Sandia National Laboratories

Exceptional service in the national interest

QUANTIFYING BOLIDE ENERGY THROUGH INFRASOUND ANALYSIS: A CASE STUDY OF THE 2023 AUSTRALIAN EVENT

E. A. Silber[1], M. Ronac Giannone[1], L. Schaible[1]

Infrasound Technology Workshop 2024 (ITW2024)

4 – 8 Nov 2024, Vienna International Centre, Vienna, Austria

[1]Sandia National Laboratories, Albuquerque, NM, 87144, USA (esilbe[at]sandia.gov)

LDRD LABORATORY DIRECTED RESEARCH & DEVELOPMENT
WHERE INNOVATION BEGINS

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

SAND2024-14692C

OBSERVATIONS OF LARGE BOLIDES

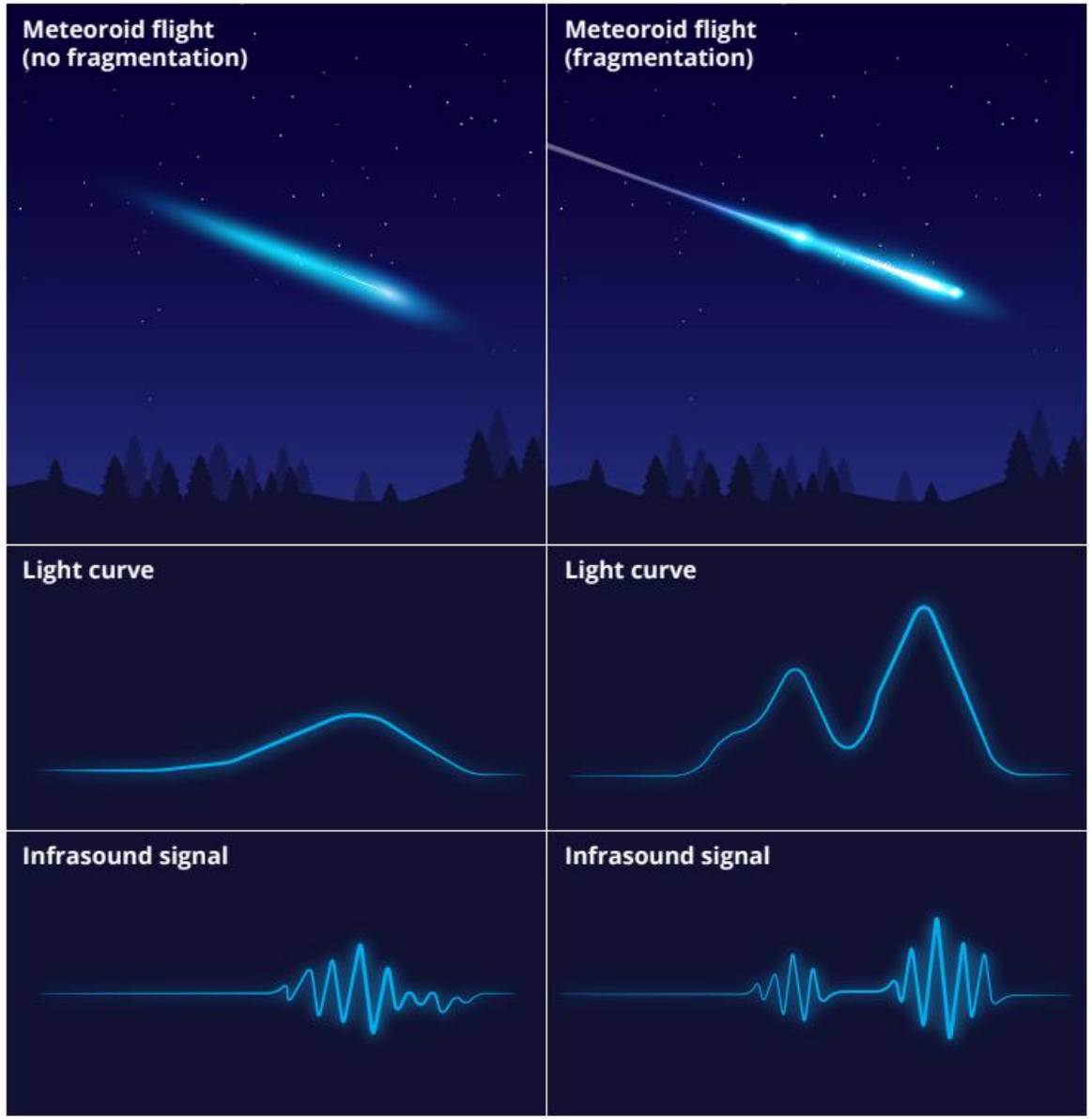
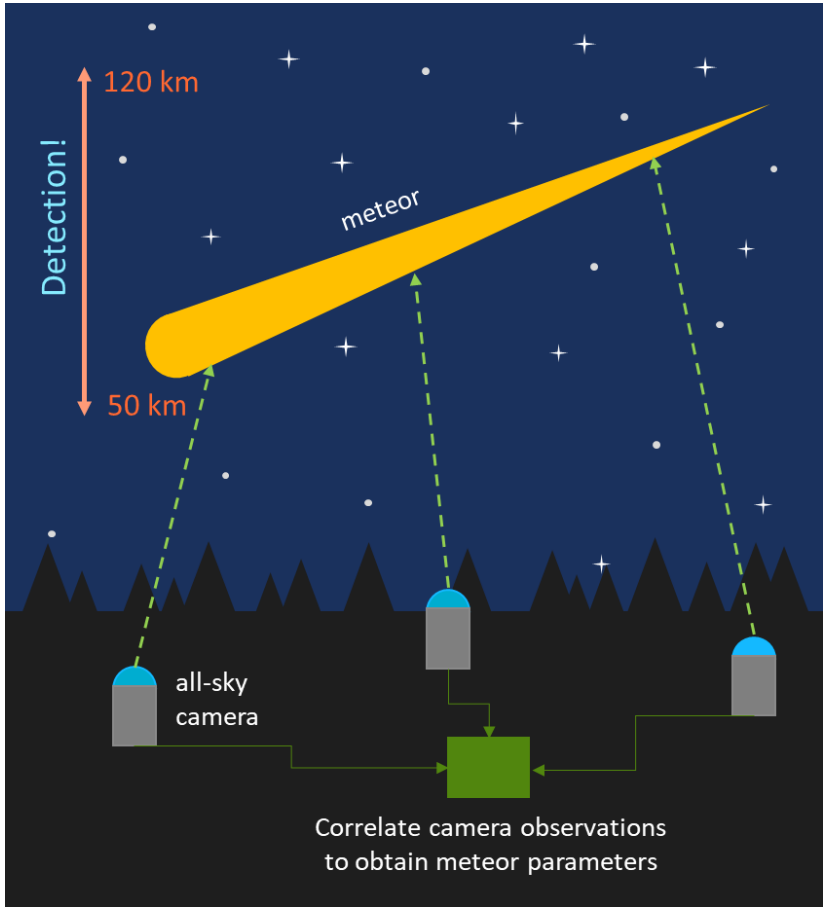


