



# Airburst & Blast Damage Risk Modeling Trends for the PDC25 Impact Scenario

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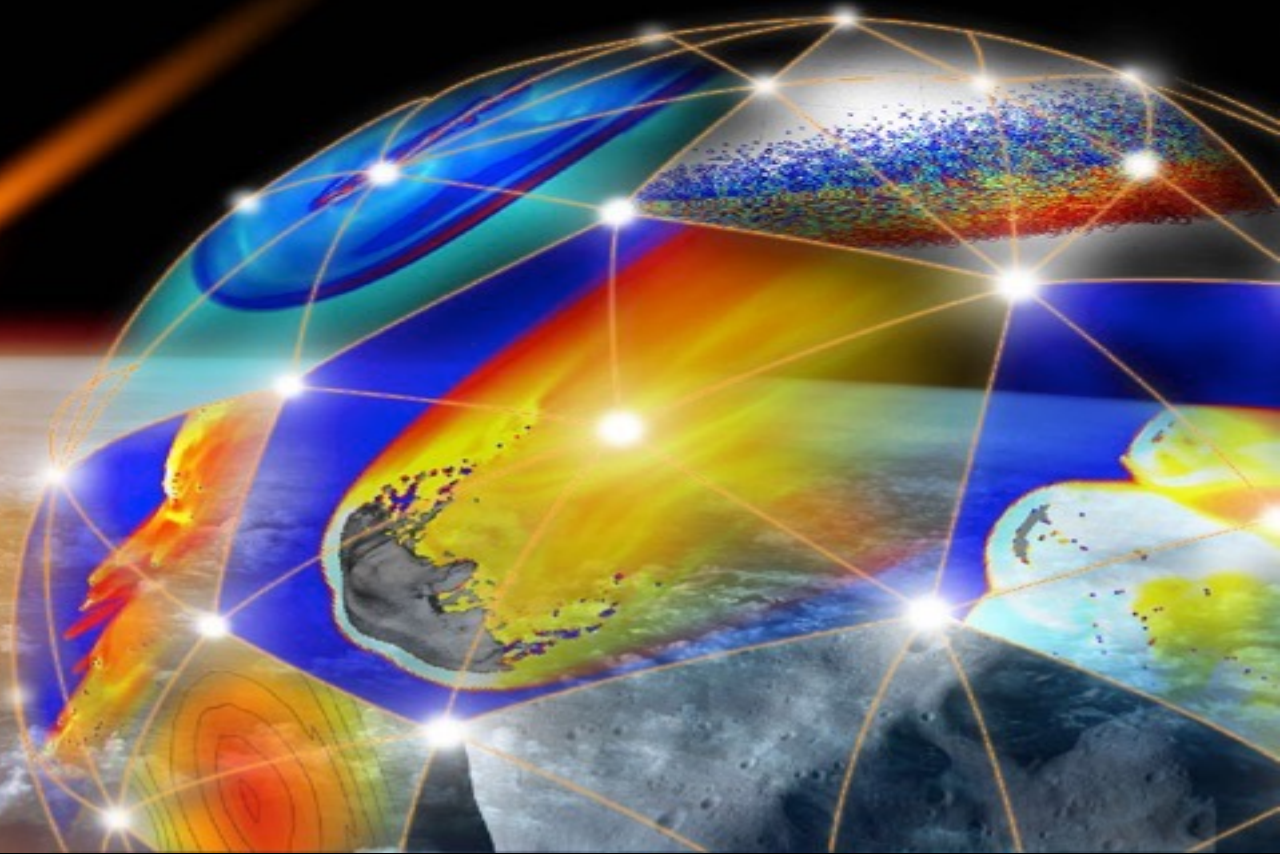
Michael Aftosmis, Wade Spurlock,  
Ashley Coates, Jessie Dotson

**Asteroid Threat Assessment Project (ATAP)**

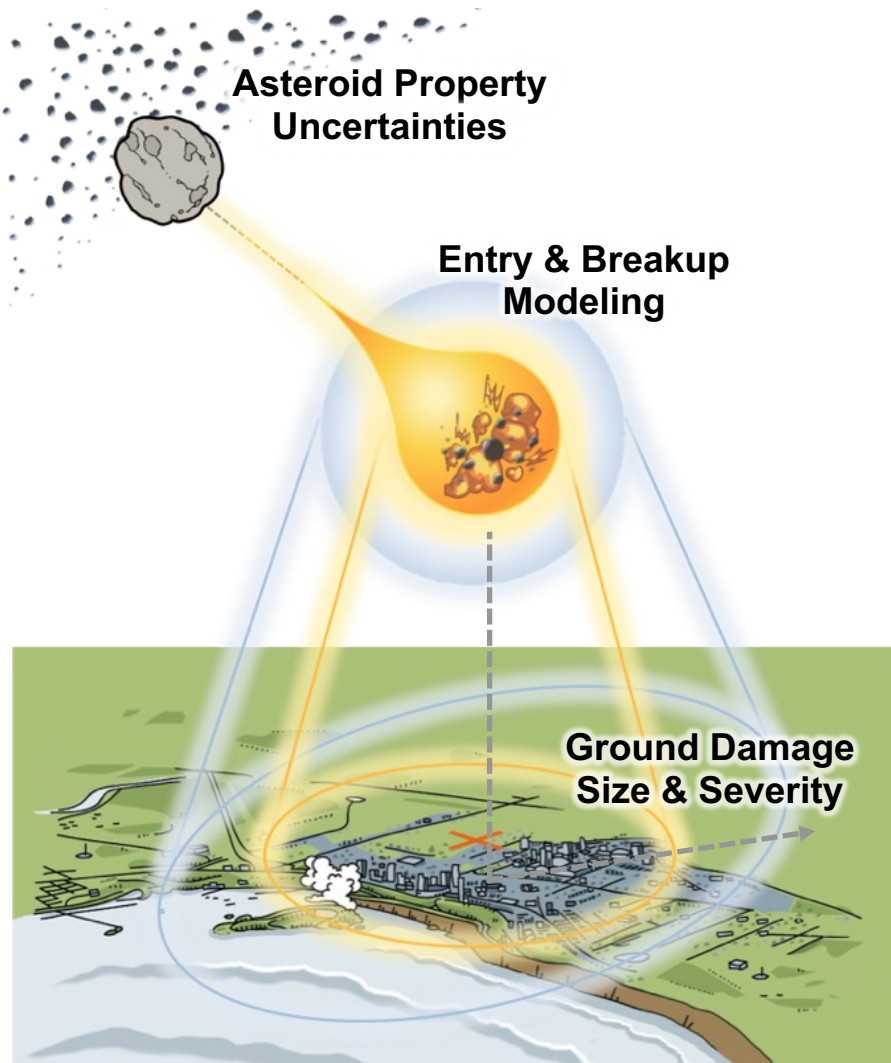
NASA Ames Research Center

**9<sup>th</sup> AIAA Planetary Defense Conference**

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# Airburst & Blast Damage Risk Study



