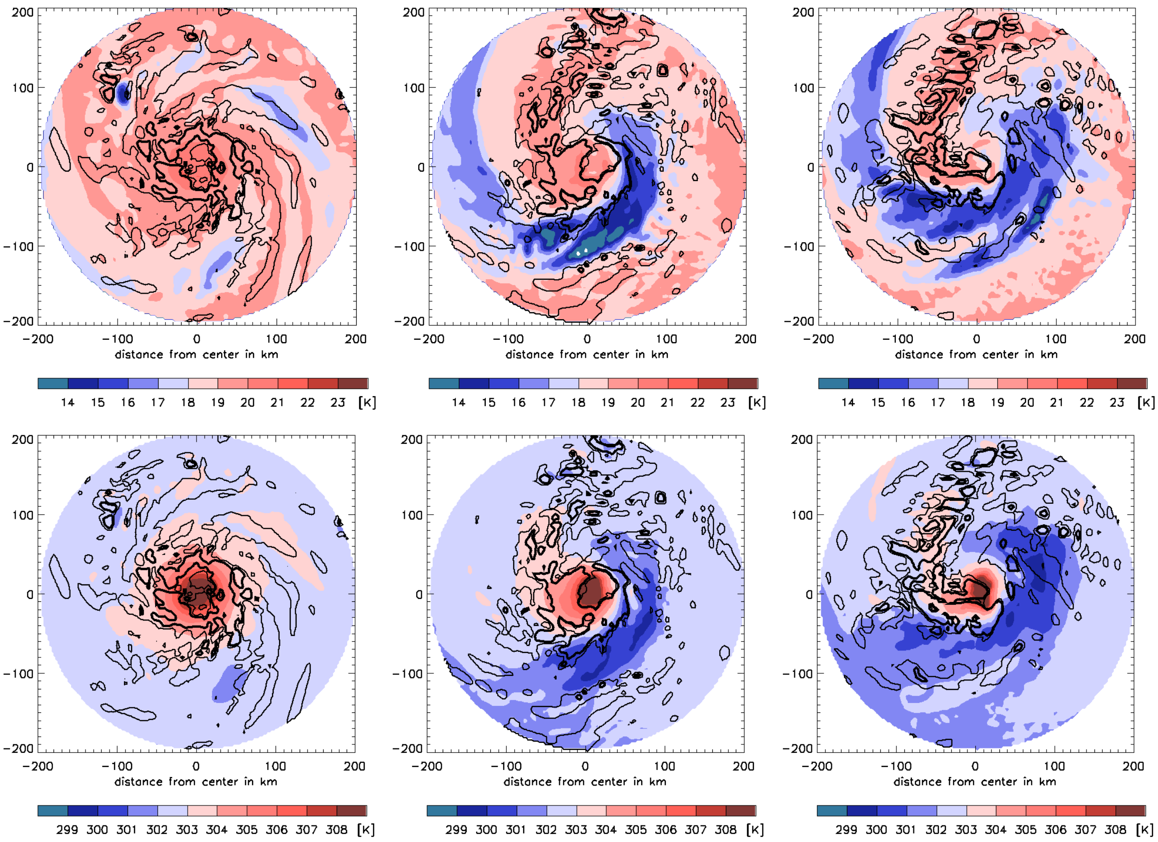

Fig. 2: Same as Fig. 7, but for the mixing ratio (upper row) and potential temperature (lower row) for the no_shear (left), 15mps (middle), and 20mps (right) case.

individual contributions to the theta_e depression. We have added a footnote in Sec. 4.1.1 summarizing the above numbers and refer interested readers to the figures given in this response.

10) Page 19, para 2: Re: low theta e air being brought down to the BL from above: this makes sense, but Fig. 7 seems to show that the low theta e air in the lowest 1km has its source fairly far from the center in the NW quadrant, particularly in the higher shear cases;

Only a small amount of the theta_e depression in the BL can possibly be explained by horizontal advection (see response to point 9). In section 4.2.2 we present evidence that the magnitude and pattern of the downward theta_e flux explains well the simulated boundary layer theta_e depression.

11) Page 32, para 1: Re: the arc clouds NW of Omar: these arc clouds may have in fact been triggered by extremely dry low to middle level air associated with a mid-latitude dry air intrusion positioned just NW of the storm (evident in total precipitable water imagery; TPW values ≤45 mm/green shading). The 15 Oct 2008 12z sounding in Nassau confirmed the extreme dryness of this mid-latitude dry air intrusion, with RH (mixing ratio) values as low as 18% (1.6 g/kg) from 600-800 hPa. One hypothesis to consider is that the enhanced shear promoted the impingement of this mid-level dry air on the TC convection. The subsequent formation of convectively-driven downdrafts could have helped triggered the arc clouds. Just something to consider. For more information, some of these ideas are discussed in NOAA HRD's 2008 Hurricane Field Program Plan (p.50-52): http://www.aoml.noaa.gov/hrd/HFP2008/HFP2008.pdf

Our analysis of the quasi-stationary flow topology (cf. item 8) indicates that impingement of dry air at mid-levels should occur very slowly, at least when the shear profile has an approximate vertical wavenumber 1 structure (not shown). Our current hypothesis is that for such a shear profile the dry air approaches the storm most closely at low-levels just above the BL. The precipitation that falls out of the swirling and sloping updrafts associated with the 'stationary band complex' then evaporates in the particularly dry air below, possibly leading to very strong downdraft formation and effective flushing of the BL with low theta_e-air.

We'd like to emphasize that the results of the analysis of the quasi-steady flow topology are preliminary.

12) Page 33, para 2: This idea of reduced BL theta e not recovering sufficiently is interesting, but it would be nice to see some expanded hypotheses here. Certainly, BL theta e doesn't always recover as it is advected into the TC circulation. Things like storm size (i.e. how does the inflow trajectory for that low theta e air parcel vary depending on storm size), vertical wind shear (which can bring that low theta e air

into the TC core more efficiently), and the thermodynamic profile of the surrounding environment (Jordan is a less than optimal first guess since the tropical atmosphere actually contains multiple soundings that are quite unique (e.g. moist tropical, Saharan Air Layer and mid-lat dry air intrusions) and not well represented by this single mean sounding);

We agree that it is of great interest and importance to investigate the recovery of the depressed BL theta_e further. The problem is not a simple one and careful studies by e.g. Powell (1990) and Wroe and Barnes (2004) point a way forward. We are currently preparing a trajectory analysis to address the origin and extent of the low theta_e-air that enters the eyewall updrafts. This analysis is beyond the scope of the current study. We anticipate that we will be able to propose meaningful hypotheses, as the results become available.

Figures

Figure 1:
- this is a very long caption. Consider explaining some of the details in the main text and streamlining the caption;
- see minor comment #1;

Caption of Fig.1: We have moved the explanation of the Carnot cycle to the main text of the introduction to shorten the caption.

References:

Dunion and Marron, 2008: A Reexamination of the Jordan Mean Tropical Sounding Based on Awareness of the Saharan Air Layer: Results from 2002, J. Climate

McBride and Zehr, 1981: Observational analysis of tropical cyclone formation. Part II: Comparison of non-developing versus developing systems, J. Atmos. Sci.

Wroe and Barnes, 2003: Inflow Layer Energetics of Hurricane Bonnie (1998) near Landfall, Monthly Weather Review

Please refer to reference list in discussion paper for further references.