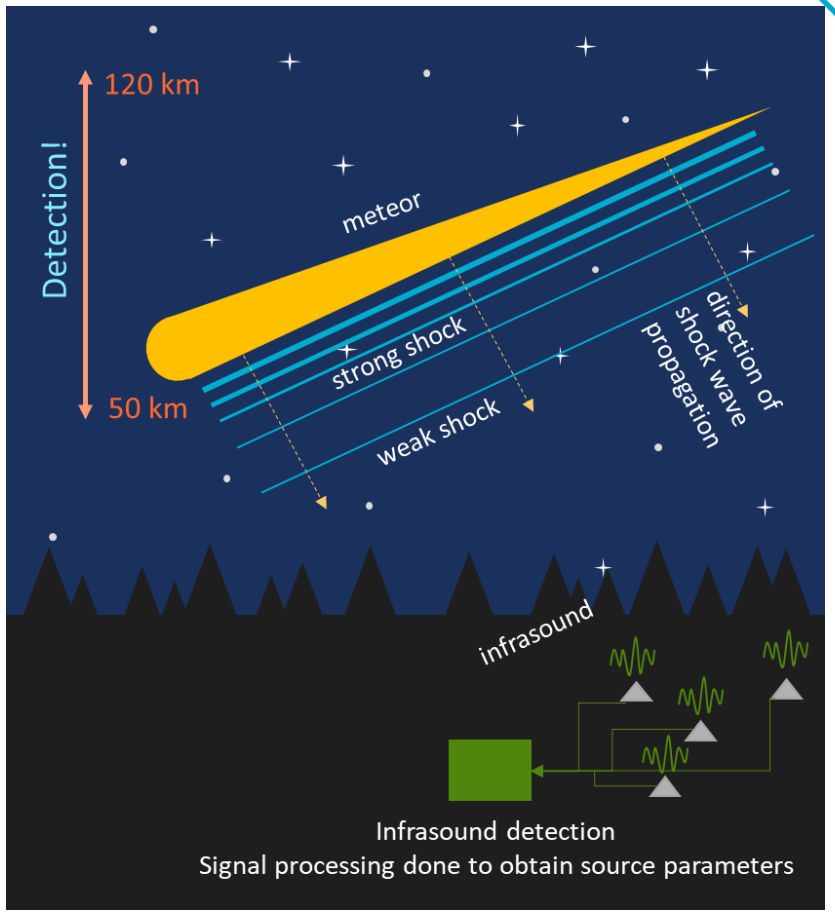
Figure adapted from Silber (2024)

- Ongoing effort to better characterize bolides
- Events recorded and documented through various means of observation
  - US Government sensors
  - GLM
  - All-sky cameras (still and video)
  - Radar
  - Casual witnesses
  - Other less conventional methods (infrasound & seismic)
- There is no perfect approach that would provide all answers we seek
- Many questions remain unanswered, and therefore it is imperative to leverage all approaches

MULTI-MODAL DETECTIONS: ALL-SKY CAMERAS AND INFRASOUND



- Optical observations from multiple vantage points can provide valuable ground truth information.
- Accurate trajectory, velocity, entry angle, etc. can be fed into infrasound search algorithm (Silber 2024).
- Infrasound detection provides additional layer of information about the source.
- Detailed studies using multi-modal detections of fireballs can provide information (and model validation and refinement) that can be later used for events with limited ground truth.
- **The Australian bolide:** the Desert Fireball Network of cameras, a project led by Curtin University, observes meteor activity in Australia



Silber, E. A. (2024). Perspectives and Challenges in Bolide Infrasound Processing and Interpretation: A Focused Review with Case Studies. Remote Sensing

AUSTRALIAN BOLIDE (MAY 20, 2023)

- Bolide over Queensland, at 9:22 pm local time (May 20, 2023)
- Was visible 600 km away
- Blackbull, a small rural locality between the Gulf communities of Normanton and Croydon, in north-west Queensland
- Many people captured the moment the green-blue fireball entered the atmosphere until the object disintegrated in a flash of orange-yellow light
- Queensland bolide is the largest event over Australia since 1988

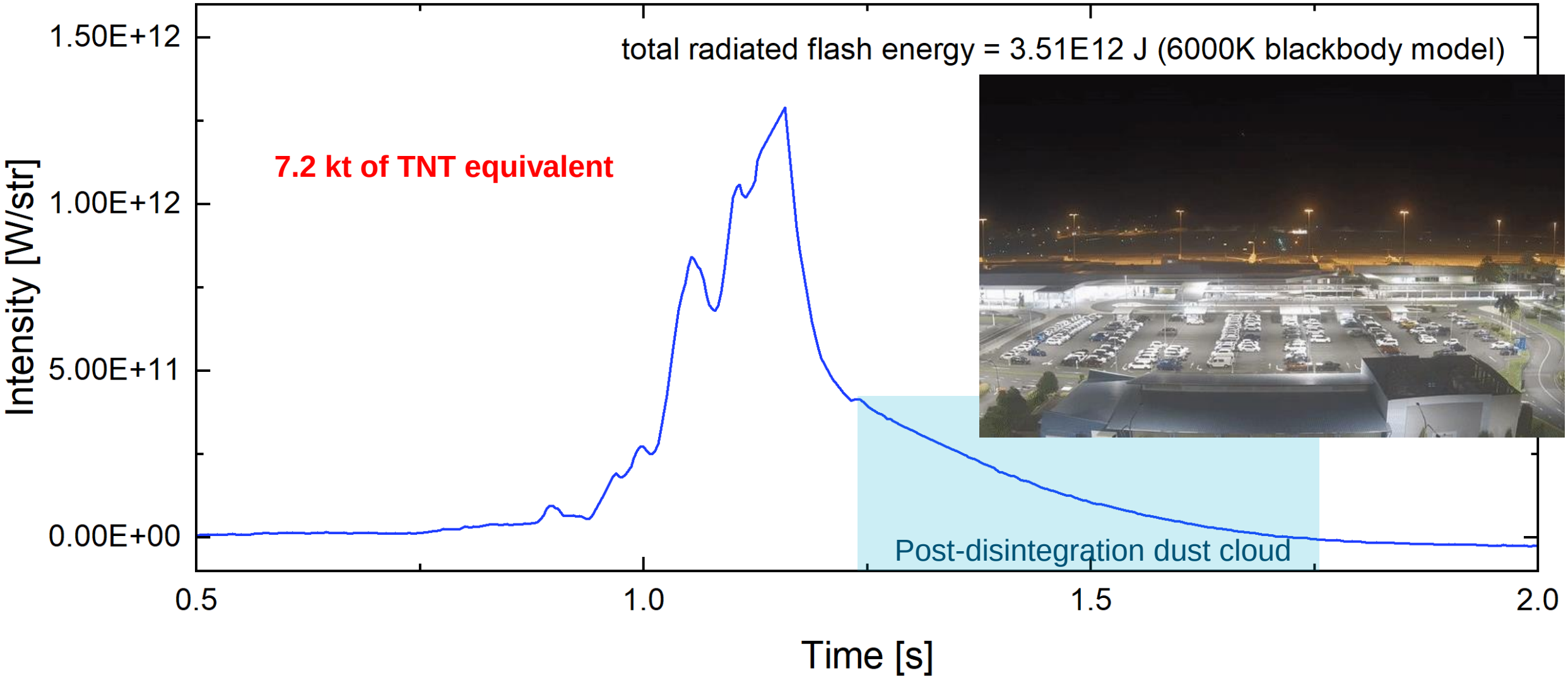
Image credit: Cairns Airport

AUSTRALIAN BOLIDE (MAY 20, 2023)