Using the Probabilistic Asteroid Impact Risk (PAIR) model to investigate airburst and blast damage trends for the 2024 PDC25 hypothetical impact scenario

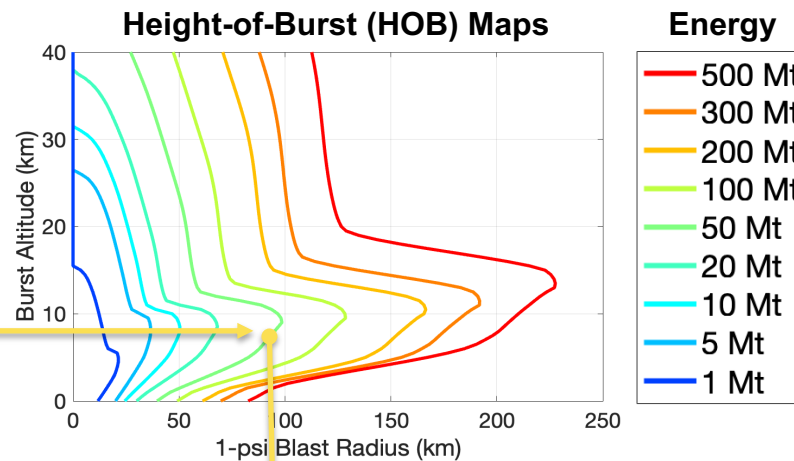
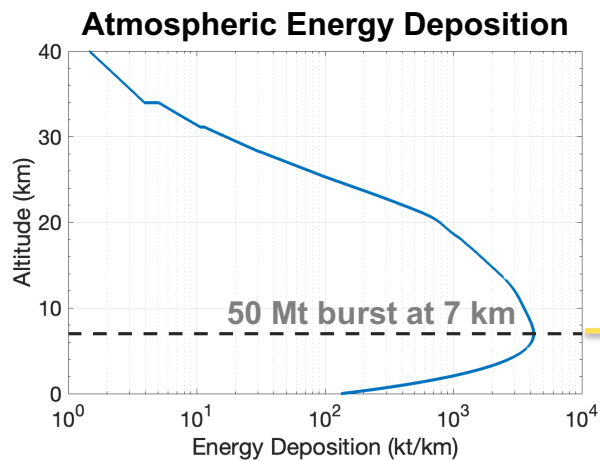
- Effects of current height-of-burst (HOB) blast damage modeling factors on damage trends
- Sensitivity to entry and airburst altitude variations
- Which sizes or properties drive the greatest damage

**Probabilistic Asteroid Impact Risk (PAIR) Model**



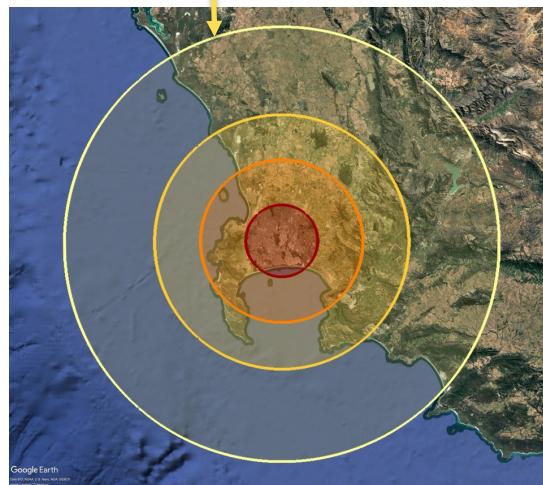
# PAIR Blast Damage Model

PAIR evaluates blast damage using simulation-enhanced Height-of-Burst (HOB) maps with effective airburst altitudes from entry modeling



- Height-of-burst (HOB) maps give blast footprint sizes based on asteroid energy and effective burst altitude
- Four blast severity levels modeled

- Entry and breakup modeled for each probabilistic impact case
- Effective burst altitude determined from energy deposition peak
- Depends on asteroid properties, entry trajectory, and breakup modeling parameters



