Fragmented Asteroid Airburst Ground Effects

Custom C++ Code for shockwave and optical pulse modeling

Extremely promising

Overview

- The Acoustical effects of these blasts are modeled using the Friedlander blast propagation equation :

$$P = P_0 e^{-t/t_0} \left(1 - \frac{t}{t_0}\right)$$

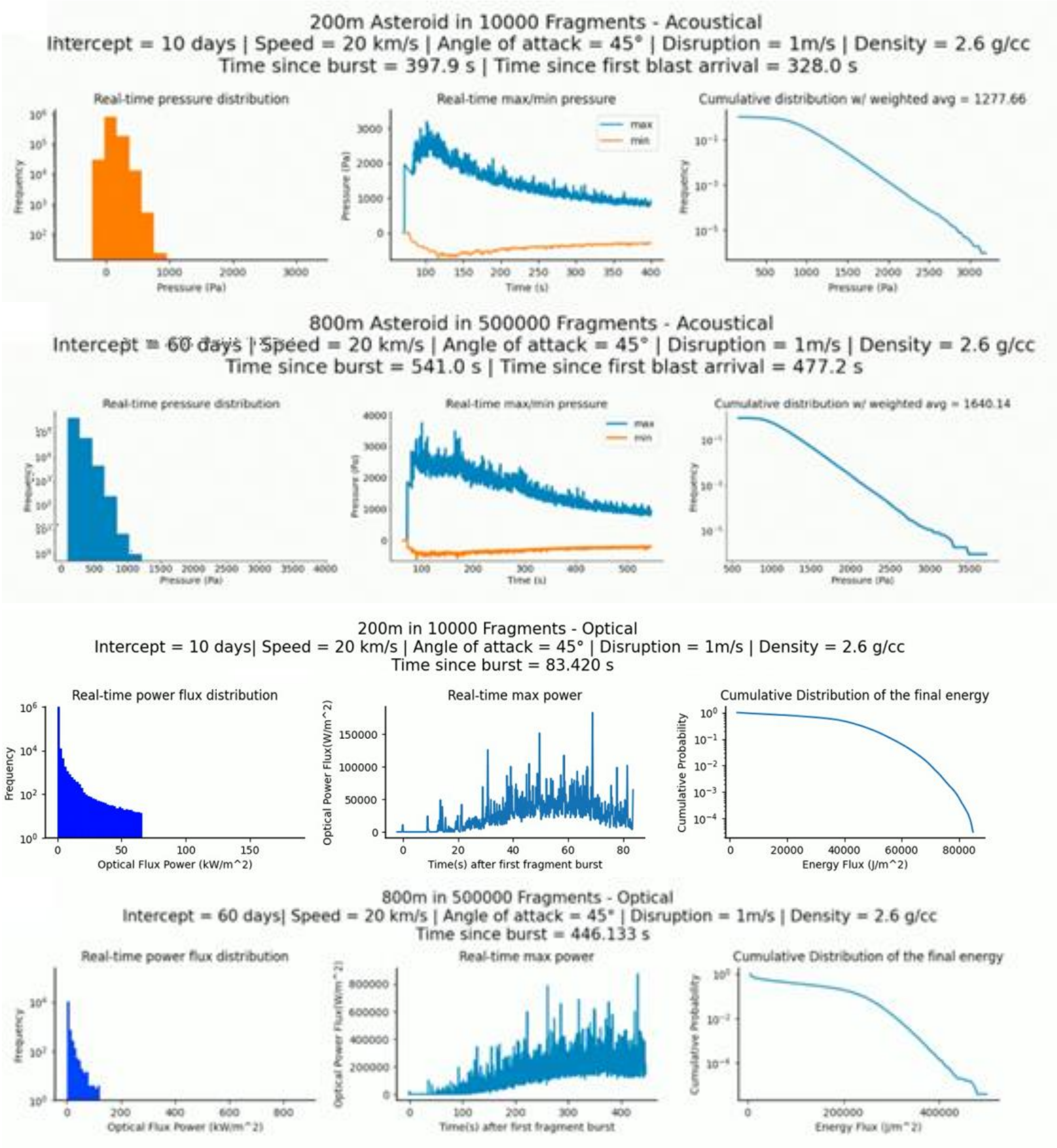
- The Time Decay constant (t_0) is extrapolated from nuclear data as a function of overpressure at any given location:

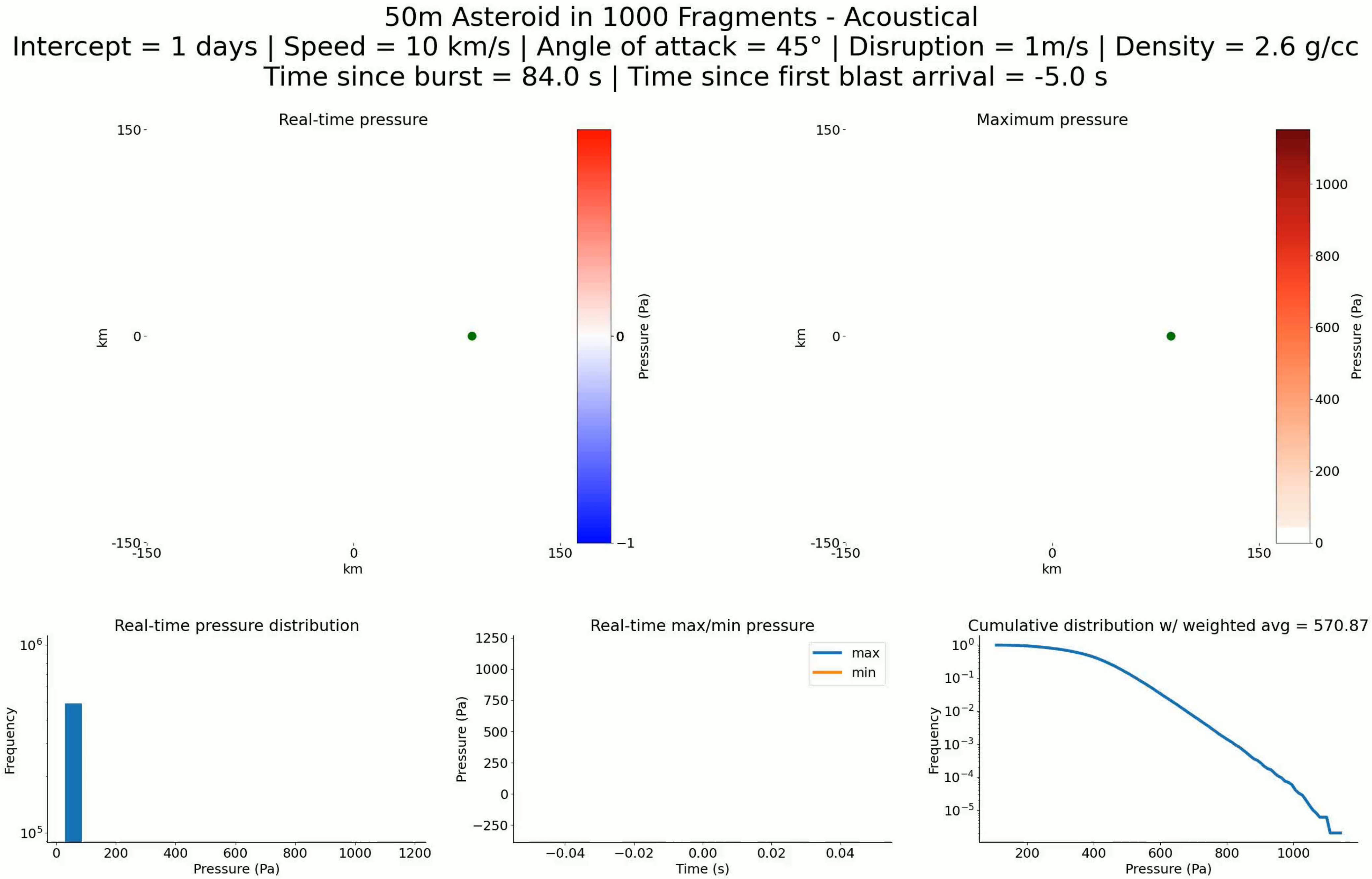
$$t_0 \begin{cases} -0.07755 \ln(P_0) + 1.051 & P < 200\,kPa \\ 0.01246 \ln(P_0) - 0.07758 & P > 200\,kPa \end{cases}$$