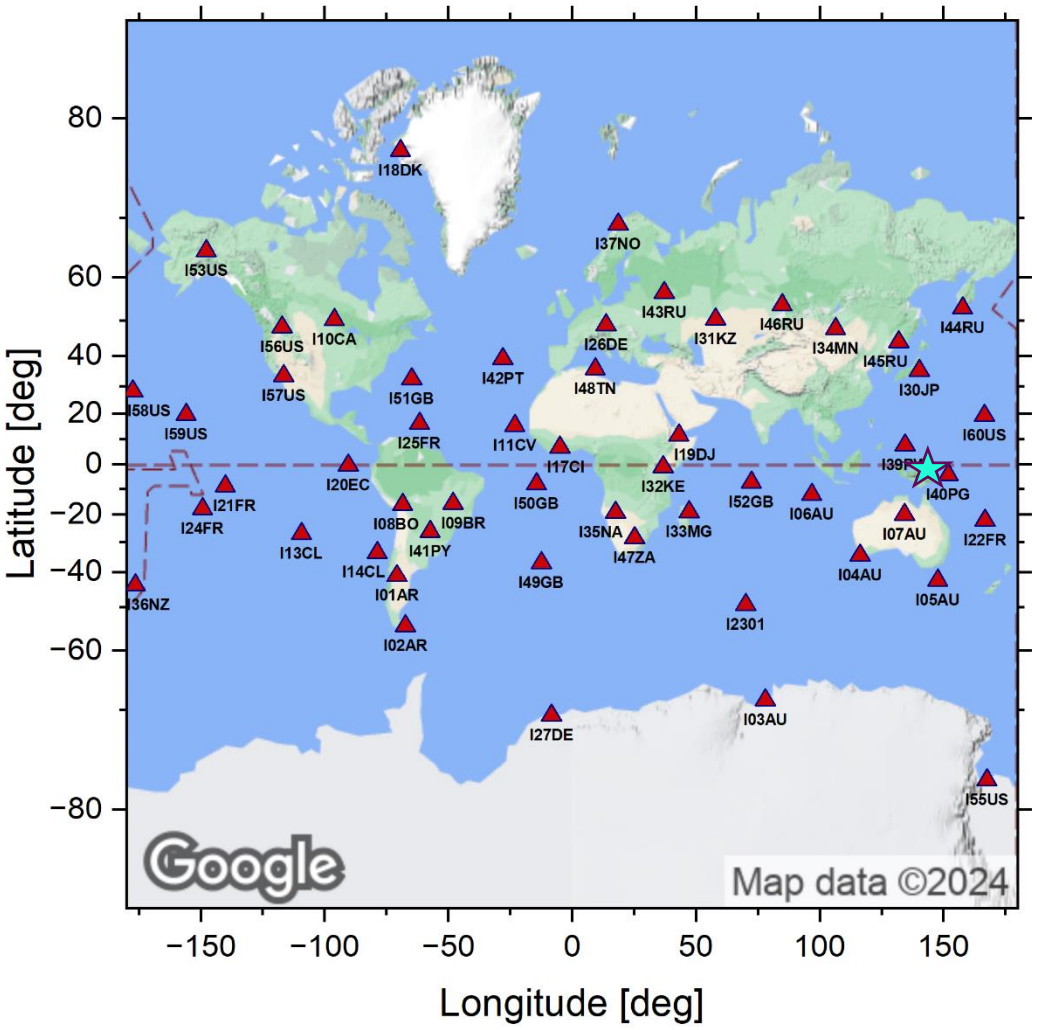
- Altitude = 29 km, v = 28 km/s
- Entry angle = 39 degrees
- Size ~ 3.5 m
- Produced a sonic boom
- E = 7.2 kt of TNT equivalent
- Top 20 in the entire JPL CNEOS database, and the most energetic bolide over Australia since 1988 (since US government started reporting bolide events)

