Precipitation, Moisture Sources and Transport Pathways associated with Summertime North Atlantic Deep Cyclones

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Authors' response

This paper aims to evaluate the moisture sources for summertime extratropical cyclones. It employs a Lagrangian back trajectory method to determine the sources and sinks of moisture for parcels that result in precipitation at the centre of cyclones. The authors have done a good job of addressing the comments I made on the original submission. There are, however, a couple of remaining points that should be addressed before publication.

Thank you for reviewing the paper again. We are glad to hear that we properly addressed your comments on the original submission. We have addressed your final two points below, with changes to the manuscript in italics.

1. Line 112: The authors state that 'ARs are capable of feeding multiple WCBs from individual cyclones. This is not correct. As shown nicely by the authors in figure 11, and described on lines 662, the cyclone-relative wind vectors point away from the cyclone centre indicating that the moisture within the AR is travelling slower than the cyclone itself. Therefore, the AR cannot feed moisture into the WCB 'because the winds still have no northerly component' (line 666)

Thank you for pointing this out. This statement was included to summarize previous studies, particularly that of Sodemann and Stohl (2013). They found that the WCBs of several cyclones in December 2006 were fed by atmospheric rivers. Indeed, our results (Figure 11) show no evidence of similar behaviour, and the recent study by Dacre and Clark (2025) also stresses that the moisture within the AR is travelling slower than the cyclone itself, implying that continual local moisture replenishment acts as a source rather than the AR structure. Including the statement would therefore generalize too much, and to avoid any confusion we have chosen to remove the full sentence from the manuscript.

2. Line 383-7, figure 8, lines 555-565: The weighted mean source distance is proportional to the ETC propagation speed. I.e. Early in the ETC lifecycle, when they are moving fastest, the weighted mean source distance is large, and later in the ETC lifecycle, when they slow down, the weighted mean source distance is small. Thus the 'moisture sources move closer to the cyclone centre' as the ETCs reach maturity (fig 8) because the ETCs transport moisture polewards at a slower speed over the same time period, so it moves a shorter distance from its origin. This is also why 'despite greater source distances observed during the intensification phase, the residence time remains relatively constant' (line 610). It would be good for the authors to link up these ideas from different parts of the paper to illustrate nicely that the weighted mean source distance is proportional to the speed at which the ETC is moving.

Thank you for pointing this out. We did not realize that we did not discuss the values of the weighted mean source distance provided in Figure 8. Therefore, we agree that it makes sense to discuss this in Section 4.2 and link it to the propagation speed of the cyclones. Furthermore, we believe it would make sense to revisit this relationship in section 4.3. The changes we made are as follows:

Another important observation of the moisture source footprint is its large spatial extent, especially during the intensification phase. Consequently, the weighted mean source distance is also large during this phase. (Line 551-552)

This north-eastward shift of the moisture footprint exceeds the movement of the mean cyclone center in all subregions except in the Gulf Stream region (Fig. A4e), as the cyclones slow down once they mature. This implies that, over time, moisture sources move closer to the cyclone center. The weighted mean source distance, which scales with the cyclones' propagation speeds, thus decreases throughout the cyclone life cycle (Fig. 8). At a later stage, local moisture recycling becomes more important, although overall moisture uptake is lower than during the intensification phase. (Lines 562-567)

Despite the greater source distances observed during the intensification phase (Fig. 9a), the residence time remains relatively constant, suggesting that moisture must be transported more rapidly during this phase. This is consistent with the presence of stronger winds and a faster-moving cyclone, both of which facilitate faster long-range transport. (Line 612-615)

One more note for the editor: after reading the manuscript, some extra spaces have been removed, "coloured" has been changed to "coloured" for consistency (in the caption of Fig. 5), just as 'lifecycle' has changed to 'life cycle' (line 387).