

Reply on co-editor's comments #3

Q: Thank you very much for your detailed response and edits to the text.

While the 2-sigma envelope shows a sub-population of parcels gaining moisture from local surface contact, the primary reservoir remains the pre-existing background specific humidity of the mid-latitude air mass (approximately 3 g/kg for the Atlantic and 2 g/kg for the Eurasian ARs). Currently, comparing these free-tropospheric parcels (averaging 750 hPa) to the surface annual mean of 2.4 g/kg creates an unintended inconsistency, as it makes the advected air mass appear relatively dry initially, especially for the Eurasian AR. To resolve this, I suggest providing the climatological moisture content of the surrounding environment at the level and latitude where active ascent begins (e.g., at ~1 day prior to arrival at ~60°N and 750 hPa for the Atlantic AR; and at ~1.5 to 2 days prior for the Eurasian AR).

Following on from that, I suggest adding an assessment of the relative importance of the original moisture content 5–7 days back versus the moisture uptake 2–4 days before arrival (with a caveat that parcels may be losing moisture and then uptaking more than they have lost, but that only happens to those parcels that reach the surface, which might be a fraction of all parcels). Depending on how the background values compare, the additional moisture uptake might represent a substantial portion of the total budget (perhaps up to 50%), or it may act as a secondary top-up to an already moisture-rich pipeline.

I appreciate the amount of work that you have already done in response to my comments and will leave it to you to decide how to integrate these ideas into the paper. I do not need to see the changes again and am happy to accept the manuscript, subject to technical changes to allow for these final updates if you choose to make them.

A: Thank you for this constructive comment. We had initially chosen the reference value of 2.4 g kg⁻¹ (Fig. 8c) to place the specific humidity values into an Arctic context. However, we agree that this comparison may underestimate how anomalously moist the nTpθ parcels are, as it includes the considerably moister summer months and introduces an inconsistency when comparing free-tropospheric parcels with near-surface climatology as the co-editor correctly pointed out.

To address this concern and following the co-editor's suggestion, we calculated more representative climatological reference values at the pressure level and latitude where parcel ascent and associated moisture loss begins. Specifically, we use April mean specific humidity at 50°N, 700 hPa for parcels reaching the Greenland coast, and at 60°N, 650 hPa for parcels reaching the central Arctic. These locations correspond to the typical environments occupied by the parcels 1 to 2 days prior to arrival. In both cases, the nTpθ parcels are characterised by specific humidity values that are twice the April climatological mean at the corresponding level and latitude.

We have also expanded the discussion to quantify the respective contributions of initial specific humidity and moisture uptake along the pathway, showing that both play a substantial role with uptake acting to amplify an already moist air mass.

The revised manuscript includes the following changes:

'The parcels have an initial specific humidity of 3 g kg^{-1} , which increases steadily to a maximum of 4.2 g kg^{-1} 2-3 days prior to arrival (Fig. 8c), indicating that moisture uptake along the pathway contributes to a substantial amplification of an already moisture-rich air mass. By one day prior to arrival, the parcels are located at approximately 50°N , 700 hPa , and carry roughly twice the April climatological specific humidity of the ambient free-tropospheric environment at that level and latitude.' See lines 342-345 on page 16.

'Two days prior to arrival, when the parcels are located near 60°N , 650 hPa , their specific humidity is more than twice the April climatological mean for this region and altitude, indicating that they are anomalously moist relative to the surrounding atmosphere.' See lines 413-415 on page 20.

The figure caption of Fig. 8 now includes the sentence: *'(c) as in (a) but for specific humidity; the black dotted line indicates the mean specific humidity at 50°N , 700 hPa for April 1979-2023.'* while the figure caption of Fig. 11 reads: *'The black dotted line in panel (c) indicates the mean specific humidity at 60°N , 650 hPa for April 1979-2023.'*