Image credit: Cairns Airport

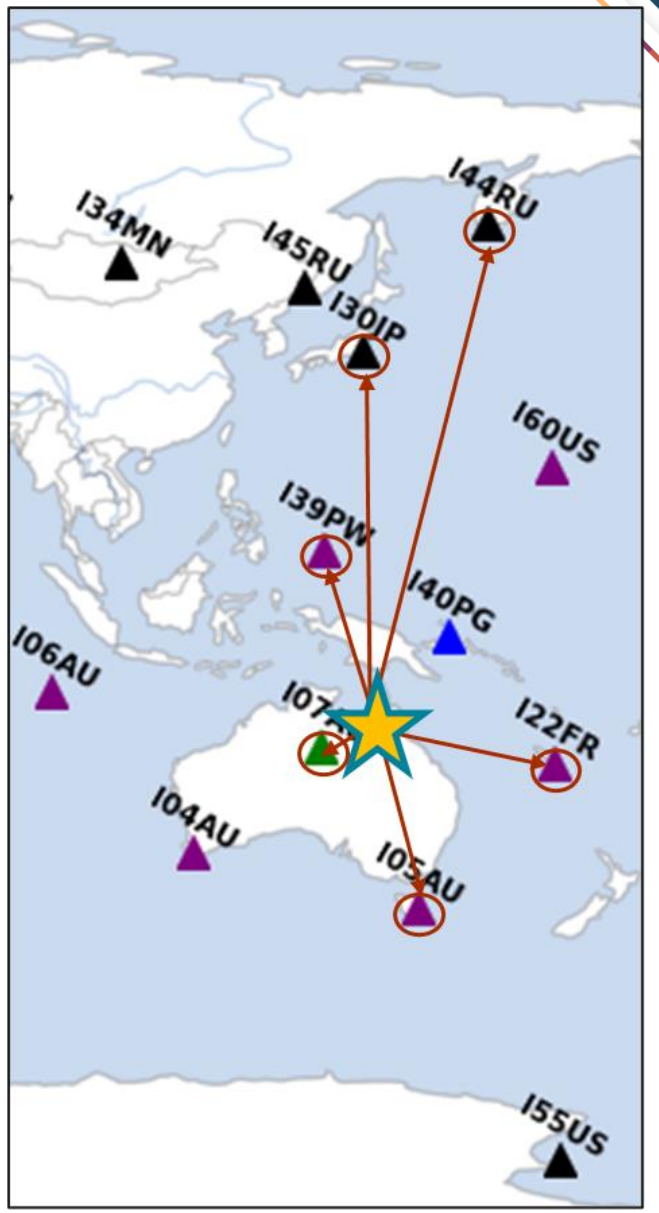
USG SENSOR OBSERVATIONS AND LIGHT CURVE



INFRASOUND DETECTIONS

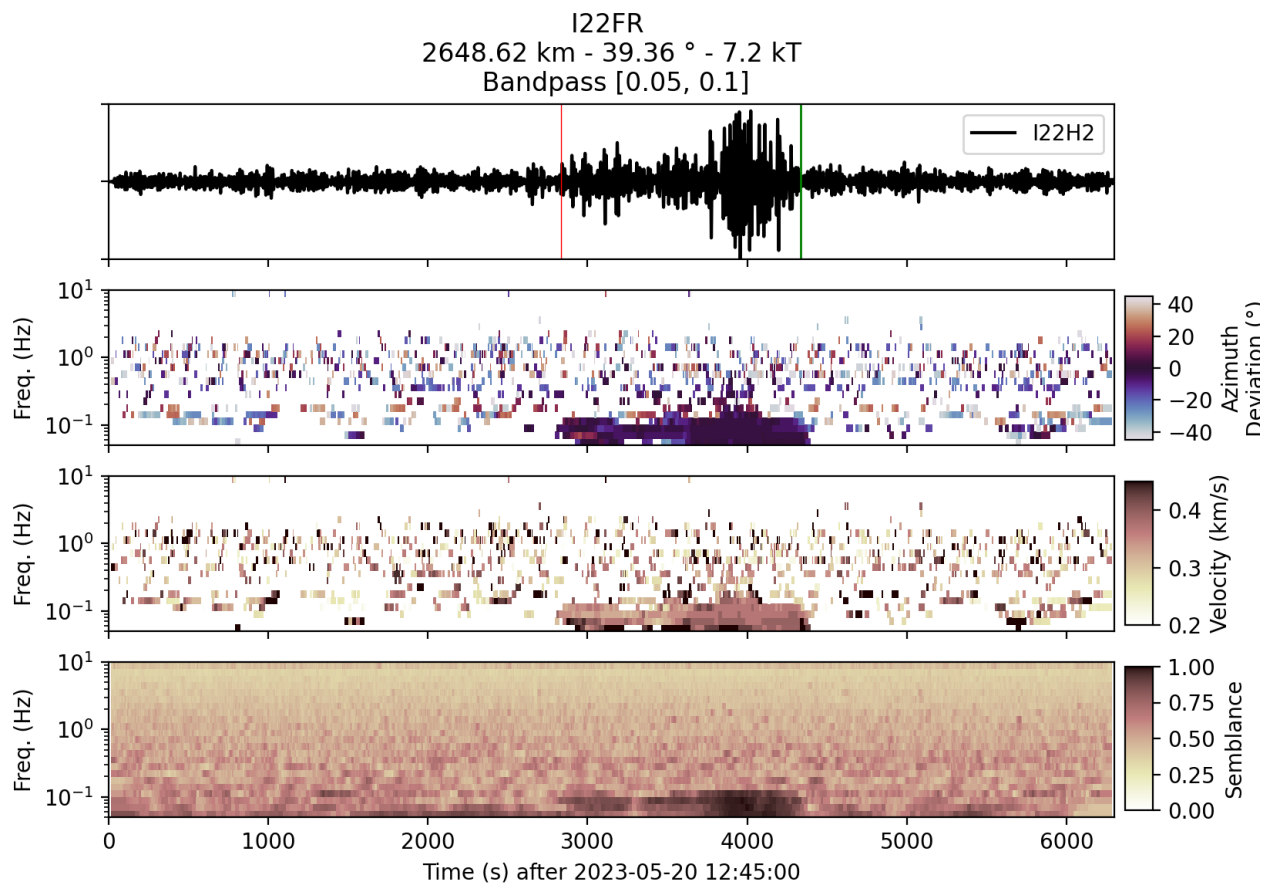


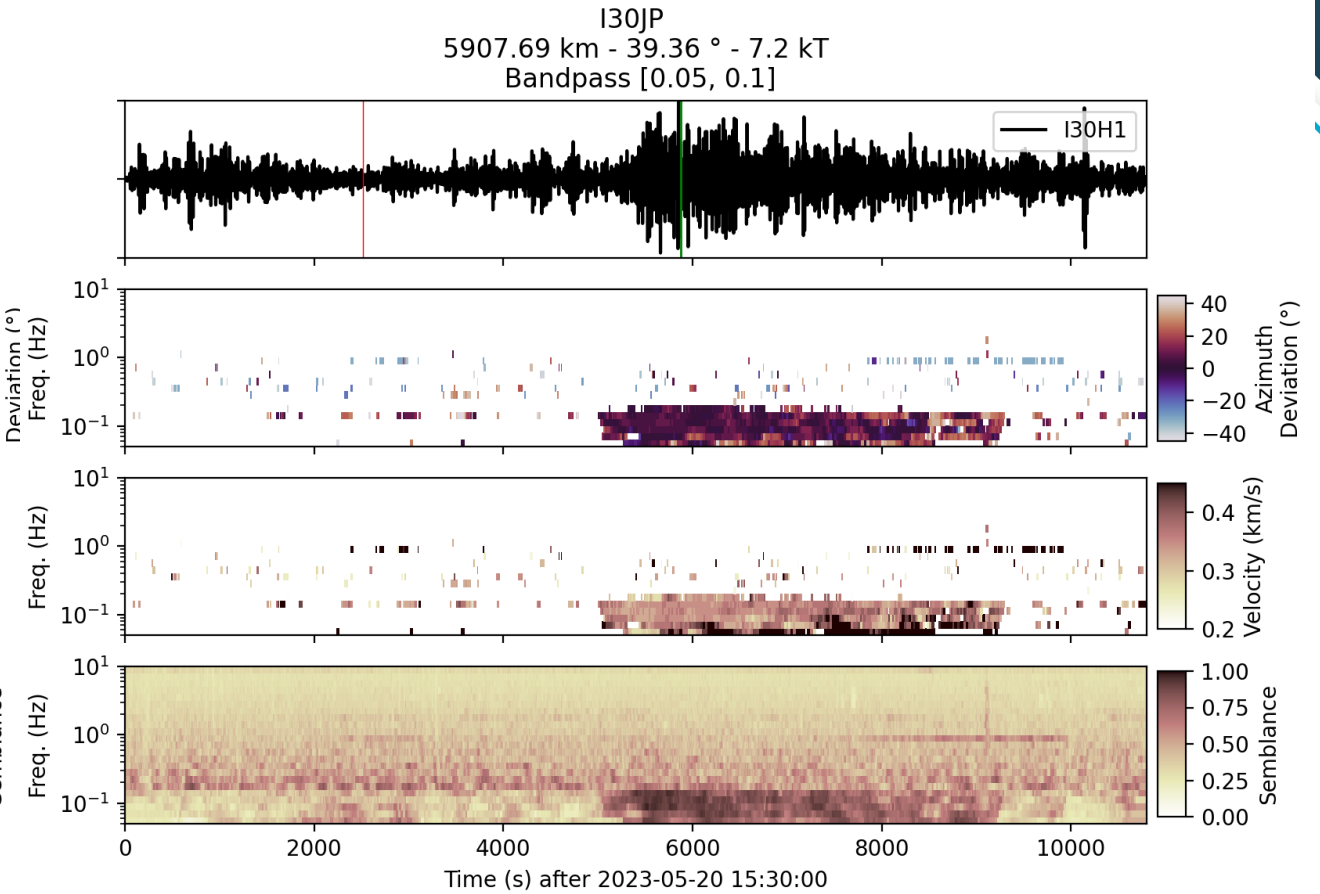
- I07AU – 830 km (weak detection)
- I22FR – 2650 km
- I05AU – 2800 km
- I39PW – 2930 km
- I30JP – 5907 km
- I44RU – 8030 km



