Counting Counter-Offensives

A Bayesian Model of Conflict Intensity

Benjamin J. Radford[1], Yaoyao Dai[1], Aaron Schein[2], Niklas Stoehr[3], Mya Fernandez[1], Hanif Sajid[1]

[1]University of North Carolina Charlotte, [2]University of Chicago, [3]ETH Zurich

Questions

- How many losses have been suffered by belligerents in Ukraine since February 24, 2022?
- Do reporting sources systematically over- or under-estimate losses?
- Can we derive estimates from noisy observations with missingness?

Data

We collect 4,609 reports of losses in the Russia-Ukraine war (Feb. 2022–Feb. 2023). These reports come from the UK, RU, UA, UN, US, open source investigators, and other sources. They encompass 21 loss categories including both human and equipment losses.

A report comprises the following data:

- Loss report value (integer)
- Date of report
- Daily or cumulative time unit indicator
- Min, exact, or max value indicator
- Reporting source ("source")
- Victim of losses ("target")
- Type of loss ("category")

Methods

We use a Bayesian latent variable model to estimate expected daily and cumulative losses for every category for both Ukraine and Russia. Our model accounts for reporting source biases with multilevel random intercepts.

Assumption about the data generating process	How we encode it in the model
Reports can be daily or cumulative and we want to use both.	Multivariate model with combined daily and cumulative likelihoods (Eq 1 & 2).
Most reports are cumulative.	Mean cumulative losses are modeled as the cumulative sum of estimated mean daily losses (Eq 4).
Actual losses are unobserved.	Cubic B-spline estimates of latent daily losses (Eq 5–8).
Reports are sometimes given as ranges ("between X and Y losses").	We estimate reporting source-specific min and max value scalars (Eq 9 & 10).
Some reporting sources are probably biased.	Hierarchical source-target-category bias terms (Eq 11 & 12).
Biases are likely to be scalar and not intercept shifts.	Our model is log-linear in parameters and exp(bias) is multiplicative of the latent variable.

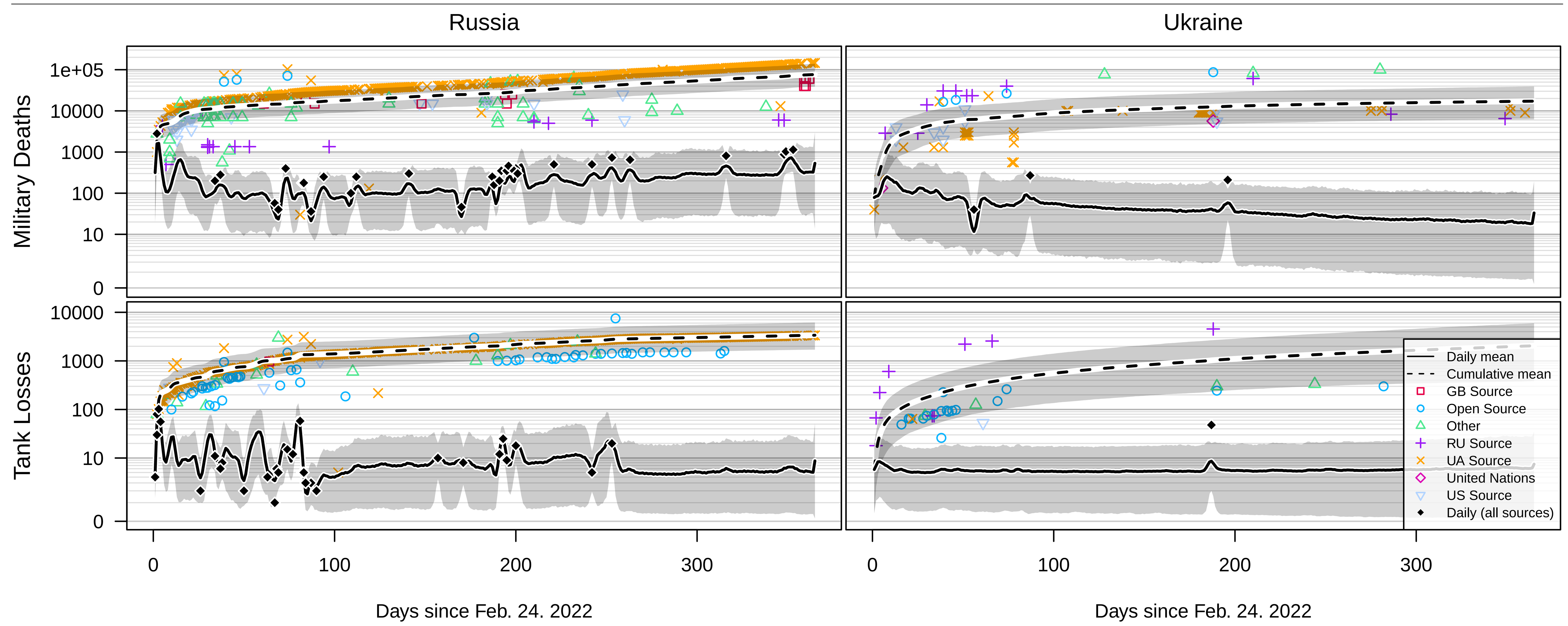
Conclusion

Russian and Ukrainian equipment losses are often comparable by category, but Russian personnel losses outpace Ukrainian personnel losses. As of the one year mark, Russia appears to have lost personnel relative to Ukraine at a rate of 5.53 to 1 (95% CI: 1.6:1–14.5:1).

