Description of the tracking algorithm

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Experience has shown that tracking of polar lows based on a filtered vorticity field at a given pressure level can act as a useful tool for forecasters. A relatively flexible algorithm has been developed and coded. The procedure can be adapted to handle output from different models and can be tuned to minimize the number of "false" or not relevant tracks.

Calculating the vorticity

The first step of the algorithm is to choose the pressure level where to calculate the vorticity ($PLEV_{vor}$). Figure 2 shows in green lines the vorticity calculated from model velocity components at $PLEV_{vor}$ = 925hPa.

Filtering of the vorticity

The filtering of the vorticity field is based on the Discrete Cosine Transform (DCT) algorithm of Denis et al.(2002).Initially a filtering matrix "S", which is of the same size as the vorticity field we are filtering, is set up such that wavelengths shorter than λ_0 and longer than λ_p are kept. For our rectangular domain the S-matrix ends up having values in a region between two ellipses as shown as red lines in Figure 2. A subroutine package from NCAR called "fftpack5" is utilized for the filtering. First a forward discrete cosine transform routine (COSTMF) is called twice for the x- and y-direction, followed by multiplication of the resulting transformed vorticity by the S-matrix and finishing with two calls for backward discrete cosine transforms (COSTMB) in the y- and x-direction.

Finding vorticity maxima, fulfilling mean horizontal gradient constraint and optional check on vertical temperature difference

If all the 8 points surrounding a grid point have smaller positive filtered vorticity than the point itself, we have found a potential track point. To simplify further processing only maxima where the mean gradient of the filtered vorticity (inside a given circle) is larger than a given minimum are kept. In Figure 1, where the conditional minimum gradient is set to 1.e-4s^{-1} within a circle of radius five grid points, the remaining potential track points are shown as red squares.

An option to remove track points where the vertical temperature difference between sea level and a given pressure level is less than a given threshold has been added. For tracking of polar lows a typical criterion could be to only keep track points where T_{500hPa} – SST > 40K.

Tracking

Initially the geographical coordinates of each grid point are calculated and stored. If a potential track grows to more than two track points, the two last points are used to extrapolate the track by assuming constant speed of the vorticity maximum and applying simple spherical geometry. The grid point closest to the new extrapolated track end point is called the first guess of the continuation of the track.

The procedure of extending an existing track or finding the start of a new track, as the next available time step is examined, is described by the steps shown in Figure 3a), 3b) and 3c).

a) First consider all possible tracks found so far that contain more than one track point. Such tracks have a first guess point for the continuation of the track, and we do a spiral search and check if a vorticity maximum is found within a given maximum search radius. If so, the track is extended and a new first guess for the next time step is calculated. If not, the track is marked as ended.
b) Next consider all possible tracks found so far that contain only one track point. Check if there are any vorticity maxima within a certain radius around the initial track point. If so, the closest one is chosen and a new first guess for the next time step is calculated.
c) As the last step check remaining grid points for vorticity maxima that are sufficiently far away from existing tracks. If so, mark the point as a potential start of a new track.

As a post processing step only tracks including more than a minimum number of track points are kept.