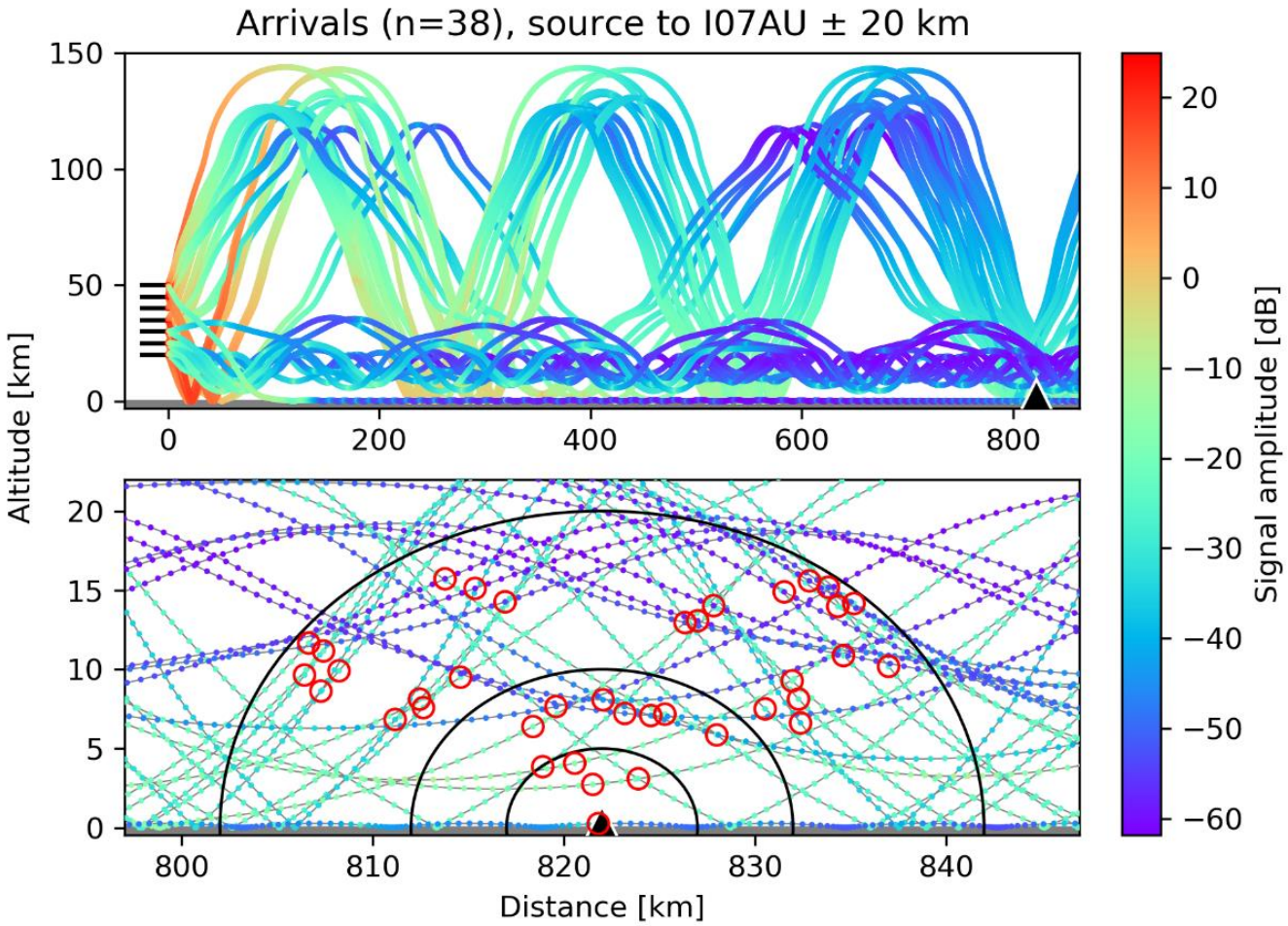
- Searched for infrasound on IMS stations of the CTBTO PrepCom
- Signals detected on 6 stations of the IMS network, predominantly east and north relative to the bolide