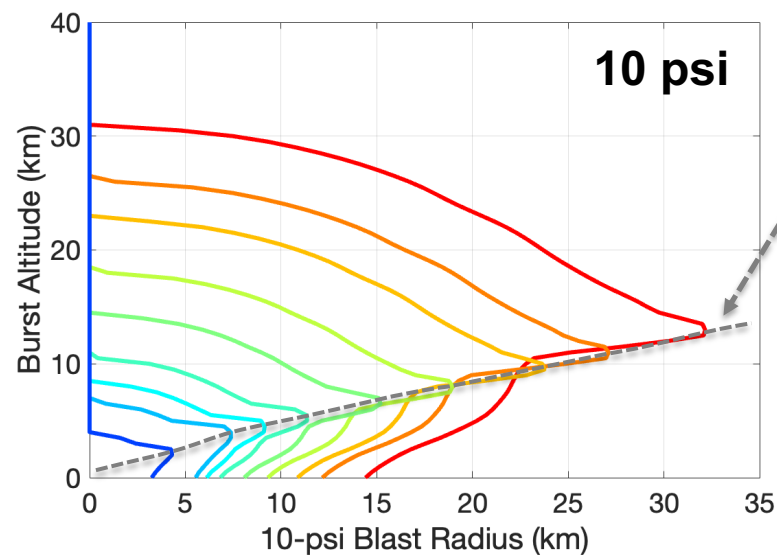
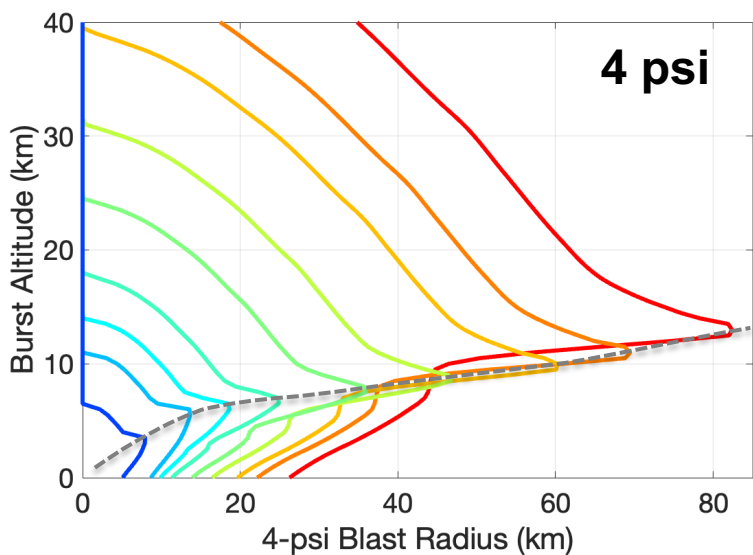
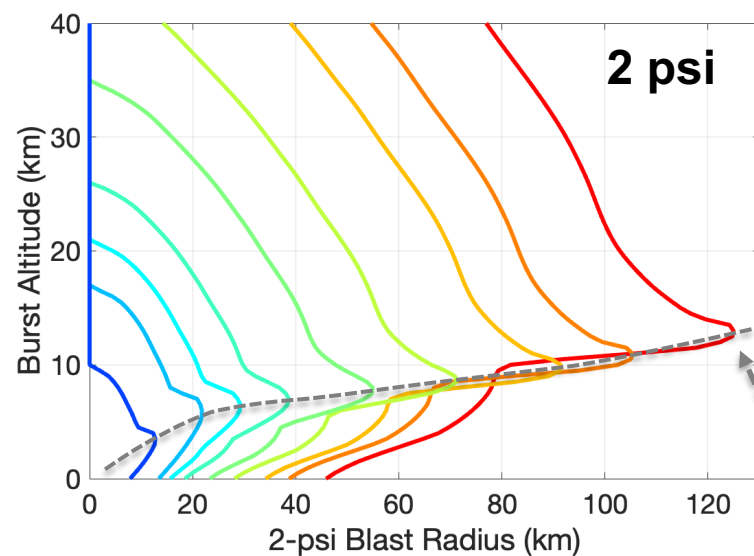
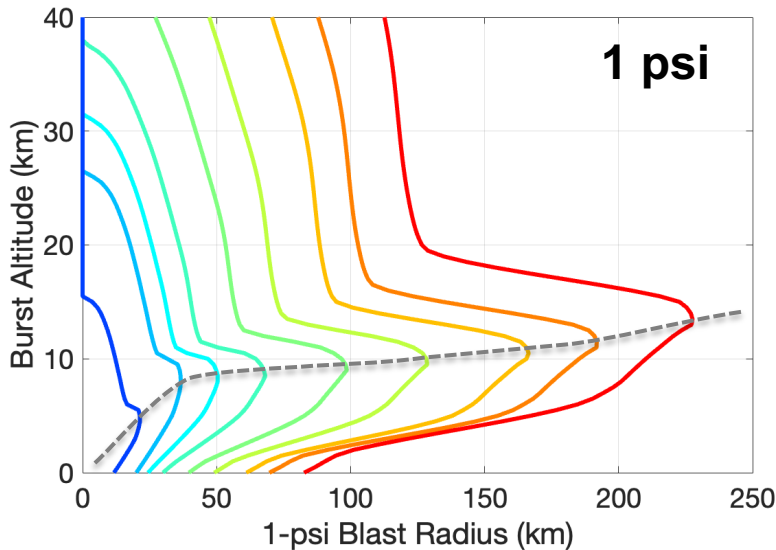
PAIR Blast Damage Severity Levels

Damage Level	Overpressure Threshold	Relative Severity	Damage Effects
<b>Serious</b>	1 psi	10%	Window breakage, some structure damage
<b>Severe</b>	2 psi	30%	Widespread structural damage
<b>Critical</b>	4 psi	60%	Most residential structures collapse
<b>Unsurvivable</b>	10 psi	100%	Complete devastation