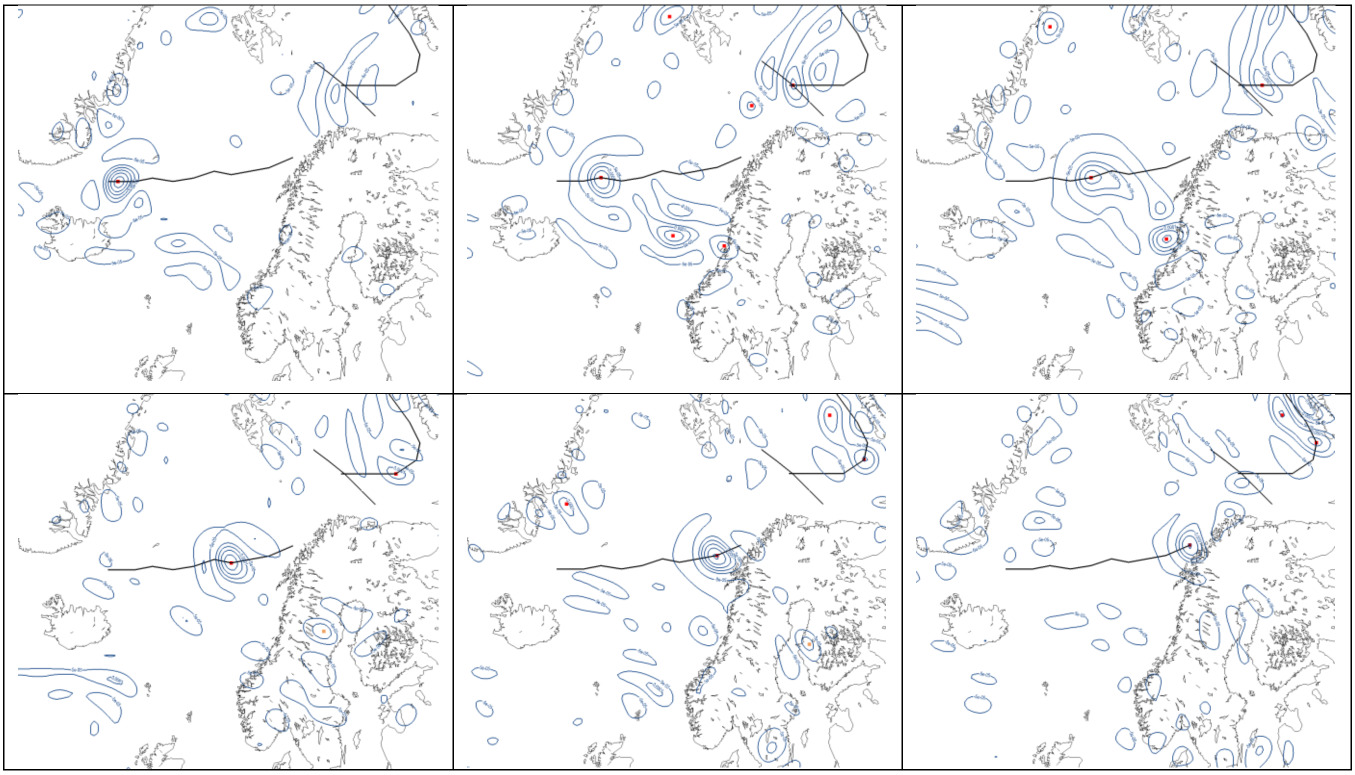

Figure 1 Six-hourly filtered vorticity (blue) at 925hPa from Hirlam 12km. Red squares mark potential track points. Calculated tracks, fulfilling criteria as described in the text, during parts of a 66 hour forecast are shown as thick black lines.