Casualty to death ratios are 2.9:1 and 4.9:1 for Russia and Ukraine, respectively.

Russian sources over-report Ukrainian deaths at a rate of 4.3 to 1 and under-report Russian deaths at a rate of 0.3 to 1. Ukrainian sources over-report Russian deaths at a rate of 1.9 to 1 but neither under- nor over-report the deaths of their own personnel.

Losses over time



Model definition

Likelihood

$$y_i^{\text{daily}} \sim \text{Pois}(\exp(\mu_i^{\text{daily}})) \quad (1)$$

$$y_j^{\text{cum}} \sim \text{NB}(\exp(\mu_j^{\text{cum}}), {}^1/_{\exp(\phi_{ct[j]})}) \quad (2)$$

Loss means

$$\mu_i^{\text{daily}} = \theta_{ct[i],d[i]} + \beta^{\text{bias}}_{c[i],st[i]} + \beta^{\text{min}}_{s[i]} I_i^{\text{min}} + \beta^{\text{max}}_{s[i]} I_i^{\text{max}} \quad (3)$$

$$\mu_j^{\text{cum}} = \ln(\Sigma_{k=1}^{d[j]} \exp(\theta_{ct[j],d[k]})) + \beta^{\text{bias}}_{c[j],st[j]} + \beta^{\text{min}}_{s[j]} I_j^{\text{min}} + \beta^{\text{max}}_{s[j]} I_j^{\text{max}} \quad (4)$$

Latent time series

$$\theta_{ct,d} = (B\beta_{ct}^{\text{spline}})_d + \beta_{ct}^{\text{const}} + \beta_{ct}^{\text{trend}} \, ({}^d/_{365}) \quad (5)$$

Priors

$$\beta_c^{\text{const}} \sim N(\mu^{\text{const}}, \sigma^{\text{const}}) \quad (6)$$

$$\beta_{ct}^{\text{trend}} \sim N(\mu^{\text{trend}}, \sigma^{\text{trend}}) \quad (7)$$

$$\beta_{ct}^{\text{spline}} \sim N(0, \Sigma^{\text{spline}}) \quad (8)$$

$$\beta_s^{\text{min}} \sim N(\mu^{\text{min}}, \sigma^{\text{min}}) \quad (9)$$

$$\beta_s^{\text{max}} \sim N(\mu^{\text{max}}, \sigma^{\text{max}}) \quad (10)$$

$$\beta_{c,st}^{\text{bias}} \sim N(\gamma_{st}^{\text{bias}}, \sigma_{st}^{\text{bias}}) \quad (11)$$

$$\gamma_{st}^{\text{bias}} \sim N(0, \sigma_1^{\text{bias}}) \quad (12)$$

$$\phi_{ct} \sim N(\mu^{\phi}, \sigma^{\phi}) \quad (13)$$

Estimated cumulative losses as of Feb. 23, 2023

ISO2	Category	n	Est.	95% CI
RU	AA Systems	233	339	[76–1070]
UA	AA Systems	13	1105	[108–5247]
RU	Armored Vehicles	400	6351	[2966–11791]
UA	Armored Vehicles	15	3280	[777–8439]
RU	Artillery	380	1483	[701–2818]
UA	Artillery	35	2290	[519–6966]
UA	Civilian Casualties	21	38155	[13245–84852]
UA	Civilian Deaths	46	13287	[4081–32399]
UA	Civilian Injuries	26	19464	[5396–46460]
RU	Helicopters	389	172	[87–311]
UA	Helicopters	30	64	[14–183]
RU	Jets	409	146	[68–273]
UA	Jets	38	122	[32–372]
RU	Military Casualties	130	218800	[108432–397361]
UA	Military Casualties	16	75538	[19994–176612]
RU	Military Deaths	523	76687	[38670–139772]
UA	Military Deaths	67	17223	[6219–39105]
RU	Military Injuries	44	148608	[45749–365649]
UA	Military Injuries	8	33081	[5260–125925]
RU	MLRS	261	488	[148–1222]
UA	MLRS	27	538	[155–1482]
RU	Tanks	501	3380	[1704–6178]
UA	Tanks	33	2051	[385–5946]
RU	UAVs	292	337	[153–707]
UA	UAVs	40	1643	[387–4371]

Estimated reporting biases