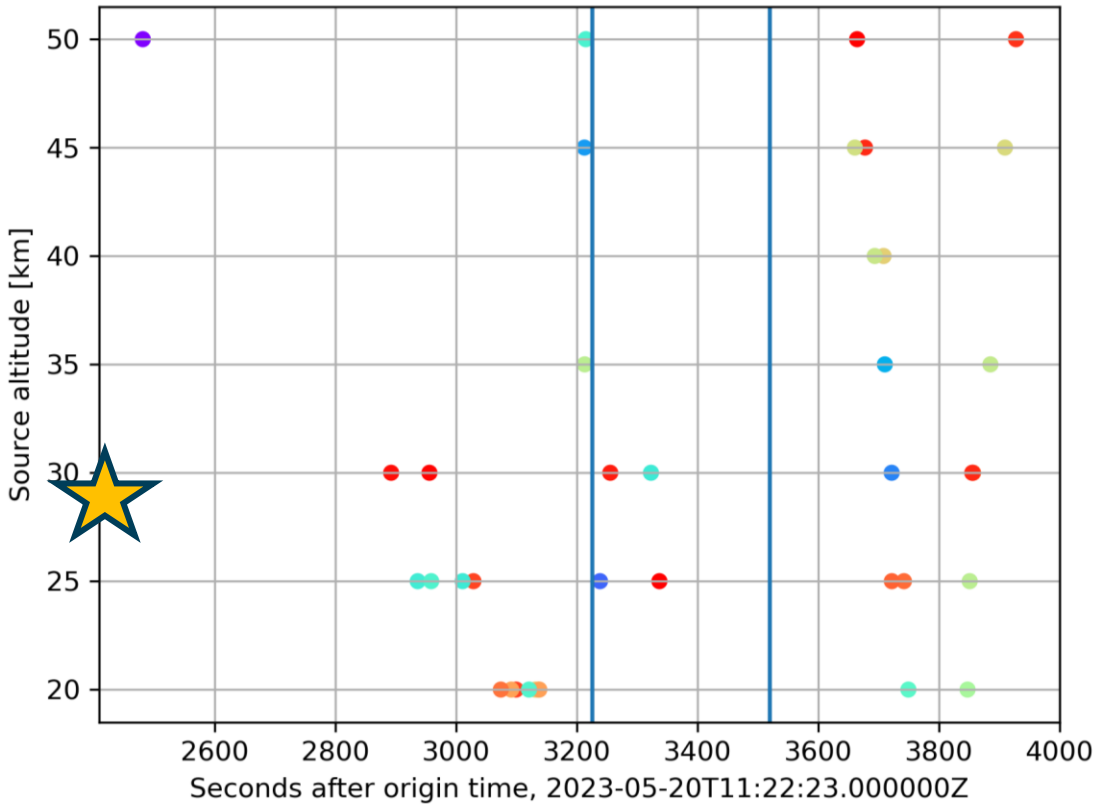
INFRASOUND DETECTIONS



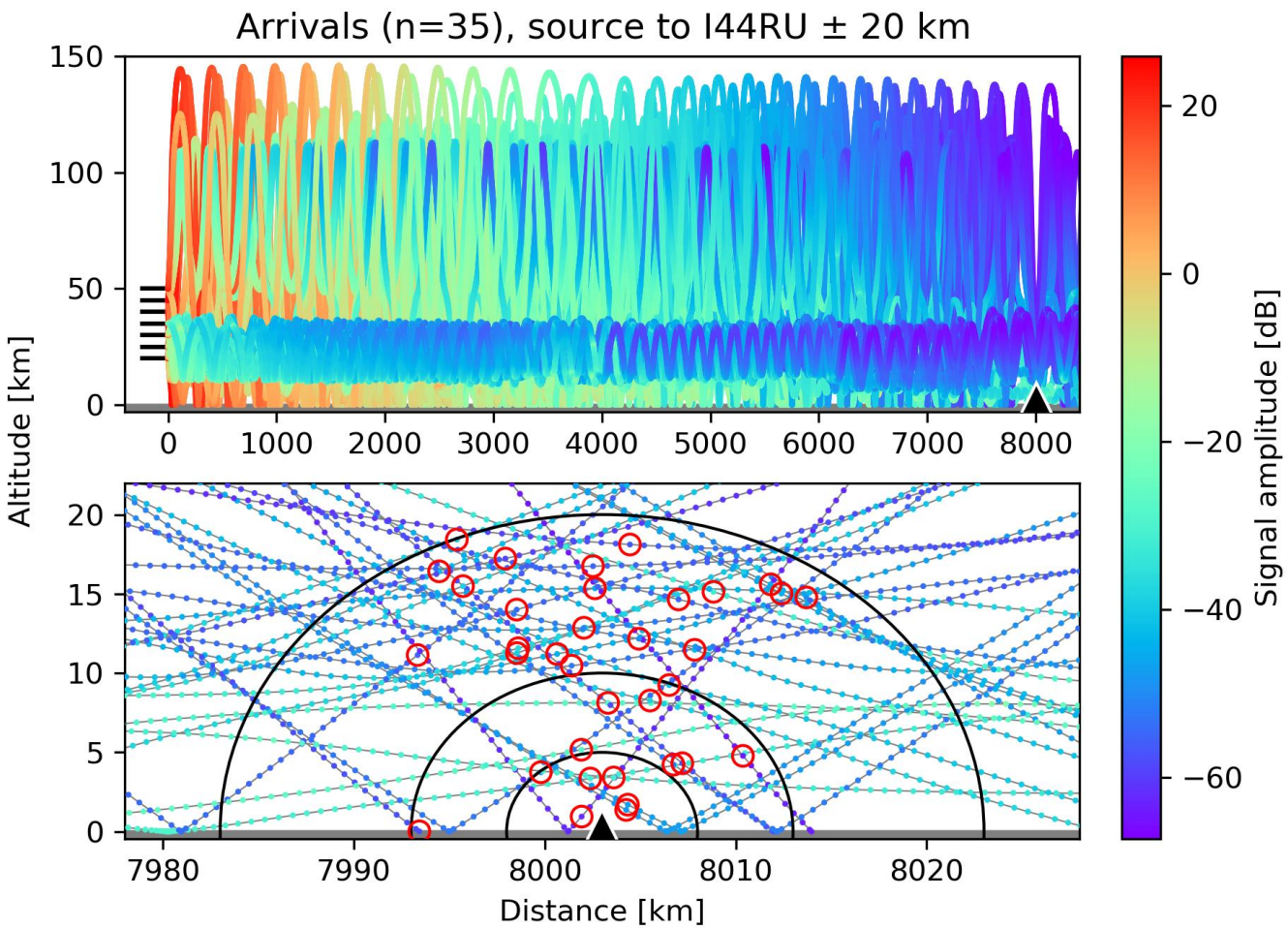


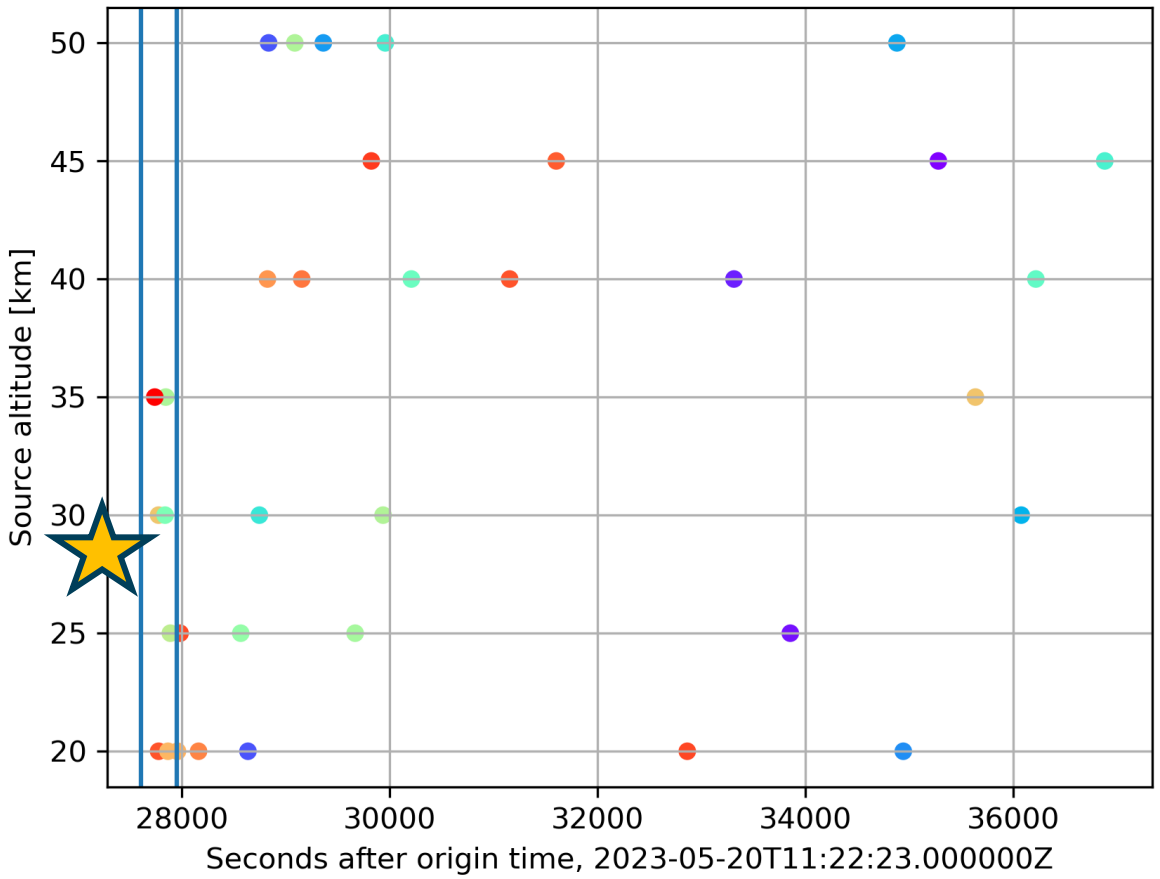
PROPAGATION MODELING





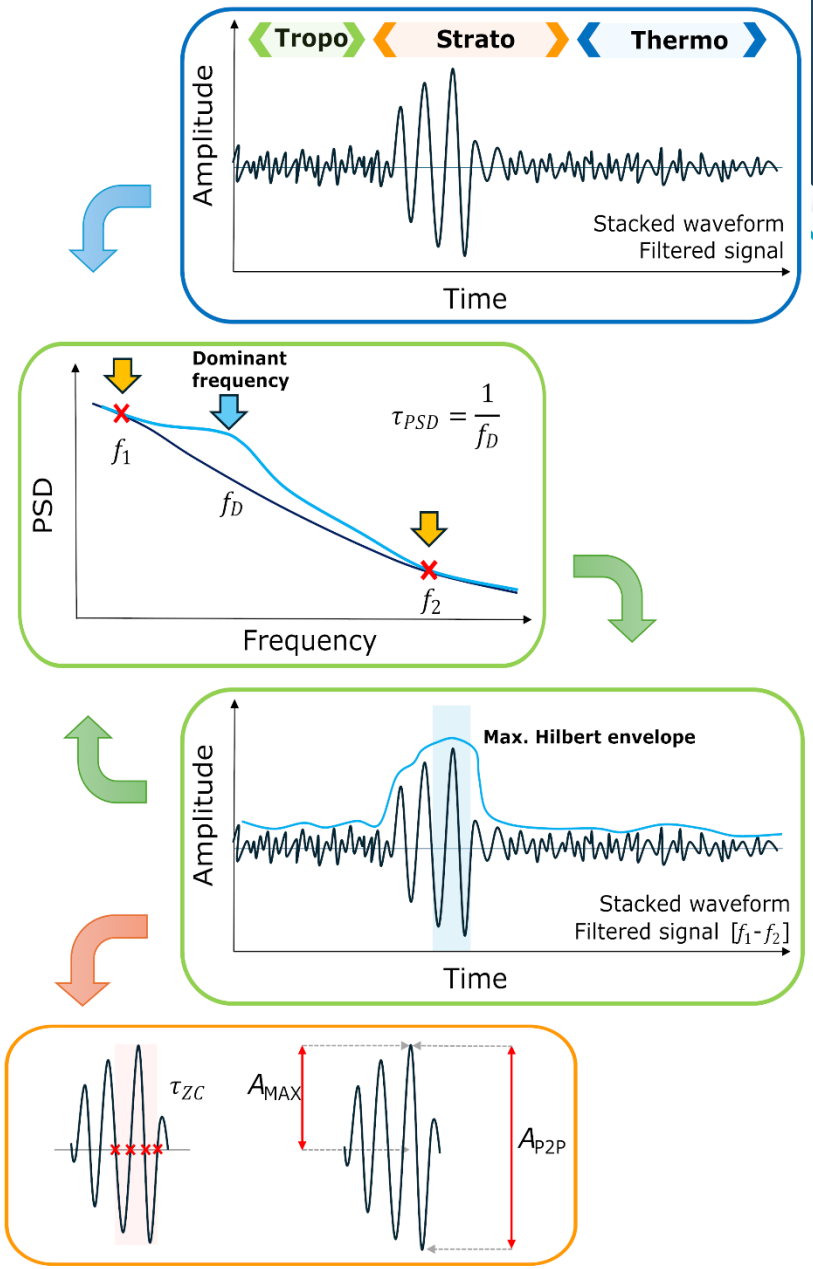
PROPAGATION MODELING





ENERGY ESTIMATE

- CNEOS derived energy from USG data: 7.2 kt of TNT equivalent
- Dominant signal period measured across infrasound stations can be utilized for estimating yield of a bolide
- We used the empirical energy relation from ReVelle (1997): log (E/2) = 3.34 log(T) – 2.58
- Fragmentation / airburst vs. cylindrical line source (shock geometry and size of blast radius are significantly different)
- Energy estimate from average signal period
  - 3.5 – 7.5 kt of TNT (ReVelle 1997)
