AN ESTIMATE OF THE BEIRUT, LEBANON EXPLOSION EQUIVALENT NUCLEAR YIELD USING PUBLICLY AVAILABLE DATA

Ileana Tibuleac and Thomas VanDeMark
Air Force Technical Application Center
Patrick SFB, Florida, USA

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POSTER

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OBJECTIVE

- **Explore the use of non-seismic constraints to supplement the seismic data equivalent nuclear yield estimates for a large explosion in Beirut, Lebanon.**
- **This method could be used to provide timely information for first-responders.**

https://s.yimg.com/ny/api/res/1.2/_2rW9ccKow2_PIdWQruz1Q--~A/YXBwaWQ9aGlnaGxhbmRlcjtzbT0xO3c9ODAw/https://media-mbst-pub-ue1.s3.amazonaws.com/creatr-uploaded-images/2020-08/d268c520-d6f3-11ea-a6df-7bf947bbcb8b

METHOD

Assumption: The peak overpressure decreases with the increasing distance of the receiving object from the center of an explosion (assumed to be nuclear) and increases with the increase of the yield or W_{TNT} (Glasstone and Dolan, 1977).

- **The <u>observed</u> peak overpressure (OP) is estimated empirically by visual comparison of the Beirut explosion damage with literature descriptions of nuclear explosion damage as a function of peak overpressure.**
- **The magnitude of the <u>expected</u> peak overpressure (OP_E) of a blast wave is estimated as a function of various yield (W_{TNT}) values, from 0.2-kT to 1.2 –kT TNT equivalent.**
- **For the preferred W_{TNT} the OP and OP_E should have very similar values at the observation distances.**

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DATA

DATA

The locations of the measurement points; the number ID at each point corresponds to the number IDs in the table on the following slide. The yellow arrows show paths to points with measurements illustrated below.

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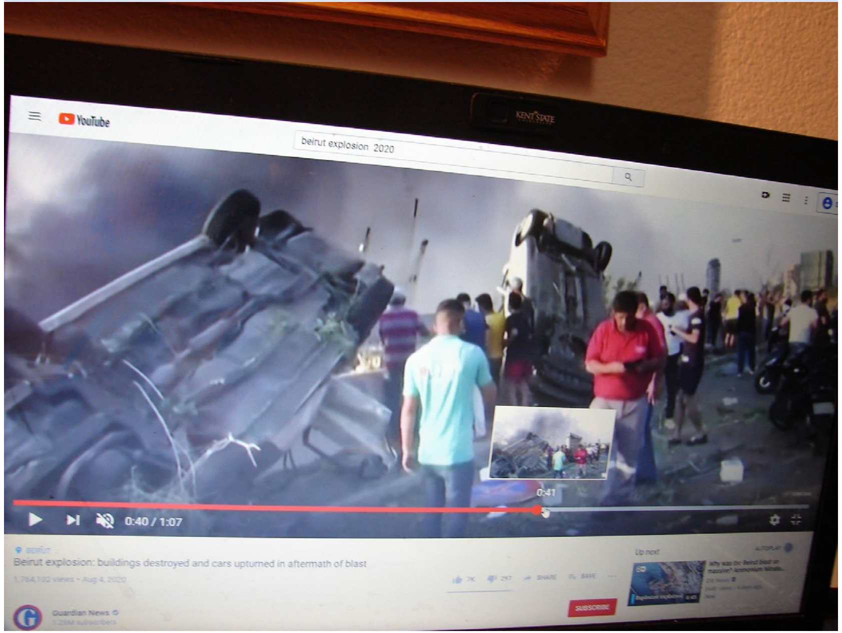
DATA

DATA EXAMPLES



Toppled cars on the highway (observation point 3 in Table 1 in text). From https://www.youtube.com/watch? v=Po_tu3kievY . An overpressure greater than 3.1 and less than 5 psi has these effects on cars oriented perpendicular to the shock front.

Orient Queen liner damaged by blast

From BBC, an overturned cruise ship, indicating an OP of ~ 4 psi (observation point 4).

