Misunderstandings about the Tunguska event, shock wave physics, and airbursts have resulted in misinterpretations of evidence at Tall el-Hammam

Mark Boslough[*], Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico, 87131.

Andy Bruno, Department of History, Indiana University, Bloomington, Indiana, 47405

Bunch et al.[1] make several incorrect statements about the Tunguska event and about airbursts in general. Collectively, these errors have led to assertions of evidence that do not appear to be supported by the data, and to conclusions that are not factually supported. Some of these mistakes come from literature in which the primary sources have been misunderstood, exaggerated, and/or misquoted. In other cases, misinformation was introduced in a chain of citations that included non-peer-reviewed or unscientific sources. A Tunguska sized airburst cannot possibly generate the claimed temperature or wind speed effects on the ground from an air blast over the distances suggested by Bunch et al.[1] and required to support their conclusions.

Claims of more than eighty million fallen trees, up to 1-m in diameter, are exaggerated

Bunch et al.[1] introduced two errors when they wrote, "The airburst generated a pressure wave that toppled or snapped >80 million tress, some up to 1-m in diameter". The "> 80 million trees" statement is a modified version of Brazo and Austin[2], who wrote "eighty million trees in the taiga (coniferous forest) were uprooted and blown down" with a citation to a 1934 paper by Whipple[3]. The "greater than" symbol was added without justification by Bunch et al.[1] The 80 million trees claim was not actually made by Whipple[3] but by a correspondent, based on Crommelin[4], whose source was Astapovich[5]. The sole aim of the primary source was to roughly estimate the energy of the explosion, starting with an educated guess about the area to approximate the number of fallen trees as a step toward his goal. Astapovich[5] began, "Apparently, it can be assumed that the area of the fallen forest occupies about 8000 km^2" and concluded, "the work of the windfall of $8 \cdot 10^7$ trees would be $4.4 \cdot 10^{21}$ ergs". Brazo and Austin[2] make several other factually incorrect or unsupported statements about the Tunguska explosion, such as "Fesenkov notes that meteorites rarely hit the earth in the morning", "a small comet entered the atmosphere from behind the sun", and "a heat wave with a temperature of approximately 16.6 million degrees Celsius at the focus was generated".

The Bunch et al.[1] claim is therefore an incorrect reporting of the number provided by Brazo and Austin[2], which in turn is a misinterpretation by Crommelin[4] of Astapovich's[5] preliminary guess based on the area of devastation that he overestimated by a factor of about four. Since Brazo & Austin's[2] 1982 article was published, the "80 million trees" claim has propagated into other sources as if it were an established fact that needs no citation.

47   The claim "up to 1-m in diameter" is partly the result of similar creeping exaggeration,
48   some of which can be attributed to Bunch et al.[1] who also neglected to get accurate
49   figures from peer reviewed sources. The size they quoted for the largest trees that were
50   blown over by the Tunguska airburst has also increased through cumulative and
51   repeated exaggerations and selective citation without checking the relevant source
52   literature. Leonid Kulik was the first researcher to arrive in the Tunguska treefall area[6]
53   and recorded his impressions based on his first glimpses of the fallen trees in his diary,
54   using the phrase "десяти-двадцативершковых великанов." This can be translated to
55   "ten-to-twenty *vershok* giants."
56
57   A *vershok* is an old unit of Russian measurement for length. Though like a foot or an
58   inch it remained imprecise for most of its history, a *vershok* corresponded to about 4.4
59   cm in Kulik's time. Thus, this eyeballed estimate of the diameter of the largest trees he
60   saw was 44 to 88 cm. Careful surveys and measurements of tree diameters did not take
61   place until the 1950s, and the largest trees were found to be close to the lower end of
62   Kulik's initial visual guess. According to the "Catalog of Fallen Trees, Caused by the
63   Tunguska Meteorite"[7], the largest category of trees includes those that are merely over
64   30 cm in diameter. Nevertheless, Brazo and Austin[2] focused only on Kulik's obsolete
65   higher estimate but added another few centimetres, stating, "He [Kulik] saw an area
66   where trees up to three feet [91.4 cm] in diameter had snapped like toothpicks". Bunch
67   et al.[1] further upped that estimate, claiming that some trees were "up to 1-m [100 cm]"
68   across. The mass of wood in a tree roughly scales with the cube of its diameter, so this
69   exaggeration overestimated the largest tree size by an order of magnitude, in addition to
70   inflating the number of fallen trees by a factor of about four.
71
72   <u>Incorrect estimate of temperatures exceeding 300,000 °C</u>
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74   Bunch et al.[1] wrote, "Based on atomic testing and Tunguska, the fireball of both sizes of
75   impactors is estimated to have expanded to ~ 1 km in diameter and reached
76   temperatures exceeding 300,000 °C in the center." This statement is incorrect, and the
77   cited publications by Alekseev et al.[8] and Glasstone and Dolan[9] do not support these
78   claims. The specific energy at the source of a nuclear explosion (nuclear energy per unit
79   mass of the bomb), and therefore its temperature, is many orders of magnitude higher
80   than that of a cosmic airburst (kinetic energy per unit mass of the asteroid).
81
82   Alekseev et al.[8] refers only to temperatures of the very small volume of shocked air
83   during the early, hypervelocity entry "fireball" phase when it is still 10 km above the
84   surface. They state that it increases up to 10 eV (~116,000 °C) but point out that the
85   radiation flux at the surface at this time is much lower due to shielding. Glasstone and
86   Dolan[9] make no mention of Tunguska or cosmic airbursts and only address nuclear
87   weapons, writing "Because of the enormous amount of energy liberated per unit mass in
88   a nuclear weapon, very high temperatures are attained. These are estimated to be
89   several tens of million degrees, compared with a few thousand degrees in the case of a
90   conventional explosion." An impactor moving at v=3 km/s has a specific kinetic energy
91   ($\frac{1}{2}v^2 = 4.5 \times 10^{10}$ erg/g) that approximately corresponds to the chemical energy of a
92   conventional explosive, idealized in the nuclear weapons literature as "TNT equivalent"