  - 4.6 – 10.9 kt of TNT (Ens et al. 2012)
  - 13 – 30.3 kt of TNT (Gi & Brown 2017)
- Energy derived from various empirical relations can exhibit large uncertainties. In this case, infrasound-derived energy is in good agreement with the USG sensor-derived energy



SUMMARY

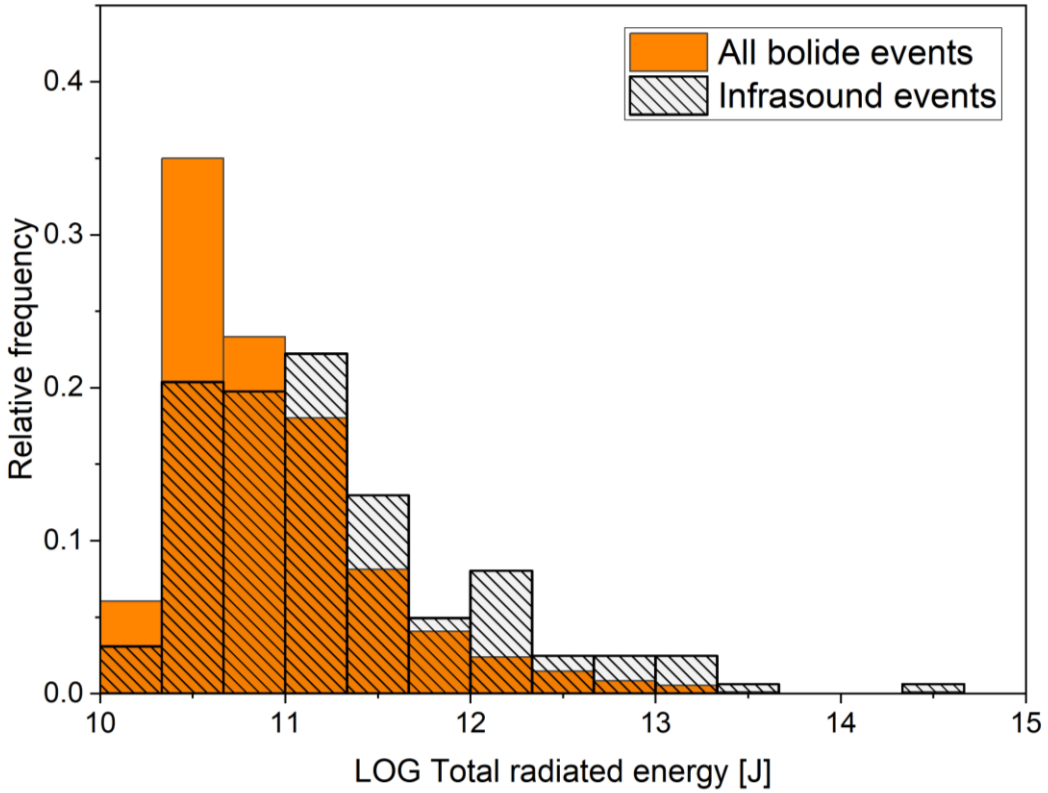
- The Australian bolide was detected from space and ground
- One of the most energetic events detected by USG sensors and the most energetic over Australia
- Different observational methods and theoretical approaches can complement each other
- Multi-modal sensing enables better characterization, and cross-validation
- Good agreement between energy estimate derived through infrasound detections and USG sensors