- The Overpressures(P_0) for any given location is calculated using the following equation:

$$P_0 = p_n \left[r(E_{ast-kt}/\epsilon)^{-1/3} \right]^{\alpha_n} + p_f \left[r(E_{ast-kt}/\epsilon)^{-1/3} \right]^{\alpha_f}$$

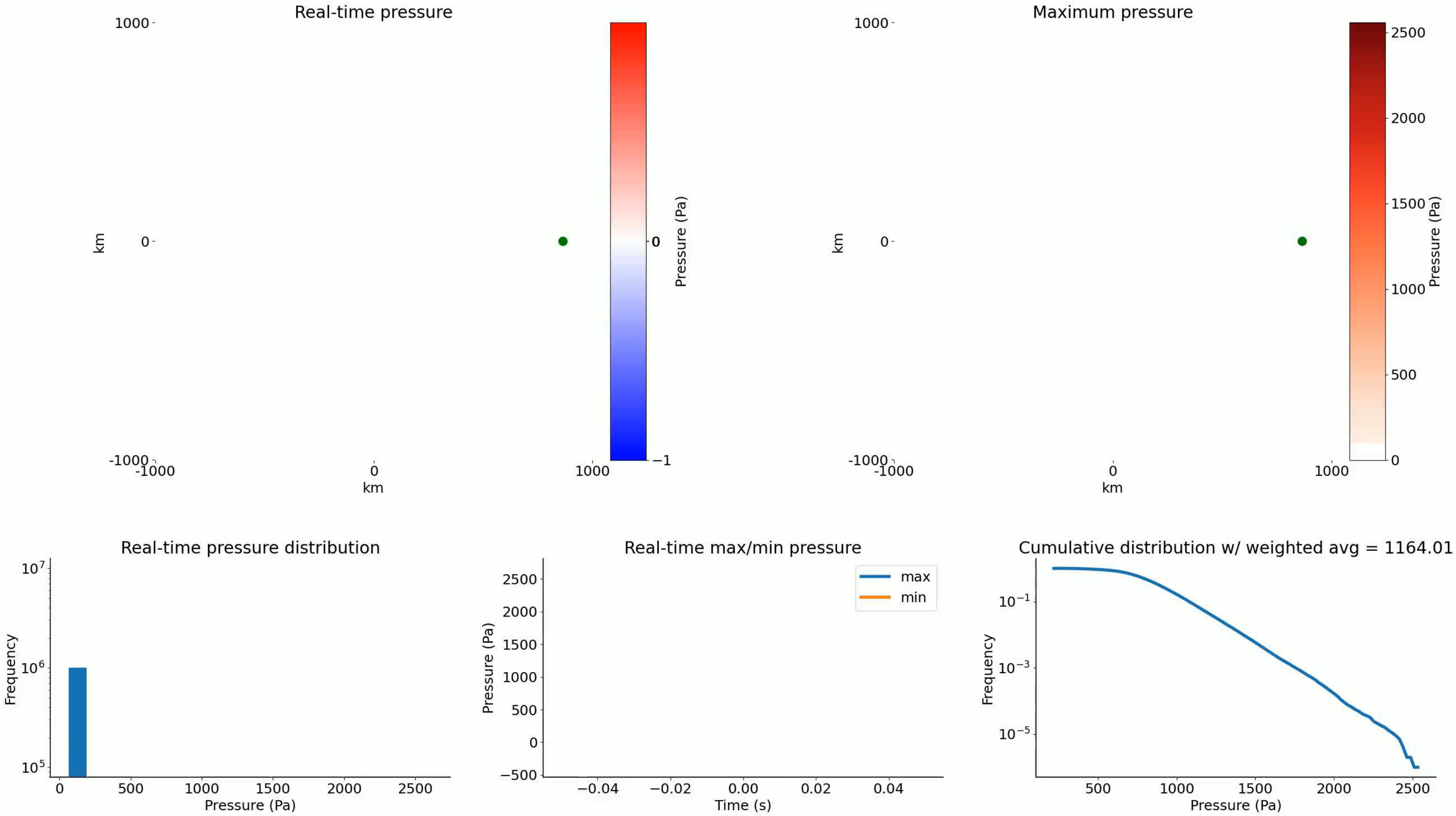
- The Optical pulses are calculated for each fragment including atmospheric propagation for every path
- For the Acceptable Threshold we chose ~2 kPa of acoustical pressure and ~0.2 MJ/m^2. These values represent the average strength of commercial windows and the approximate energy at which grass catches fire.
- Examples shown for 200 meter with 10 day prior and 800 meter with 60 day prior, both with 20 km/s. These are extremely aggressive intercepts. **Longer time scale intercepts are always desired and have less ground effects.** Mean fragment size is ~10m. **Smaller mean fragment sizes are even better and have less ground effects.**