# PAIR Simulation-Enhanced HOB Maps

PAIR HOB maps for four blast overpressure levels



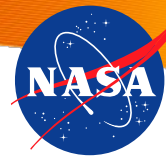
Energy

- 500 Mt
- 300 Mt
- 200 Mt
- 100 Mt
- 50 Mt
- 20 Mt
- 10 Mt
- 5 Mt
- 1 Mt

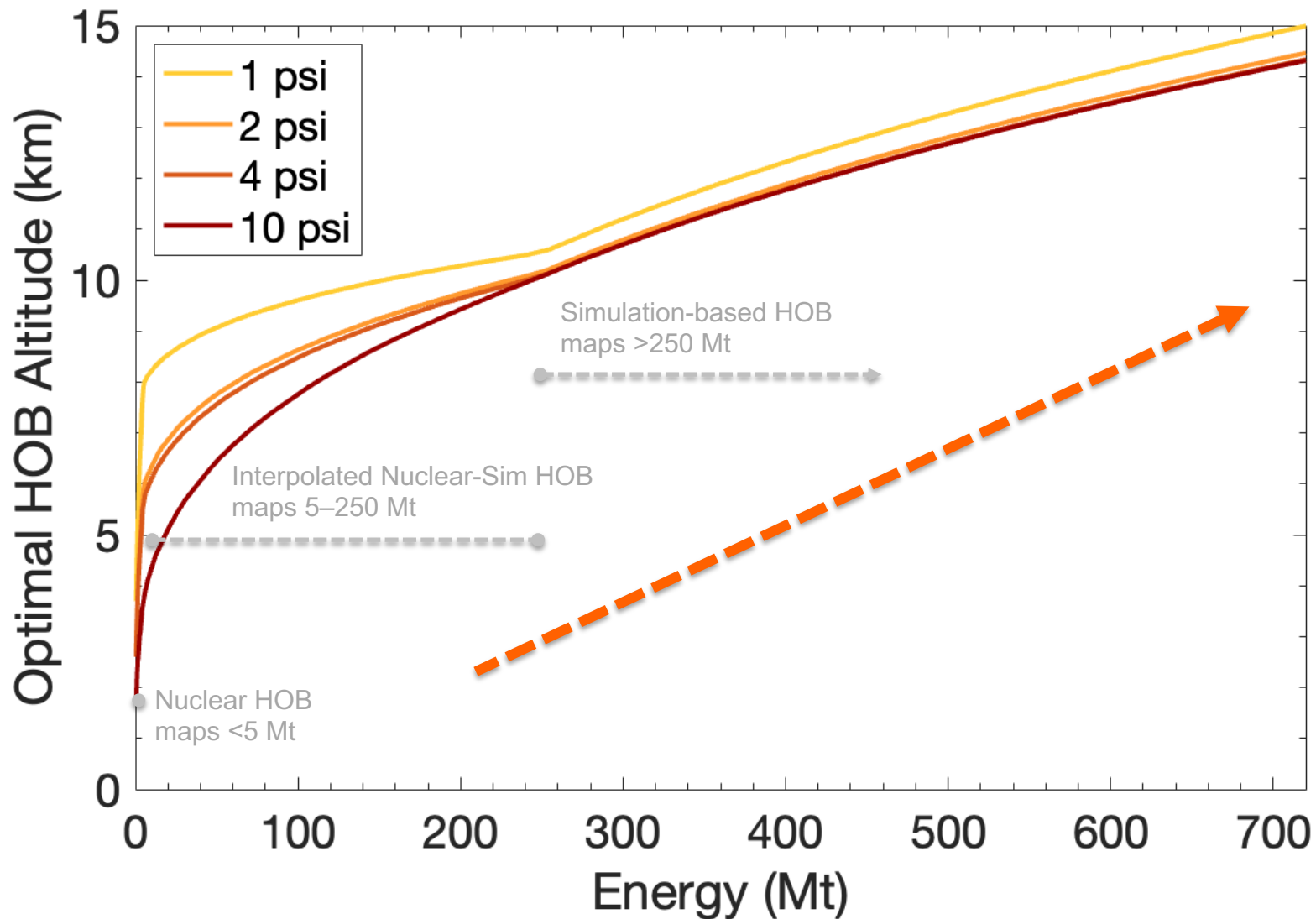
**PAIR blast model** uses simulation-based maps for energies > 250 Mt, nuclear HOB maps for energies < 5 Mt

**“Optimal” HOB:**

**Worst-case** airburst altitude causing **largest ground damage** extent for a given energy and overpressure level



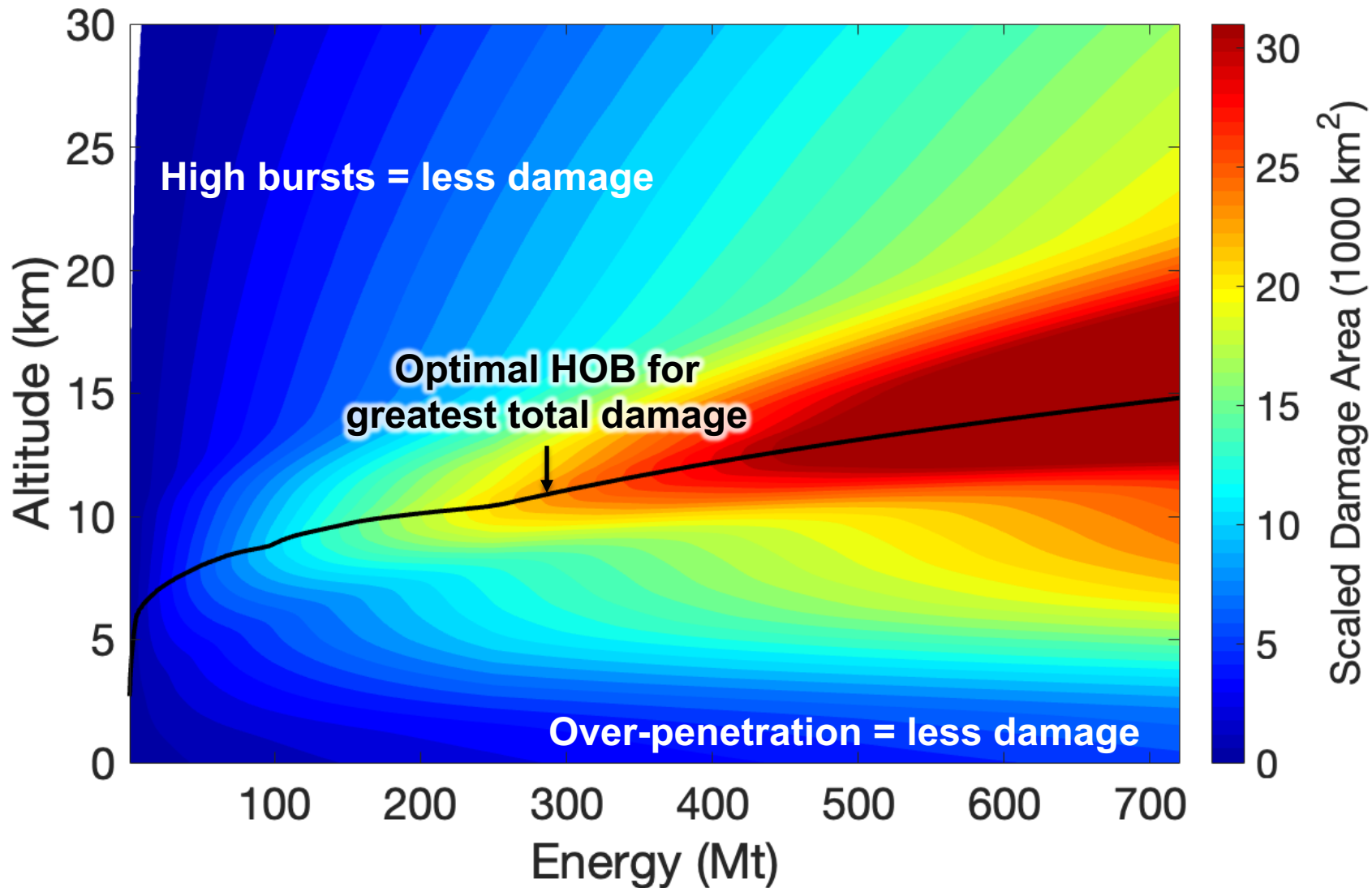
# PAIR Optimal Height of Burst (HOB) by Energy



- Optimal (worst-case) HOB increases with energy
- Larger cases must burst higher to do maximal damage



# Total Severity-Scaled Damage



**Total effective damage area from all blast levels, scaled by relative severity**

- 10% 1 psi (serious) area
- 30% 2 psi (severe) area
- 60% 4 psi (critical) area
- 100% 10 psi (unsurvivable) area