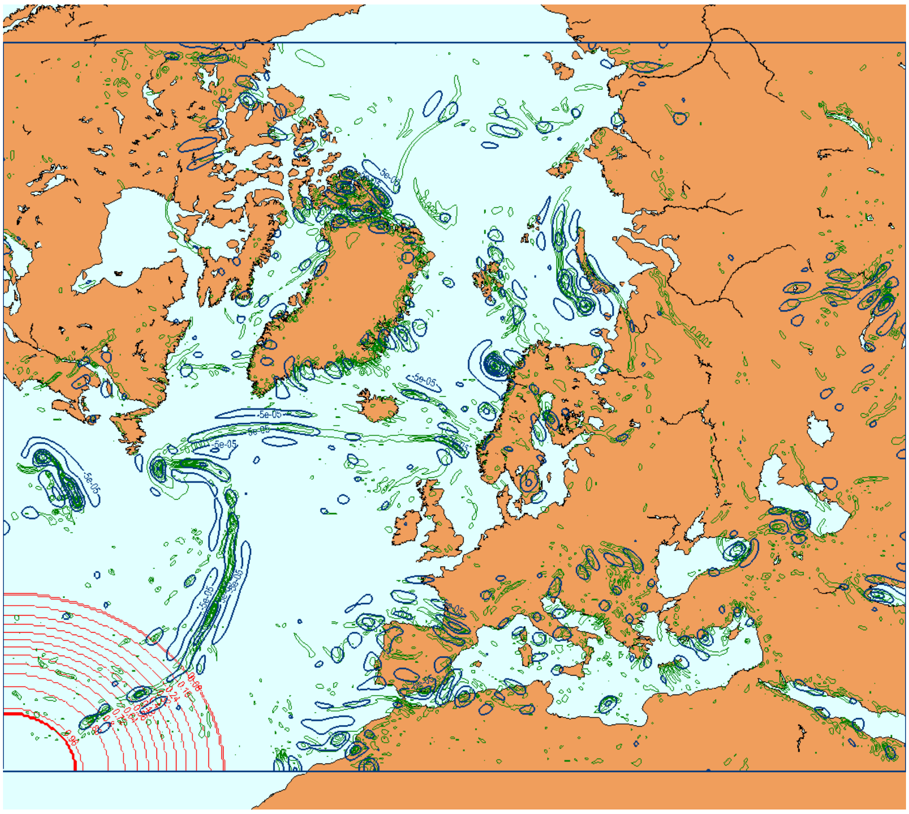

Figure 2 Example of S-matrix (red) used in the filtering, vorticity (green) and filtered vorticity (blue).