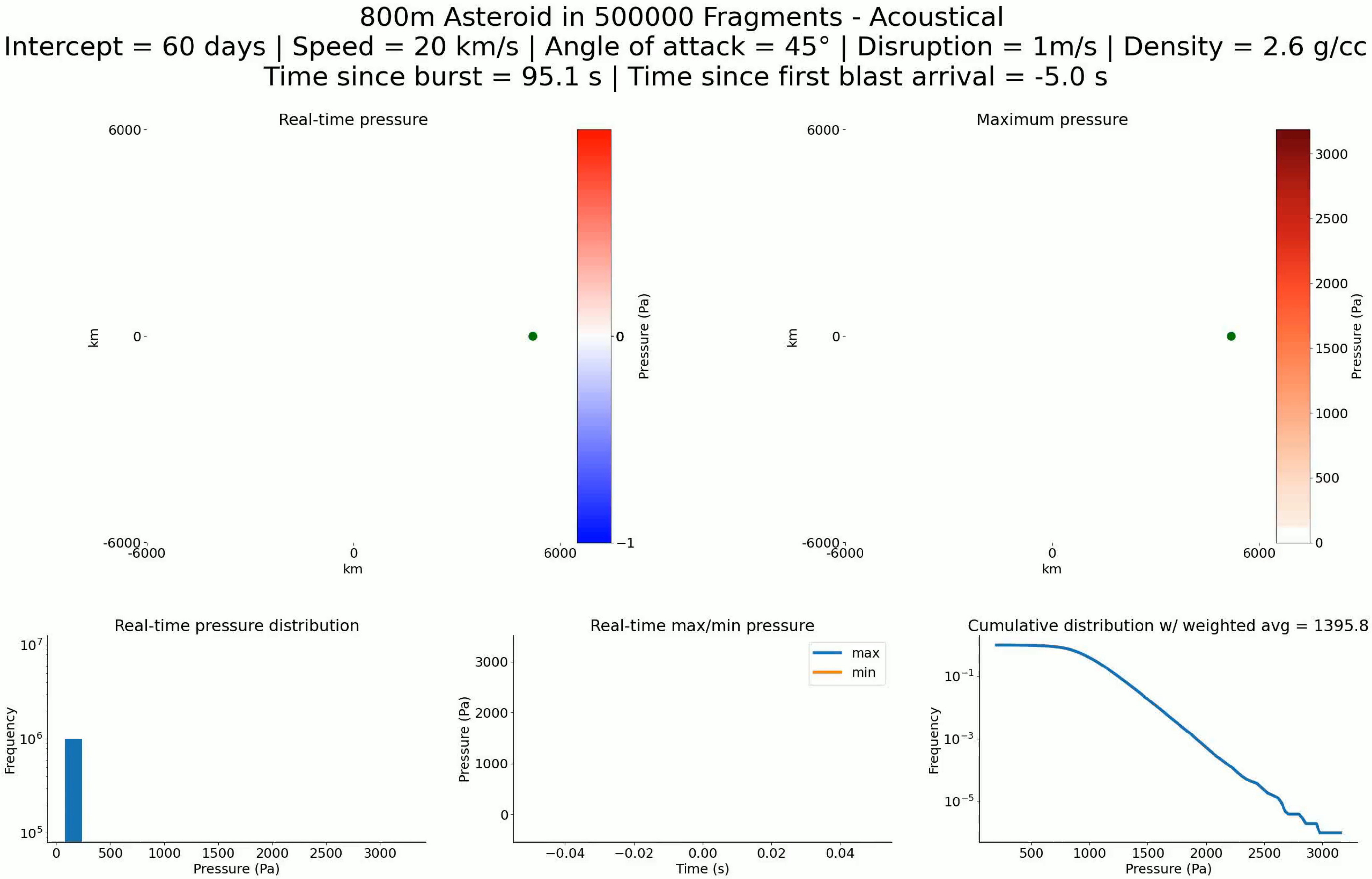


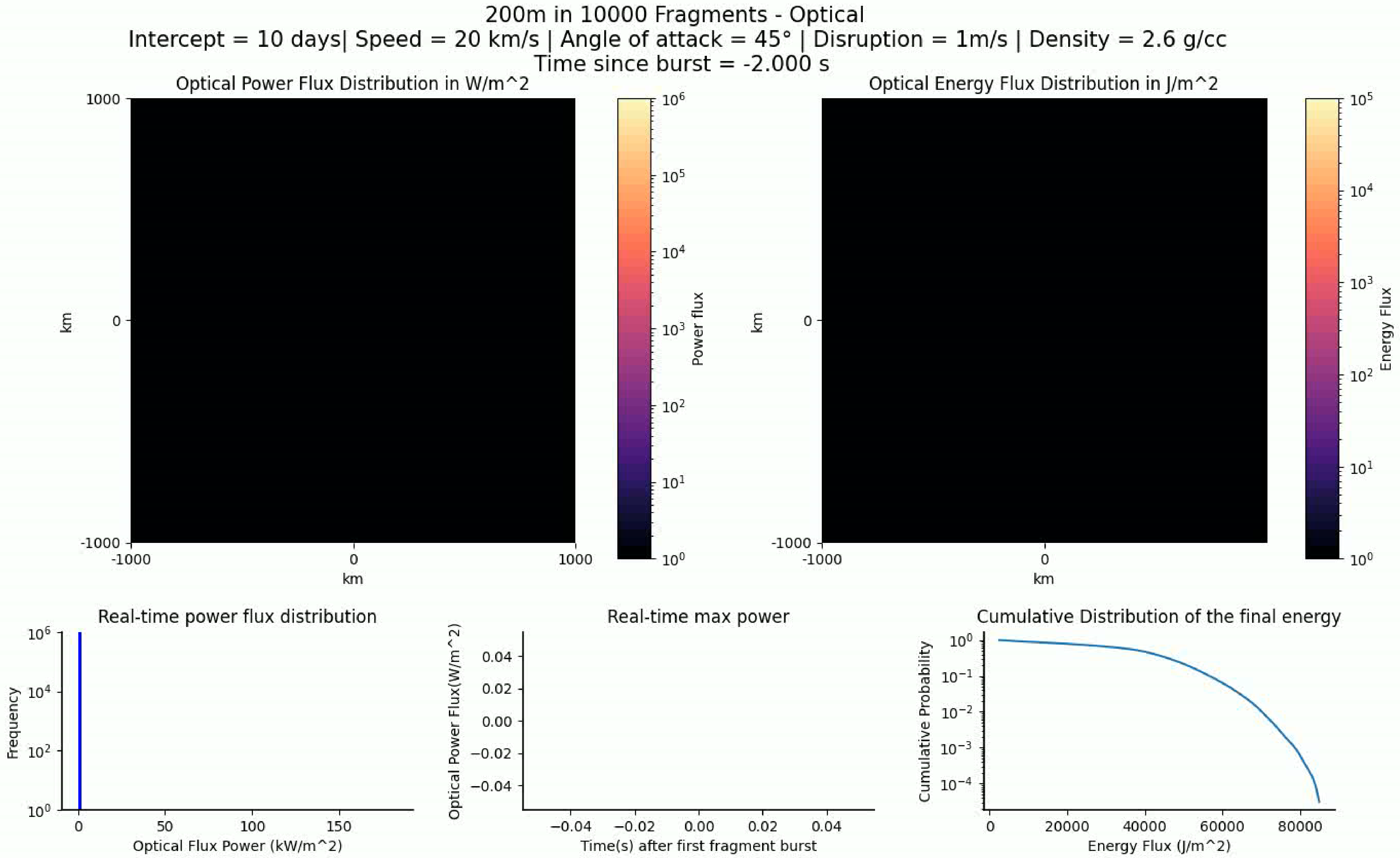


50m Asteroid in 1000 Fragments - Acoustical
Intercept = 1 days | Speed = 10 km/s | Angle of attack = 45° | Disruption = 1m/s | Density = 2.6 g/cc
Time since burst = 84.0 s | Time since first blast arrival = -5.0 s