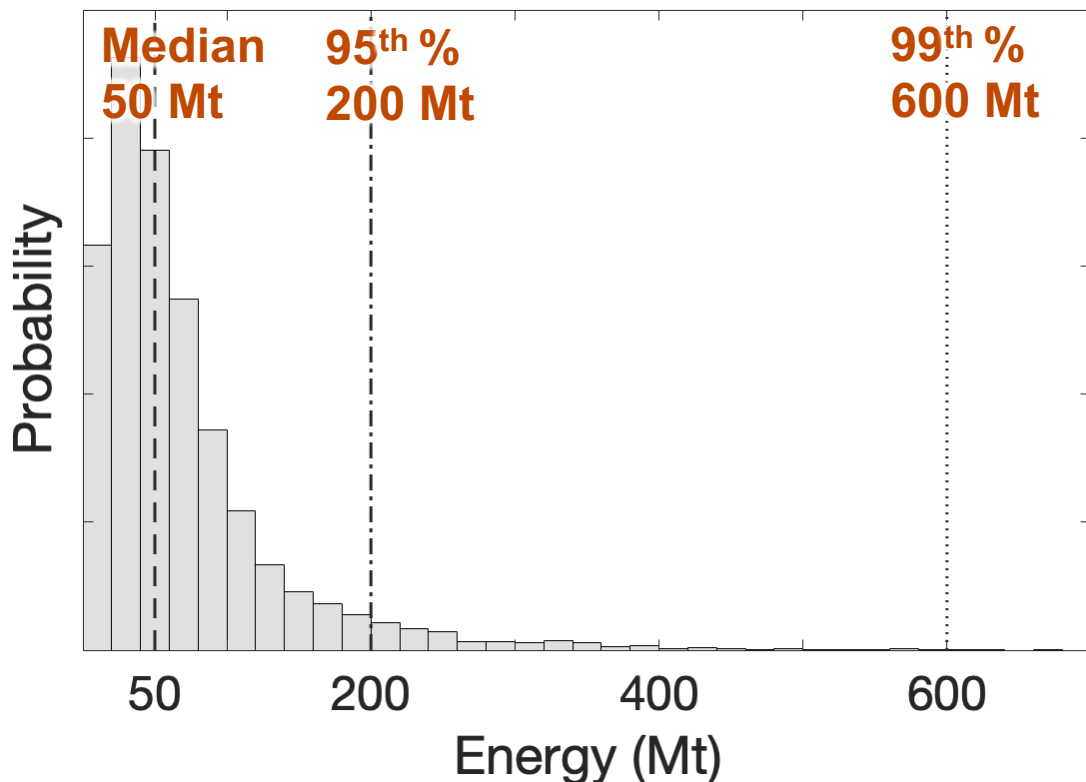
$$A_s = 0.1(A_{1psi}) + 0.3(A_{2psi}) + 0.6(A_{4psi}) + 1(A_{10psi})$$



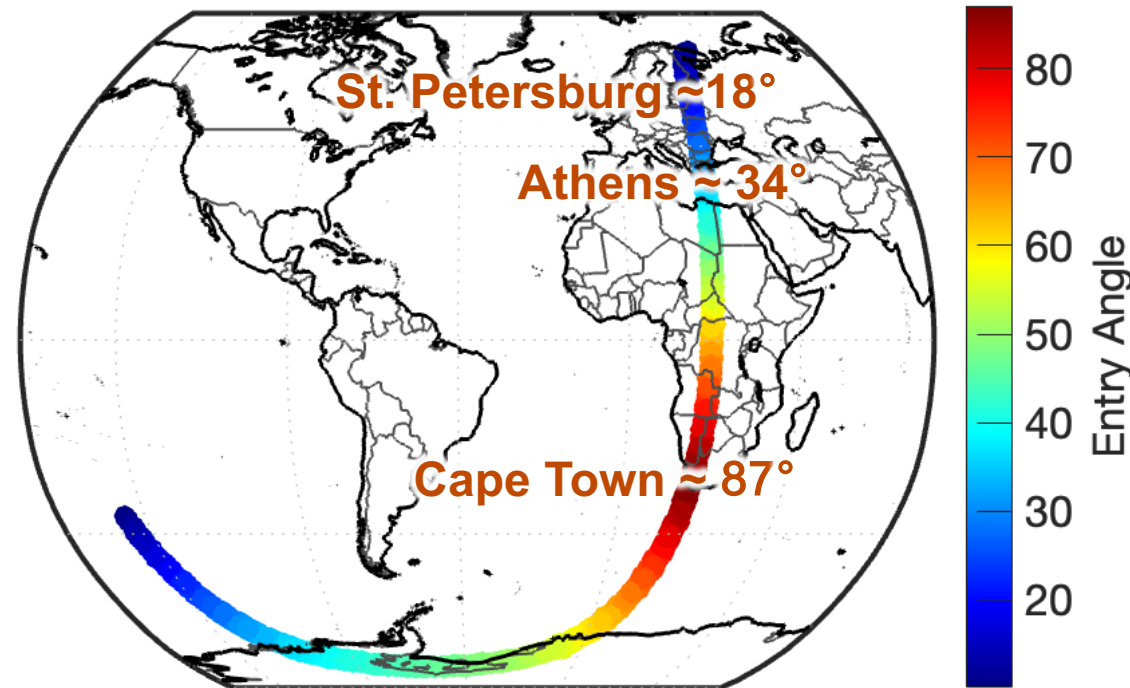
# PDC25 Epoch 1 Asteroid Size & Entry Ranges

Early JWST data constrained asteroid size & type, but there is still a large range of possible impact energies and long uncertain impact corridor with full range of entry angles

**Asteroid Energy Ranges**



**Entry Angle (from horizontal)**



[Property inference model: J. Dotson et al., 2024]

[Impact entry data: D. Farnocchia, CNEOS/JPL, <https://cneos.jpl.nasa.gov/pd/cs/pdc25/>]