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DATA

Point #	Measurement ocation Lat, Lon) degrees	Damage	Radius r from ground zero (m)/(ft)	Overpressure OP (psi)
1	33.901554N 35.518960E	Crater Concrete building partially damaged	~20/65.6	7-20
2	33.899093°N 35.518477°E	Roundabout near the first standing concrete structure	270/885.6	5
3	33.898133°N 35.521344°E	Toppled cars	425/1394	4
4	33.903734°N 35.523538°E	Overturned cruise ship	477/1564	4
5	33.896503°N 35.517001°E approximately	Car driving away from the explosion, windows pulverized and inside damage	592/1941	1.7
6	33.895471°N 35.520655°E	Tamashii 700 Rue 12. Structural damage, windows pulverized	665/2181	1.5
7	NE of the explosion location	Buildings heavily damaged	742/2433	1.5
8	Sursok Museum 33.893276°N 35.516424°E	Doors and windows blown up, ceilings and walls fell	937/3073	1
9	NW building 33.905926°N 35.509890°E	Roof destroyed, building standing, probably needs demolition	973/3191	1.1
10	Odd angle house 33.897162°N 35.528157°E	Roof and upper level heavily damaged	975/3198	1
11	Saint George Hospital 33.893383°N, 35.523686°E	Doors blown out, ceiling damage	1000/3280	0.7
12.	St Maroon Maronite Church 33.893327°N 35.509954°E	Structural damage, ceiling fell on priest	1243/4077	0.6
13	Getaiwi neighborhood 33.893811°N 35.529120°E	Windows and doors blown out	1266/4152	0.5
14	Mohamad Al-Amin Mosque 33.895004°N 35.502223°E	Windows and doors blown, otherwise light damage	1367/4483	0.5
15.	St George Church 33.896200°N 35.504923°E		1428/4683	0.25
16	Sfeir – Semler Gallery 33.900446°N 35.536569°E		1618/5307	0.25
17	BBC headquarters 33.895004°N 35.502223°E	Woman inside building, windows shattered, thick dust, shaking, no structural damage, minor if existent injuries (BBC).	1711/5612	0.25

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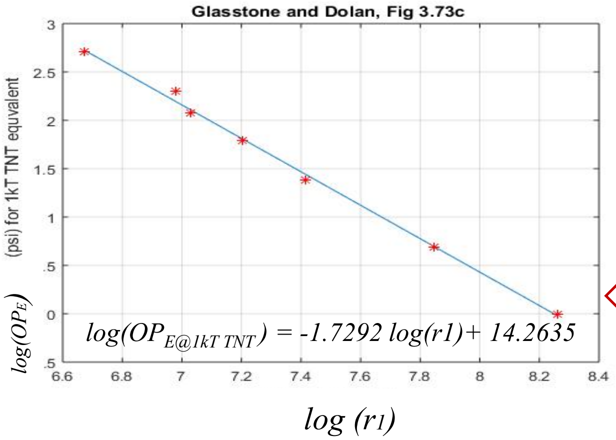
METHOD

The expected peak overpressure OPE



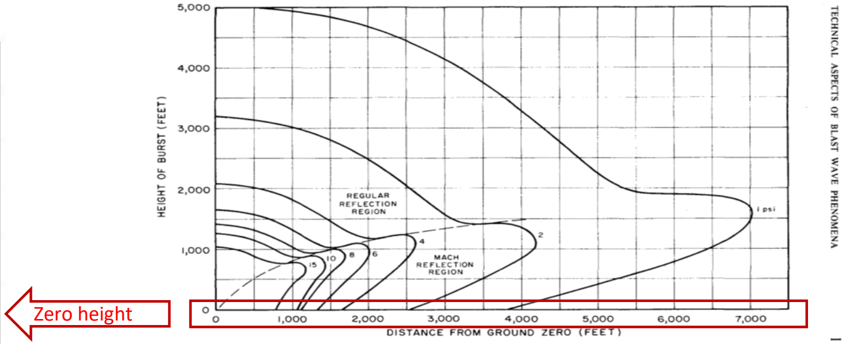


Figure 3.73c from Glasstone and Dolan, 1977.

The left figure shows the OPE dependence of distance from the explosion (r1). Each value in the left figure is extracted from the calculations of peak overpressure as a function of distance for a 1 kT burst at zero height shown in the right figure.