Real-time pressure
Pressure (Pa)
km
Maximum pressure
Pressure (Pa)
km
Real-time pressure distribution
Frequency
Pressure (Pa)
Real-time max/min pressure
max
min
Pressure (Pa)
Time (s)
Cumulative distribution w/ weighted avg = 570.87
Frequency
Pressure (Pa)

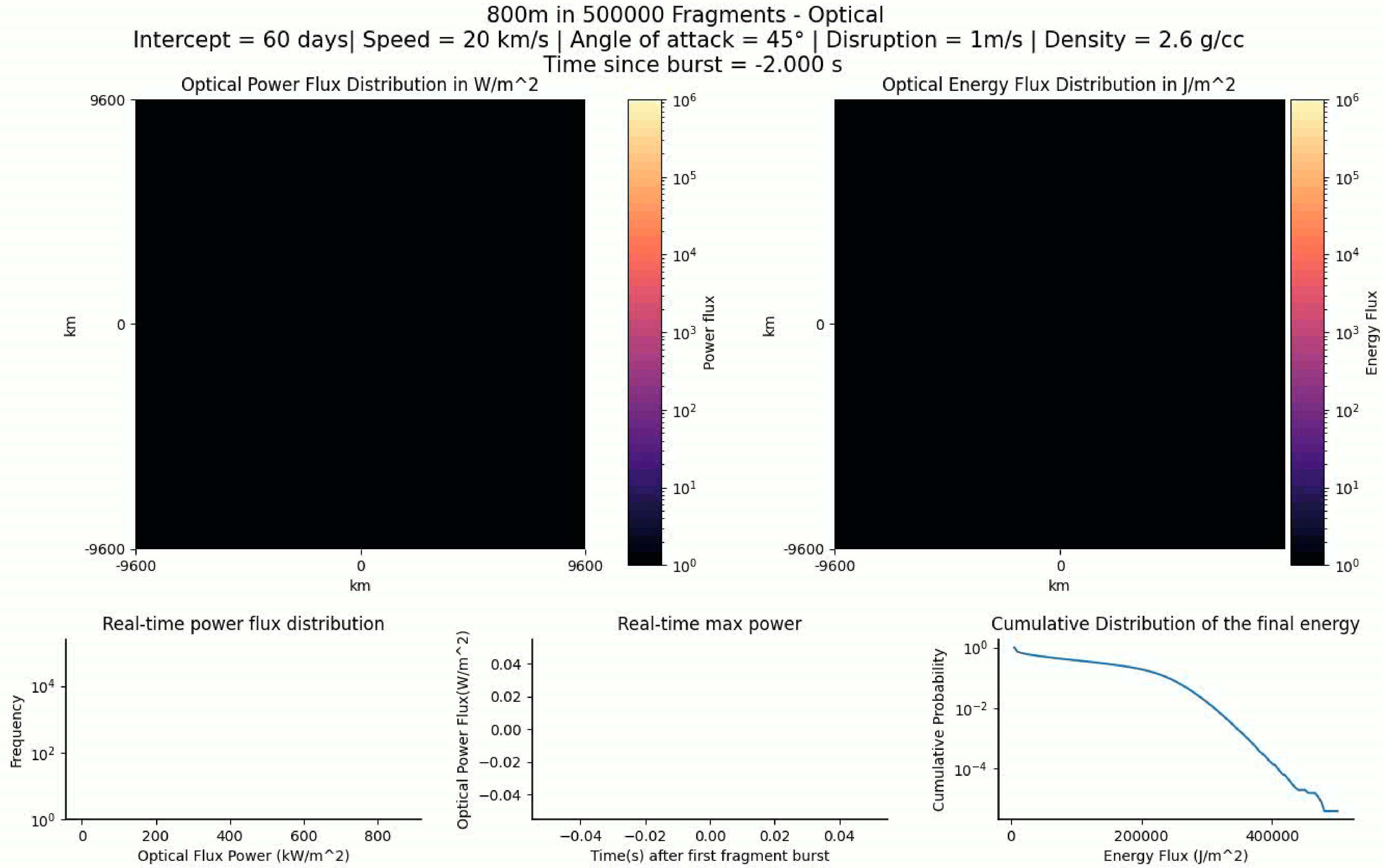
200m Asteroid in 10000 Fragments - Acoustical
Intercept = 10 days | Speed = 20 km/s | Angle of attack = 45° | Disruption = 1m/s | Density = 2.6 g/cc
Time since burst = 65.2 s | Time since first blast arrival = -5.0 s