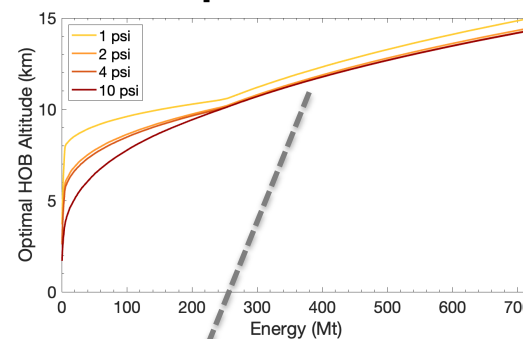


# Airburst & Total Blast Damage Trends among PDC25 Cases

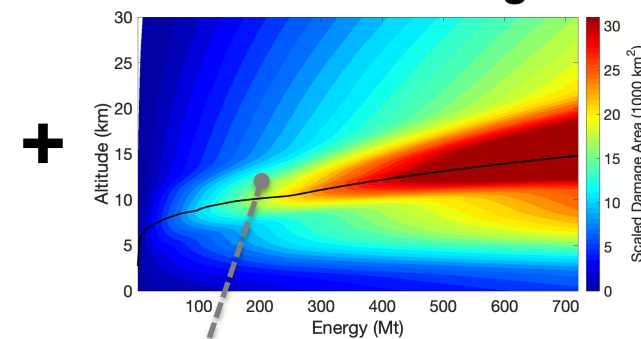
Energy and burst altitude of all asteroid cases modeled, colored by total blast damage

- PDC25 Cases
- Scaled optimal
- 1-psi optimal
- 10-psi optimal

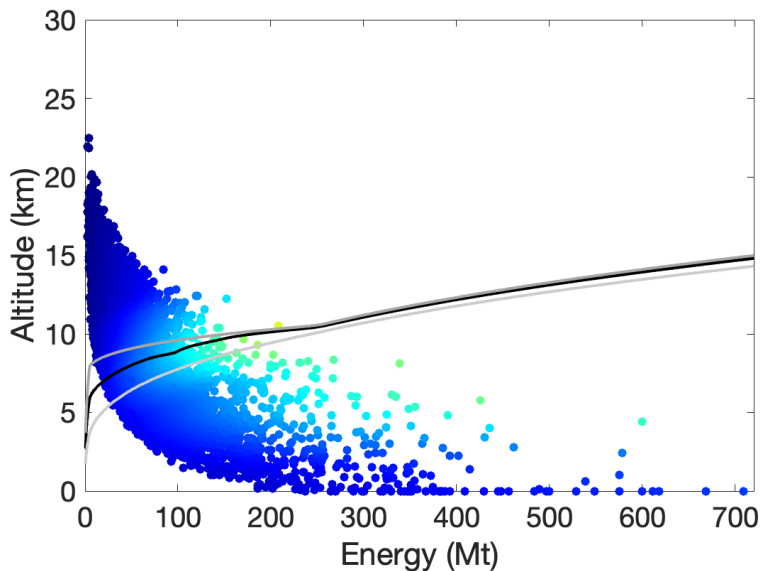
Optimal HOB



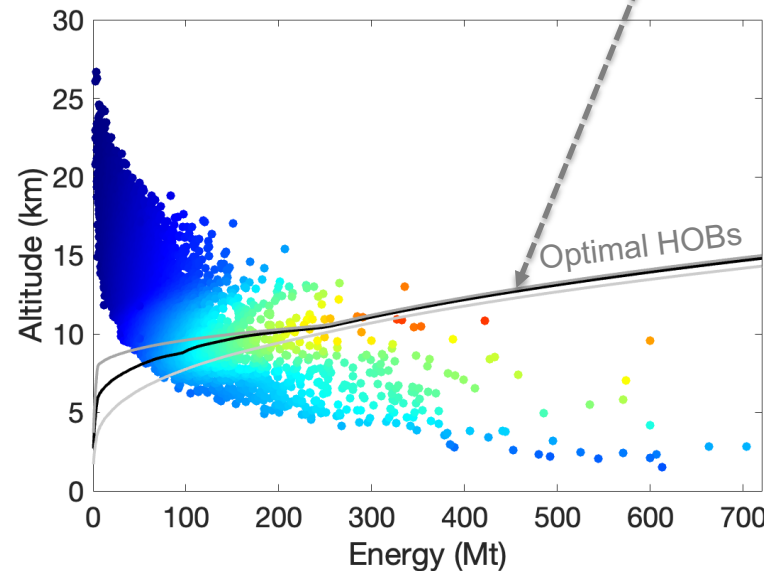
Total Blast Damage



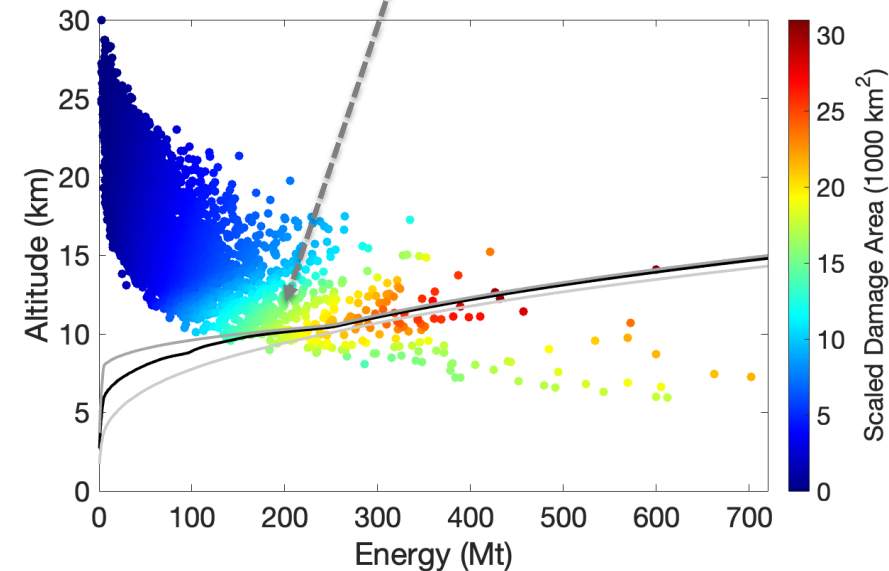
Cape Town (87°)



Athens (34°)

