MEMORANDUM

TO: Matt

FROM: Jon Caulkins

DATE: March 4th, 2023

RE: Mobility

**Summary**

Goal is to create metrics capturing the intensity and fluidity of conflict along a “front” from a large number of “conflict” dots representing actions/fires/damaged vehicles, etc.

This memo sketches one strategy for doing that.

Note: It only makes sense if there is a well-defined front line, as there is in Ukraine.

**Procedure**

For any given time period t (e.g., a week or a month)

1. Eliminate dots that are not at/near the front and so are not relevant.
2. Draw a curve through the remaining dots starting and ending at well defined end-points, e.g., the Belarus border on the north and the sea on the south. That indicates the location of the battle front at time t. I don’t know how to do that, but I would guess there is some standard procedure for doing that.
3. Define 101 points Xit that are at the ith percentile of distance as one follows the front from one terminus (e.g., border with Belarus) down to the other (e.g,. the Black Sea coast), for i = 0%, 1%, …, 99%, 100%.

Since these Xit are just points (locations on a map), you can use any standard method for computing attributes of those points. E.g., you could count the number of conflict dots that are within 5 miles of each of these Xit as a measure of the intensity of conflict at that point. Call that measure N( Xit ). Then you could plot N( Xit ) vs. I to indicate where the conflict is most intense as one traces the battlefront from north to south.

So that’s a way to characterize the location and characteristics of the battlefront at any single period of time t, but you are interested primarily in changes in that battlefront. That’s easy. Just repeat those steps for the next time period t+1. Then if N( Xit+1 ) > N( Xit ) that would mean the battle (as measured) got more intense at the point on the front that is the ith percentile of the way from north to south on that front.

You can also compute how far that part of the front has moved with any distance metric D( x, y) just by computing D(Xit , Xit+1 ). (Actually, most distance metrics are non-negative; you might want to choose one such that negative numbers means the battlefront is moving west (Ukraine is retreating) and positive means the battlefront is moving east (Ukraine is advancing), rather than just measuring how far the front has moved.

Plotting D(Xit , Xit+1 ) vs i would indicate where the front is fluid/active/moving and where it is bogged down. And you could test hypotheses. E.g., one story is that periods of fluid movement are presaged by attacks on cities. Another story is that fluid movement happens when the attacker makes a surprise attack where things have been quite (i.e., the N() score in preceding periods has been slow). And you could look at things like how the average distance moved from one period to the next has evolved as a function of time, t. E.g., maybe things are fluid for a while and then bog down into trench warfare. Or they are fluid in the summer but bog down in winter.

**Limitation**

The purpose of the proposed procedure was to match up a point on the battlefront at time t with a corresponding point at time t+1. The methods for that was looking at each points percentile of the way from north to south end of the battle front. There could though be a potential distortion if on one side of the battle front one side advances or creates a salient.

E.g., imagine a battlefront that at time t is a straight line all the way from north to south of length 1. Then at time t+1, the battle front is straight line from top to halfway point, and then below that is a semi-circle with radius one-quarter. The entire front’s length will have grown from length 1 to length ½ +  / 4 = 1.285. That means the location that at time t had been at i = 100\* 0.5% should be mapped to the point that at time t+1 is 100 \* 0.5 / 1.285%, not the one at i = 100\* 0.5% at time t+1. So the procedure should probably be followed to track movement along a section of the front that is moving, with those north and south end points being fixed locations that one can see by eye have not moved, not always the very farthest north or south one can go and still be in Ukraine.