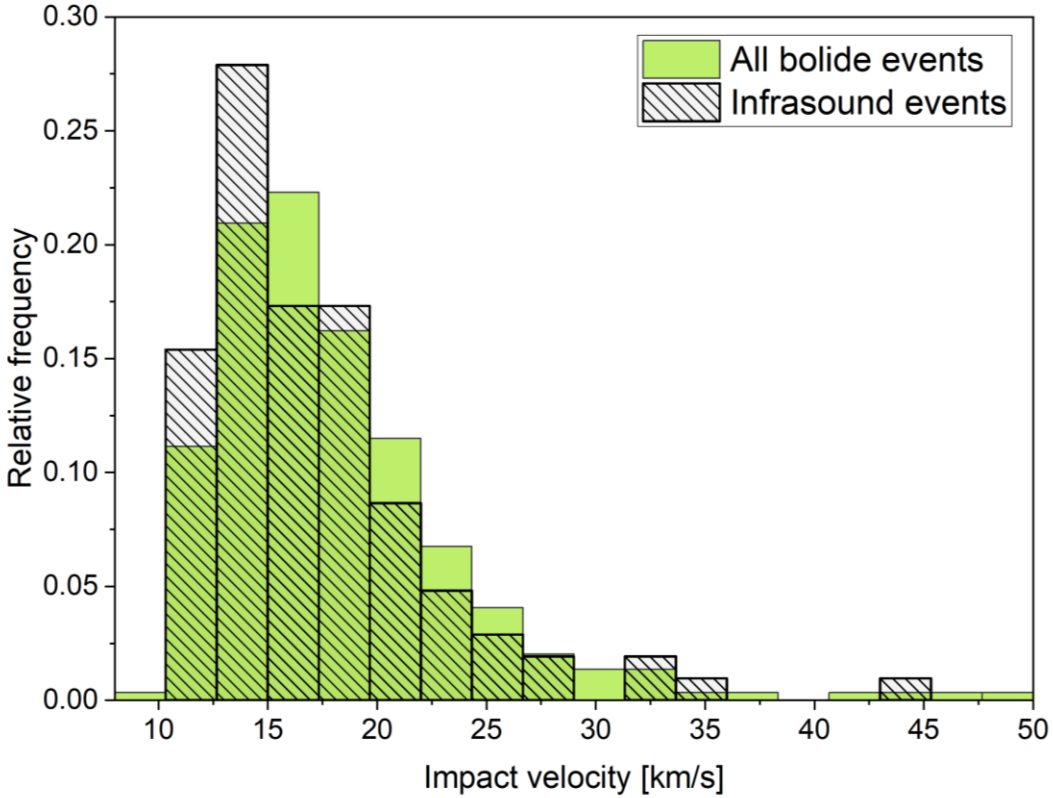
- Stay tuned for a publication

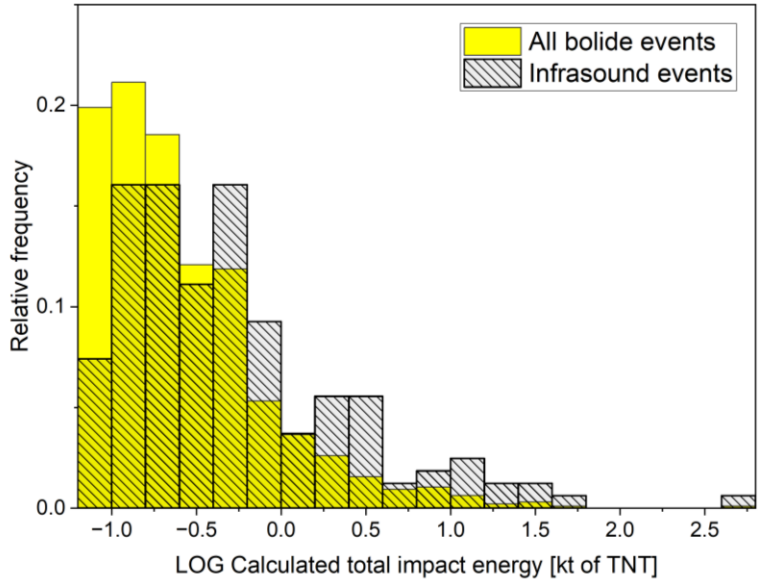
ACKNOWLEDGEMENTS

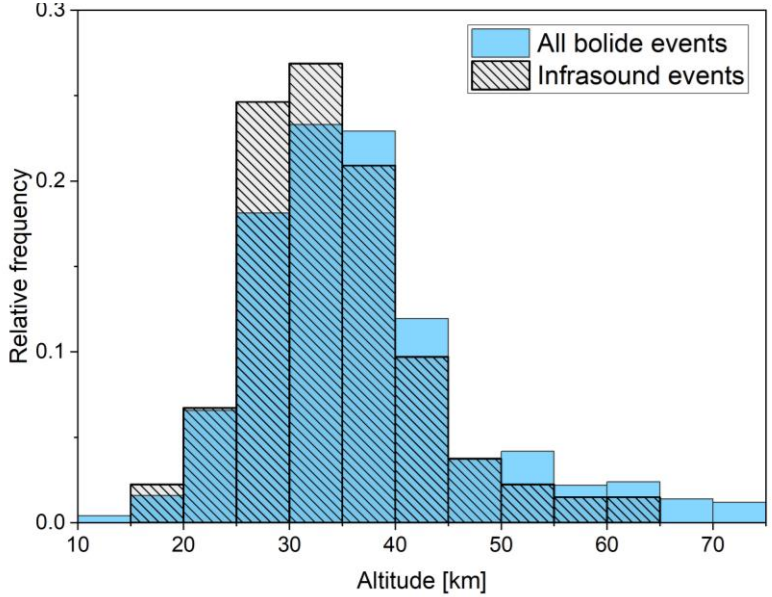
Sandia National Laboratories is a multimission laboratory operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

EXTRA SLIDES


All bolide events
Infrasound events
Relative frequency
LOG Total radiated energy [J]


All bolide events
Infrasound events
Relative frequency
Impact velocity [km/s]


All bolide events
Infrasound events
Relative frequency
LOG Calculated total impact energy [kt of TNT]


All bolide events
Infrasound events
Relative frequency
Altitude [km]