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RESULTS

Compare OPE and OP

At *different* W_{TNT} *values than 1-kT* it is assumed that the same *OP* will correspond to a scaled radius. According to the scaling laws in Glasstone and Dolan 1977, if r_1 is the radius from ground zero for a 1-kt TNT burst, the radius r_W from ground zero of a burst with W_{TNT} yield and the same overpressure satisfies the following equation:

$$r_W * W_{TNT}^{-1/3} = r_1 * W_{1kT\ TNT}^{-1/3}$$

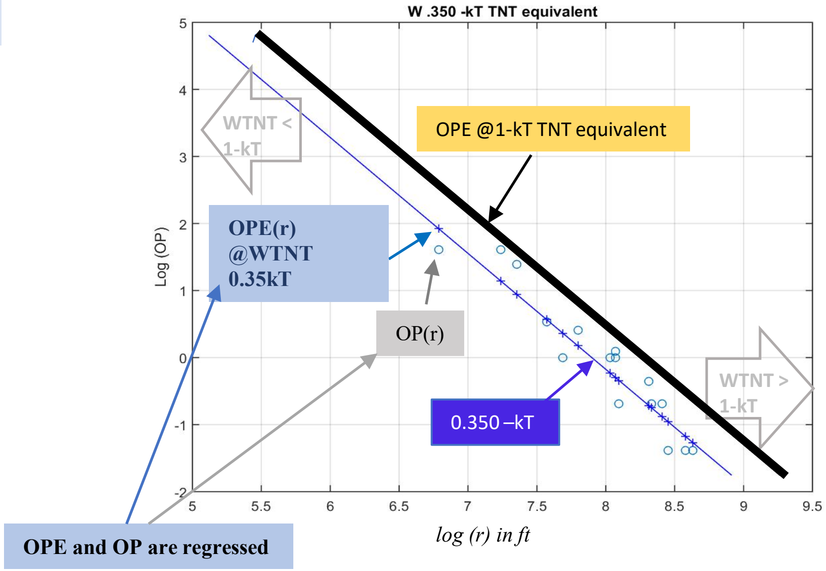
where $W_{1kT\ TNT}$ is the energy of a 1-kT TNT equivalent blast, with a value of one.

The OP_E at W_{TNT} can be expressed as:

$$\log(OP_{E@W\ TNT}) = -1.7292 \log(r_W) + 14.2635$$

A linear regression of the *OP(r)* as a function of *OPE (r)* for WTNT between 0.1 and 1.2-kT with an increment of 0.1 –kT results in a preferred W_{TNT}. "*r*" is the observed radius.

OPE is estimated at distances scaled for WTNT from 0.1 to 1.2 –kT TNT.



This figure shows the variation of the natural logarithm of the OP as a function of the natural logarithm of the distance r (ft) from the explosion location. The black straight line is the 1 –kT TNT equivalent OP_E variation with distance. The open circles are the OP values. The crosses are the OP_E values at W_{TNT} 0.350 –kT TNT equivalent estimated at the observed distance in ft from the event location. The observed OP (open circles) and estimated OPE @ WTNT 0.350 kT (crosses) are compared. The blue straight line corresponds to distances scaled for W_{TNT} 0.35 – kT TNT equivalent which is the preferred value.

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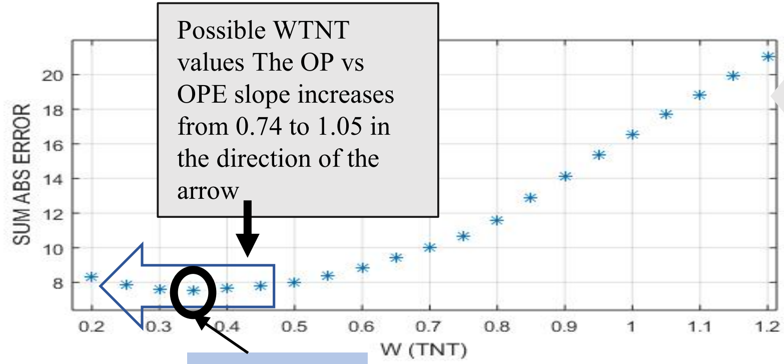

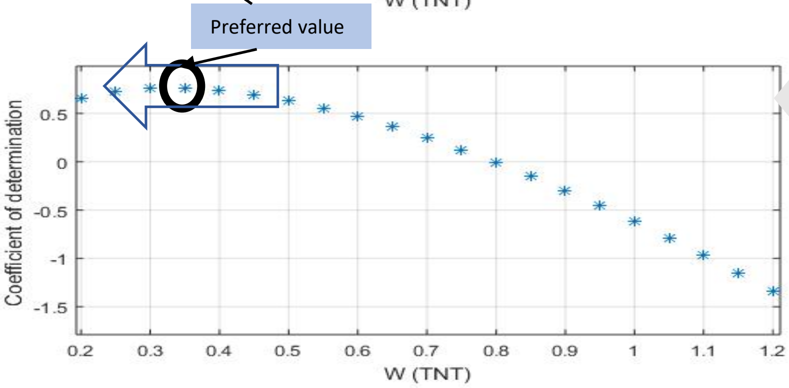

The sum of the absolute error values when OPE is estimated at distances scaled for WTNT from 0.1 to 1.2 –kT TNT. The error is defined as the difference between OP and OPE.