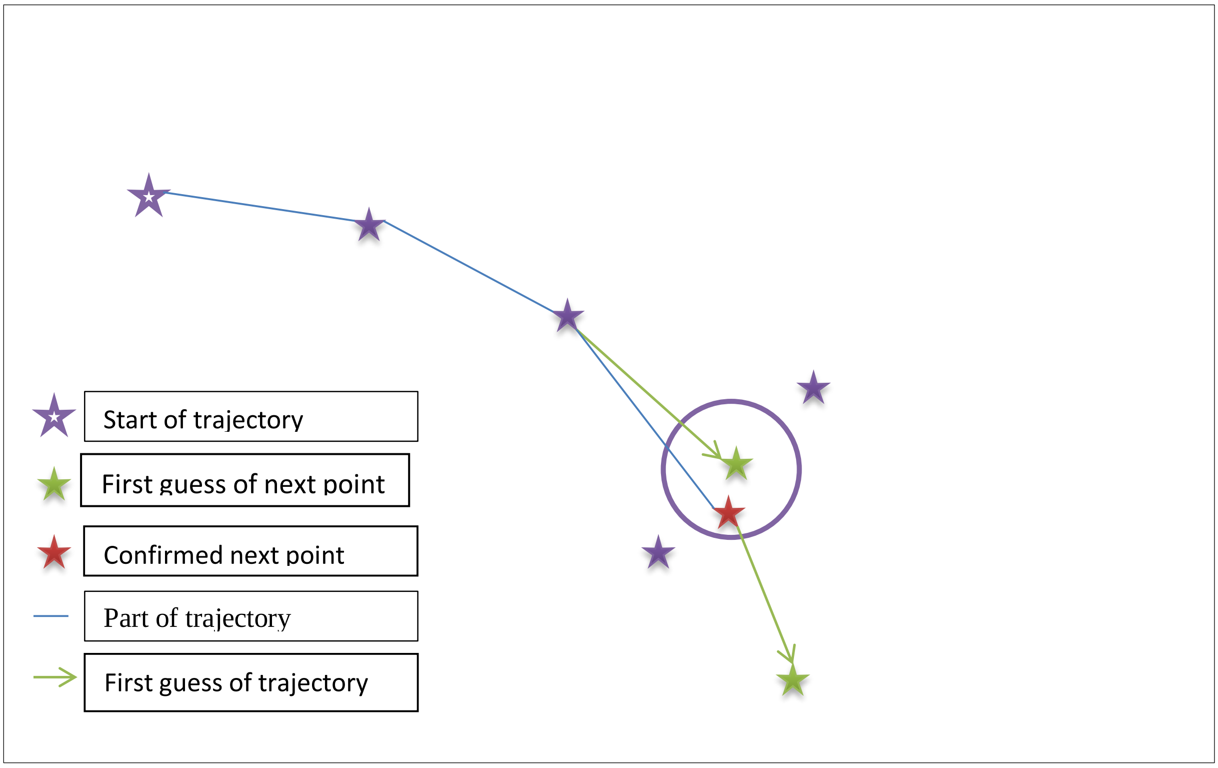

Figure 3 a) Continuing an existing track.

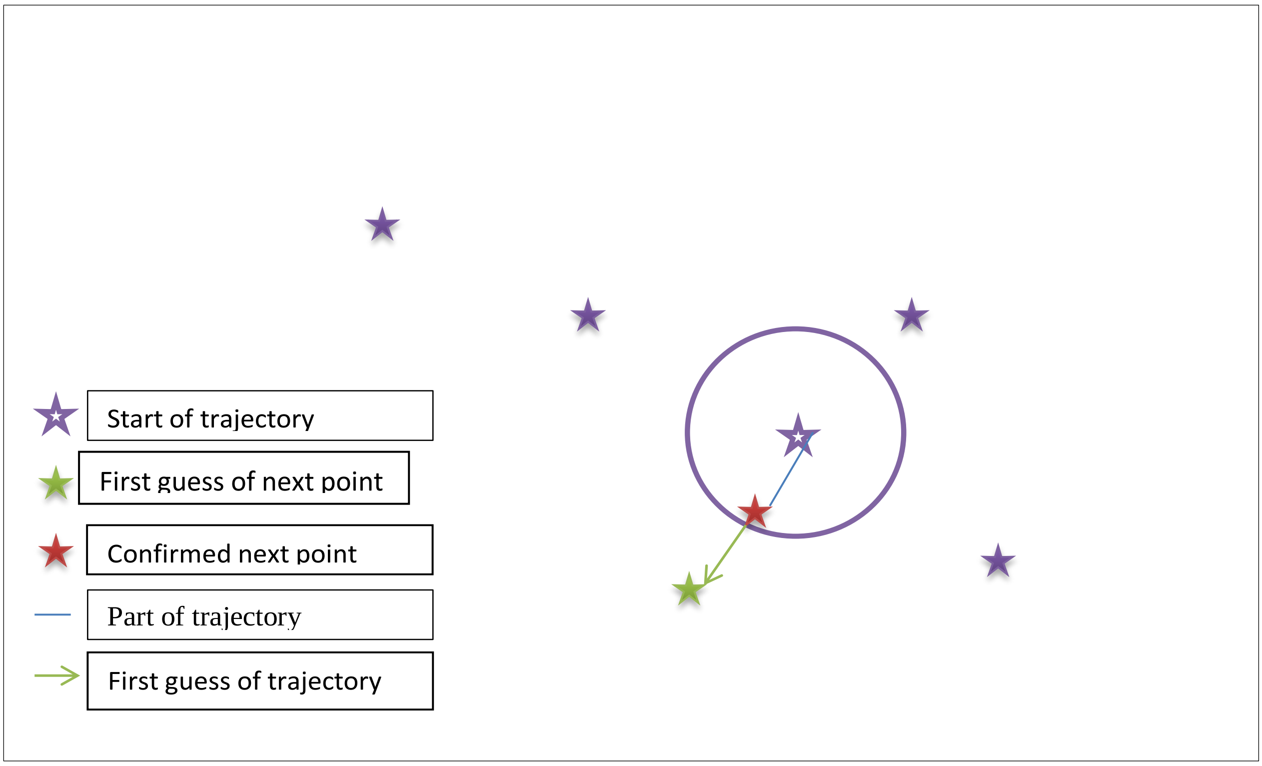

Figure 3 b) Finding the second point, and continuing.