800m Asteroid in 500000 Fragments - Acoustical
Intercept = 60 days | Speed = 20 km/s | Angle of attack = 45° | Disruption = 1m/s | Density = 2.6 g/cc
Time since burst = 95.1 s | Time since first blast arrival = -5.0 s
Real-time pressure
Maximum pressure
km
Pressure (Pa)
6000
0
-6000
0
-1
3000
2500
2000
1500
1000
500
Real-time pressure distribution
Frequency
Pressure (Pa)
Real-time max/min pressure
max
min
Time (s)
−0.04
−0.02
0.00
0.02
0.04
Cumulative distribution w/ weighted avg = 1395.8



200m in 10000 Fragments - Optical
Intercept = 10 days| Speed = 20 km/s | Angle of attack = 45° | Disruption = 1m/s | Density = 2.6 g/cc
Time since burst = -2.000 s
Optical Power Flux Distribution in W/m^2
Power flux
Optical Energy Flux Distribution in J/m^2
Energy Flux
km
1000
0
-1000
Real-time power flux distribution
Frequency
Optical Flux Power (kW/m^2)
Real-time max power
Optical Power Flux(W/m^2)
Time(s) after first fragment burst
Cumulative Distribution of the final energy
Cumulative Probability
Energy Flux (J/m^2)


800m in 500000 Fragments - Optical
Intercept = 60 days| Speed = 20 km/s | Angle of attack = 45° | Disruption = 1m/s | Density = 2.6 g/cc
Time since burst = -2.000 s
Optical Power Flux Distribution in W/m^2
Optical Energy Flux Distribution in J/m^2
9600
0
-9600
km
Power flux
Energy Flux
Real-time power flux distribution
Frequency
Optical Flux Power (kW/m^2)
Real-time max power
Optical Power Flux(W/m^2)
Time(s) after first fragment burst
Cumulative Distribution of the final energy
Cumulative Probability
Energy Flux (J/m^2)

Conclusions

- **Threat mitigation feasible with as little as 60 days intercept before impact for 800m and lower for smaller diameters.**
- Pressures under 2 kPa and optical flux under 0.2 MJ/m^2.
- **Little to no damage from threats as large as a kilometer, PDC 2023 threat (800m) can be managed with minimal ground effects with an intercept time > 60 days (1 m/s mean disruption speed)**
- **Note that the product of the intercept time and the mean disruption speed is the key metric as it sets the fragment cloud size. We choose a modest 1 m/s mean disruption speed in the models shown.**