An additional condition is for the slope of the *OP* and OP_E regression to be as close to one as possible.

The coefficient of determination or R^2 value when multiplied by 100 shows that a linear equation predicts R^2*100 % of the variance in the *OP*.

A possible W_{TNT} interval of 0.25-0.45 -kT is estimated for W_{TNT} with a preferred value of 0.350 – kT. The best W_{TNT} values had in the order of importance the lowest absolute error, the highest R^2 and the linear fit slope close to one.

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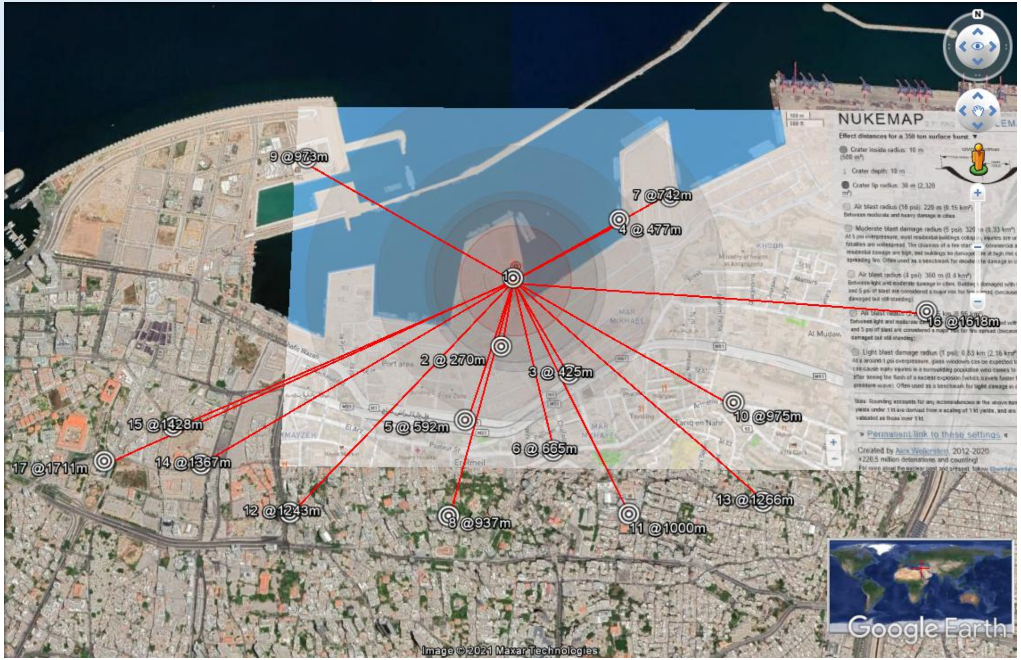
Error discussion

Our observations roughly follow the OP distribution predicted by an Internet application named NUKEMAP available on the website https://nuclearsecrecy.com/nukemap/ last accessed May 6. 2021.

The figure shows the OP_E (psi) expected from a nuclear explosion with a yield of 0.350 –kT TNT.



A reasonable comparison to the nuclear equivalent yield values (0.5 and 1.1 kT TNT) published by Rigby et al., 2020 and Dewey, 2021 also shows that this method can be used to provide a quick first order estimate of the yield in order to prepare an adequate response to such an event.

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Error discussion

Possible errors:

- **A detailed evaluation of each Beirut building was not possible at the time when the measurements were made.**
- **Complexities of the overpressure front propagation are expected to occur at OP less than 1 psi when the front propagates in a congested area of high rise buildings. Thus, the empirical OP evaluations may be too low at distances larger than 1500 ft from the Beirut explosion location.**
- **Because of potentially large errors in estimating high OP values the measurement within 300 ft the explosion (observation point 1) was not used in calculations.**

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ileana.tibuleac@us.af.mil

SUMMARY

- **Empirical overpressure measurements based on damage observed in images from news coverage and social media can be used to supplement seismic data yield estimates in the early phase of response to a catastrophic explosion.**
- **Using this novel method an equivalent nuclear yield interval of 0.250 – 0.450 -kT is estimated for W_{TNT} of the Beirut explosion with a preferred value of 0.350 – kT TNT.**
- **Within the scientific community the application of multiple methods has resulted in different yields for this surface explosion and further investigations are needed to reconcile these estimates.**