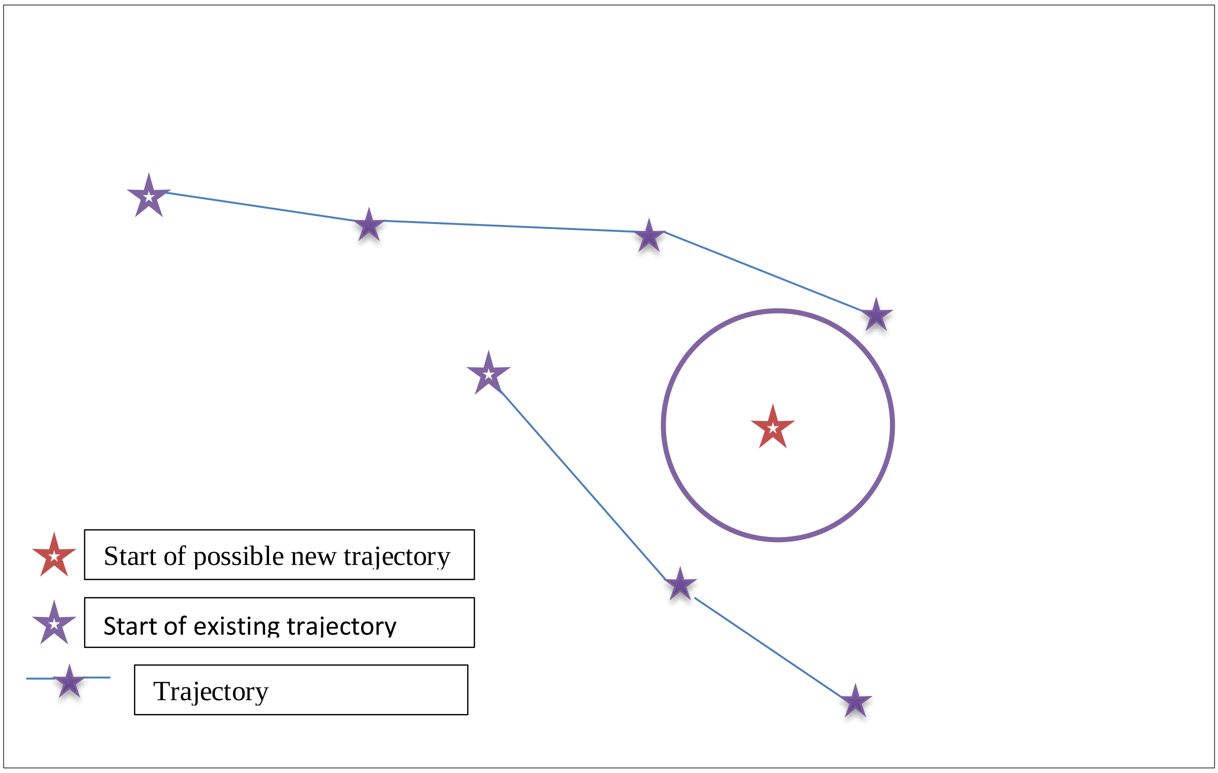

Figure 3 c) Finding a possible start of a new track.

References

Denis B, Cote J, Laprise R (2002) Spectral decomposition of two-dimensional atmospheric fields on limited-area domains using the discrete cosine transform (DCT). Mon Weather Rev 130; 1812-1829.

NCAR FFTPACK5: http://www.cisl.ucar.edu/css/software/fftpack5/