Technical Details and Postprocessing for the African Easterly Wave Tracking

For a broader overview and more, see Lawton et al. 2021. This provides a more detailed overview for those looking to use the AEW tracks or the tracking code for their own work.

a) General Description

A detailed description of the standalone African Easterly wave (AEW) tracker and database is provided here. The tracking methodology is similar to that of Brammer and Thorncroft (2015) and Elless and Torn (2018), with some key differences. To track AEWs, we first compute a "modified curvature vorticity" field as an average of the non-divergent component of the 700 hPa wind within a radius of 600 km of each gridpoint. The non-divergent wind was calculated via a Helmholtz decomposition within the Windspharm python package (Dawson 2016).

At each longitude, we take meridional averages of the modified curvature vorticity field in 10° bands ranging from 5° to 20°N. The value and center latitude of the maximum band is retained for each longitude and mapped to a 1D array. We then pull out the local maxima (in longitude) that clear the requirements to either initiate a new wave (value greater than 2e-6 s-1) or continue the track of an existing wave (value greater than 1e-7 s-1). For these data, a weighted centroid technique is used to find the center, with the longitude of the maxima and latitude of the selected band used as a first guess. This centroid technique is similar to that used for vortex center finding discussed in detail by Ryglicki and Hart (2015), in this case using the modified curvature vorticity. The centroid radius used in this tracker is 600km, which performed the best when conducting centroid testing.

Preliminary wave centers that clear the initiation threshold and are not within 500km of an existing wave at the last timestep (6 hours) are considered new waves. Wave initiation is only considered at or east of 40°W. At or east of 17°W, initiated tracks are classified as new AEWs and saved for the next iteration. New centers west of 17°W are still saved but not classified as AEWs; instead, they are classified as waves of unknown origin. If a wave center is within 500km of an existing wave at the last timestep and clears either the initiation or existing wave threshold, it is considered an extension of an existing wave and added to its track.

Even though curvature vorticity is radially averaged, there still exists noise that can cause wave tracks to break prematurely or jump to other unrelated vorticity centers. To address this, a meridional speed restriction of 3° or less every 6 hours is used for AEWs over land (no such limitation is placed on AEWs over the ocean). Tracking is heavily biased towards westward movement; tracks are only allowed to move 100km eastward (300km for centers over the ocean) over a 6-hour time period. This reduces track "jumps" backward while still allowing some flexibility for noise. Furthermore, wave tracks that remain mostly stationary (moving 2° or less per day) or move eastward for a duration of 1 day or more are terminated. Tracked waves in close proximity (300km or less) to one another are merged. Recently terminated wave tracks are also checked at 12 and 18 hours to see if they can be extended. For these extensions, continuing AEW centers must be within 700km or 1000km of the old wave center for the 12- and 18-hour checks, respectively.

The first step of tracking is based heavily on the method used by Elless and Torn (2018), who showed it was quite effective at identifying AEW centers over and near the coast of Africa. Over the ocean, however, a different tracking technique is utilized that is similar to that developed by Brammer and Thorncroft (2015). For all existing waves located at or west of 20°W that have been tracked for at least three days, the wave speed and direction at the previous timestep is used to estimate a new wave center position. This first guess is then recentered to the actual position of the wave using the aforementioned centroid technique. If the new center meets the threshold of a continuing wave (curvature vorticity greater than 1e-7 s-1), this center is retained. Here, we loosen the proximity requirement such that the new center has to be within 700km of the old center for extrapolated AEWs between 20 and 60°W. This is because some recurving waves and TCs accelerate in this region. West of 60°W, the old requirement of 500km is retained. Like before, broken AEW tracks are checked at 12- and 18-hours to see if they can be extended. However, note that for extrapolation extension, the proximity requirement is more limited at 700km. If extrapolation fails to extend a wave track, the track is terminated.

b) Post Processing and Smoothing

Several post-processing steps are taken after the AEW tracker is run for a season (July – September of a given year). This is done using separate code following the initial AEW tracking step. This makes our AEW tracker more suitable for reanalysis or complete model datasets but could cause errors if run on model or continuously updated output (note that post-processing can be neglected if desired by the user). First, tracks are checked to see if they are duplicates of other tracks. This is because in some situations – especially over continental Africa -- the tracker will incorrectly initialize a new AEW near a pre-existing one. Any identified duplicates are removed, retaining whichever AEW track exists for the longest period of time. An exception to this is for merged AEWs. AEWs are allowed to “merge” to identical tracks if each AEW existed independently prior being co-located. Additionally, broken AEW tracks are reconnected if the end point of one AEW track is within 700km of the start point of another AEW track (if consistent with eastward propagation). Linear interpolation is used to connect these separated tracks. All AEW tracks shorter than 2 days are removed from the final database. Finally, longitude and latitude coordinates of AEW tracks are smoothed using 2nd order Savitzky-Golay filter, using a 2-day window. Both the original and smoothed coordinates are retained in the final database files, though smoothed tracks are used for the associated analysis.

c) Sensitivity and Tradeoffs

As highlighted above, several important tradeoffs were made in order to get tracks of sufficient quality for analysis. Despite the 700-hPa curvature vorticity field being generally smooth enough to track wave features in ERA5, this comes with caveats. First and foremost, AEWs are not independent of other atmospheric features: interactions with the Intertropical Convergence Zone (ITCZ), monsoon troughs, other tropical waves, mid-latitude systems, and large circulations (e.g. the Central American Gyre) regularly occur. Additionally, the wave axes of AEWs are often tilted in latitude, with the location of the maximum curvature vorticity can shift along a given wave axis. Thus, a smooth and continuous signal does not always accompany a wave over time. Furthermore, modified curvature vorticity signal at 700 hPa can also weaken downstream, especially over the open ocean, but then re-intensify later on. Further complicating things are discontinuities in ERA5 data fields across various time intervals as a result of its data assimilation scheme. As a result, curvature vorticity fields can appear to “jump” or change their strength in seemingly unphysical ways.

Upon conducting sensitivity testing – which involved objective comparisons via long-term statistics and qualitative comparisons via spatial tracks and Hovmoller diagrams– it became clear that attempting to accommodate too many of these sensitivities can result in AEW tracks that are unphysical. Thus, the final settings of the AEW tracker utilized in this study were carefully selected to err on the side of caution with the deliberate goal to reduce the number of false tracks. The most dramatic changes were seen when adjusting the initialization (2e-6 s-1) and existing (1e-7 s-1) modified curvature vorticity threshold. These were adjusted and experimented with extensively, and these final values here produced qualitatively most realistic AEW wave tracks for ERA5 data from 1979-2020. Other thresholds discussed here only resulted in minor changes to the final AEW database, though we found their inclusion helped produce slightly more realistic AEW tracks (especially in edge cases). Regardless, this objective wave tracker – like any – will not capture every single wave that moves off of Africa and may occasionally end a wave track pre-maturely. Final settings used in this analysis are contained in the attached python code.

References

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