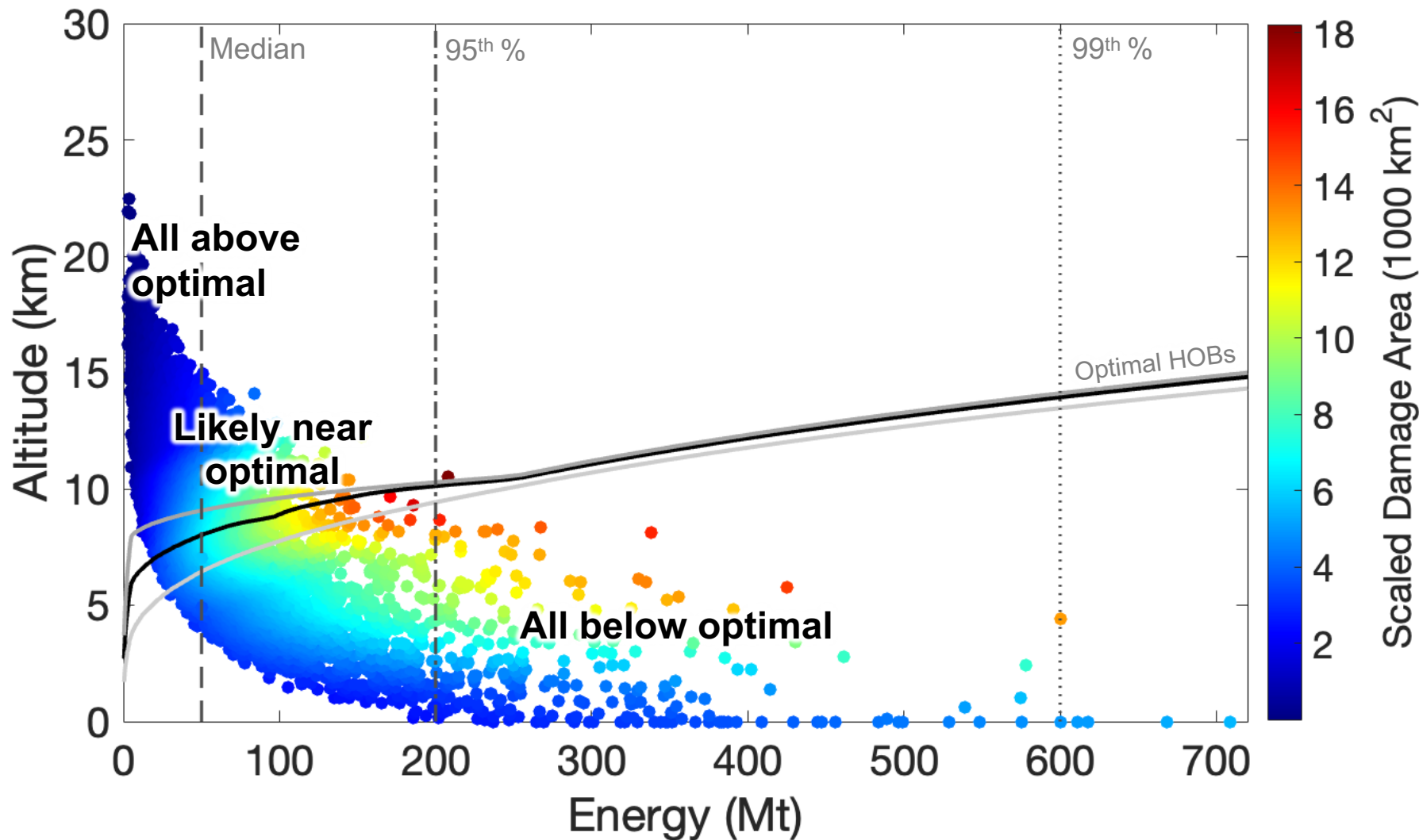


St. Petersburg (18°)