93   and defined as 4.2×10^{10} erg/g (Glasstone & Dolan[9]). 3 km/s is also considered the
94   speed above which an object is moving at hypervelocity. This hypervelocity threshold
95   can be scaled to typical cosmic velocities to show that the average temperature of a
96   fully vaporized cosmic body during an airburst is more than an order of magnitude lower
97   than 300,000 °C.

99   This misunderstanding by Bunch et al.[1] might be attributed in part to the use of the term
100   "fireball" to mean more than one thing by airburst and bolide researchers and nuclear
101   weapons experts. It has also been used to refer to the ejecta plume[10] and to the
102   downward jet[11] (both dominated by vaporized meteoritic material, not air) in some of the
103   earliest supercomputer simulations of airbursts. This misunderstanding is compounded
104   by their misrepresentation of a simulation by Boslough[12] that "near-surface
105   temperatures are at the high end of the temperature scale that ranges up to > 1400° K
106   (sic)". This appears to be based on the authors' misinterpretation of the visualization in
107   their Fig. 53. The conclusions of Bunch et al.[1] are entirely dependent on material
108   exposure to high temperature (exceeding a thousand °C) over a large area for a
109   sufficient period of time, but there is no evidence for such effects at Tunguska, and no
110   physical model suggests that a Tunguska-sized impact can do this. The discussion and
111   cited sources make it clear that Bunch et al.[1] think "superheated" wind behind the shock
112   wave is the source of heat at the surface, as opposed to the brief flash of thermal
113   radiation from an overhead airburst, as took place at Tunguska.

115   <u>Overestimation of the speed of "hypervelocity" winds</u>

117   Bunch et al.[1] wrote, "the evidence is consistent with the hypothesis that the city's
118   mudbrick walls were pulverized by hypervelocity winds from a high-temperature event of
119   cataclysmic proportions". There is not a single source in the vast body of scientific
120   literature on Tunguska that suggests "hypervelocity winds" (> 3 km/s) at the surface.
121   The actual wind speeds behind the blast waves at Tunguska were tens of m/s[15], about
122   two orders of magnitude lower than the hypervelocity threshold.

124   This notion of superheated air and hypervelocity winds appears to have originated with
125   their second citation, to coauthor Silvia[13]. He cited Collins[14], whose illustration of his
126   concept of such an event was captioned, "Regardless of the nature of the destruction
127   that befell the Cities of the Plain, one thing is clear from the biblical text: the fiery blast
128   came from above. Superheated air and/or some kind of impact, like that of a
129   disintegrated comet fragment moving at a high rate of speed, could have obliterated
130   virtually everything in its target area, perhaps leaving only the foundations of the largest
131   structures," with the following citation: "Yahweh rained down burning sulfur on Sodom
132   and Gomorrah...out of the heavens" (Genesis 19:24).

134   A simple calculation contradicts this assumption. Glasstone and Dolan[9] show that for
135   circumstances with an optimal height of burst that produces the 4 psi (~28 kPa) blast
136   radius of Wheeler & Matthias[15] the overpressures do not exceed about 10 psi (~69 kPa)
137   anywhere at the surface. Peak overpressures from a Tunguska-sized airburst at a
138   distance of 10 to 30 km would be in this pressure range. The air cannot be described as

"superheated" because its temperature increase would not be more than 20 to 45 °C[16]. This is not hot enough to melt pottery or mudbricks[17]. There would be no high-temperature (> 1000 °C) or hypervelocity (> 3 km/s) air blast from a Tunguska-sized airburst to create the effects described by Bunch at al.[1] at the location of Tall el-Hammam.

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*Corresponding author

Author contributions
MB conducted the analysis and wrote the comment. AB contributed to the historical research about the origins of misconceptions about the Tunguska event.

Competing interest statement
The authors declare no competing interests.