# Airburst & Total Blast Damage Trends for Steep Entry (Cape Town)

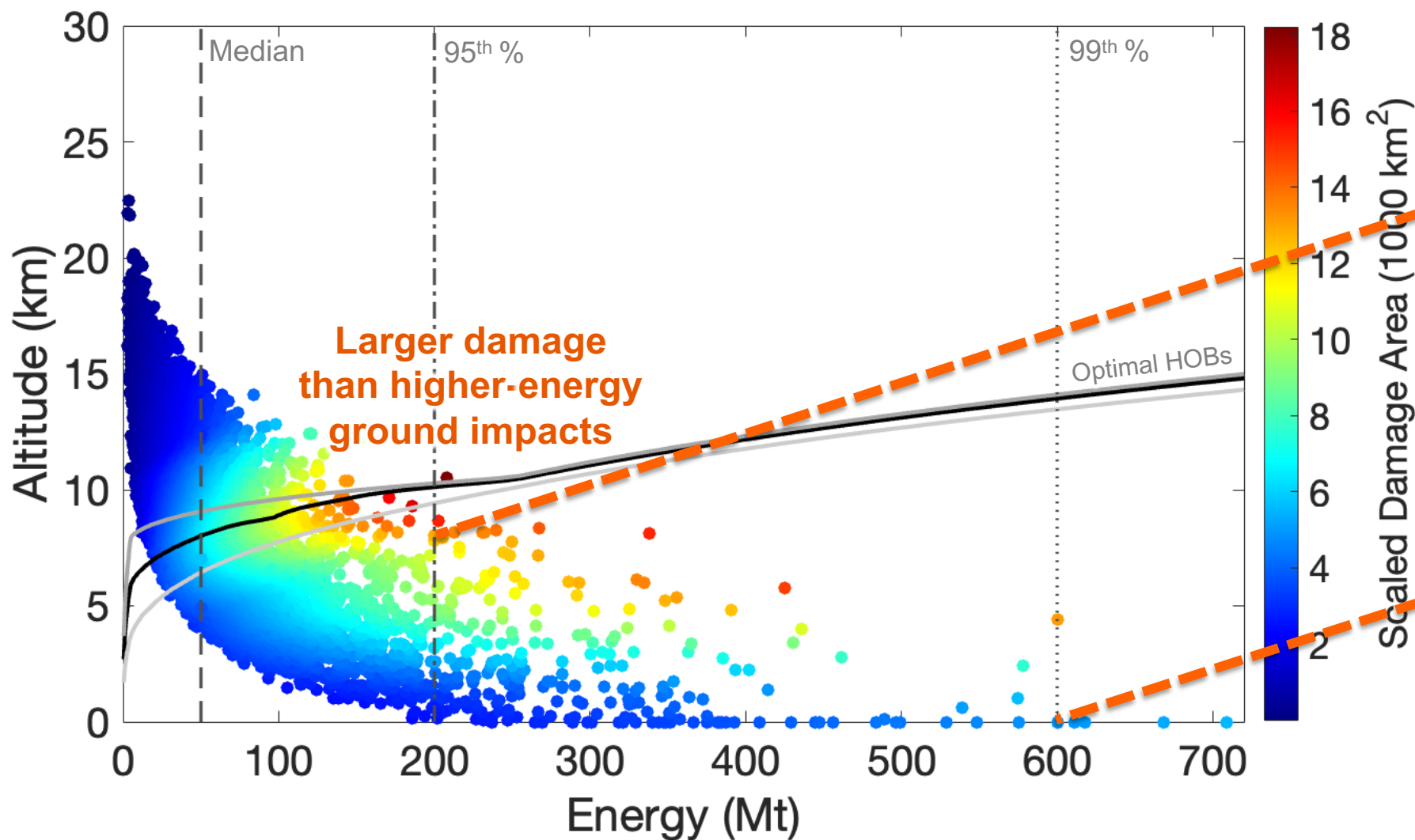


## Steep entry trends:

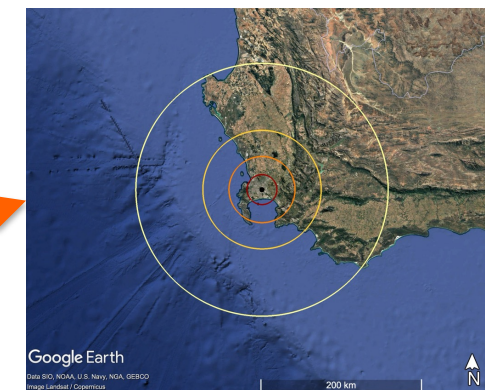
- Cases ~50–100 Mt likely to burst near optimal
- Cases under ~10–20 Mt burst above optimal
- Cases over ~250 Mt all over-penetrate below optimal



# Airburst & Total Blast Damage Trends for Steep Entry (Cape Town)



200 Mt at 8 km altitude

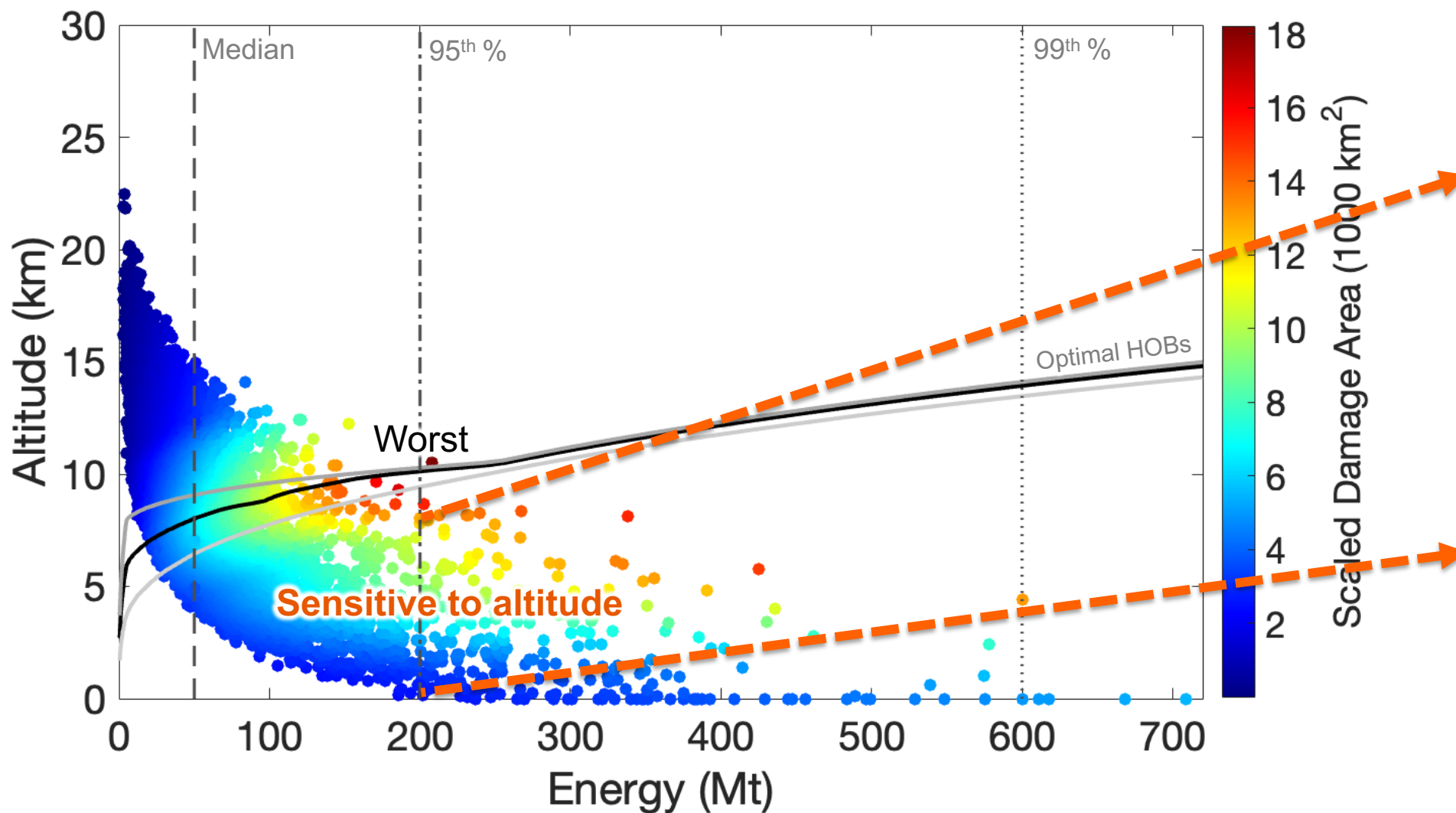


600 Mt ground impact

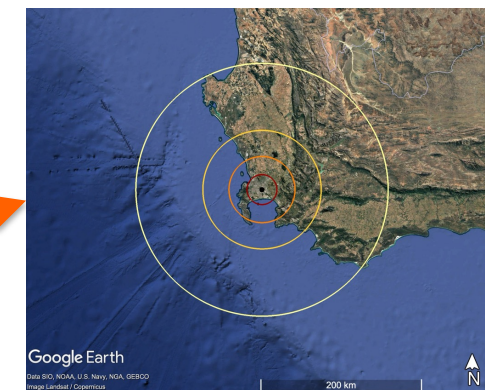




# Airburst & Total Blast Damage Trends for Steep Entry (Cape Town)



200 Mt at 8 km altitude

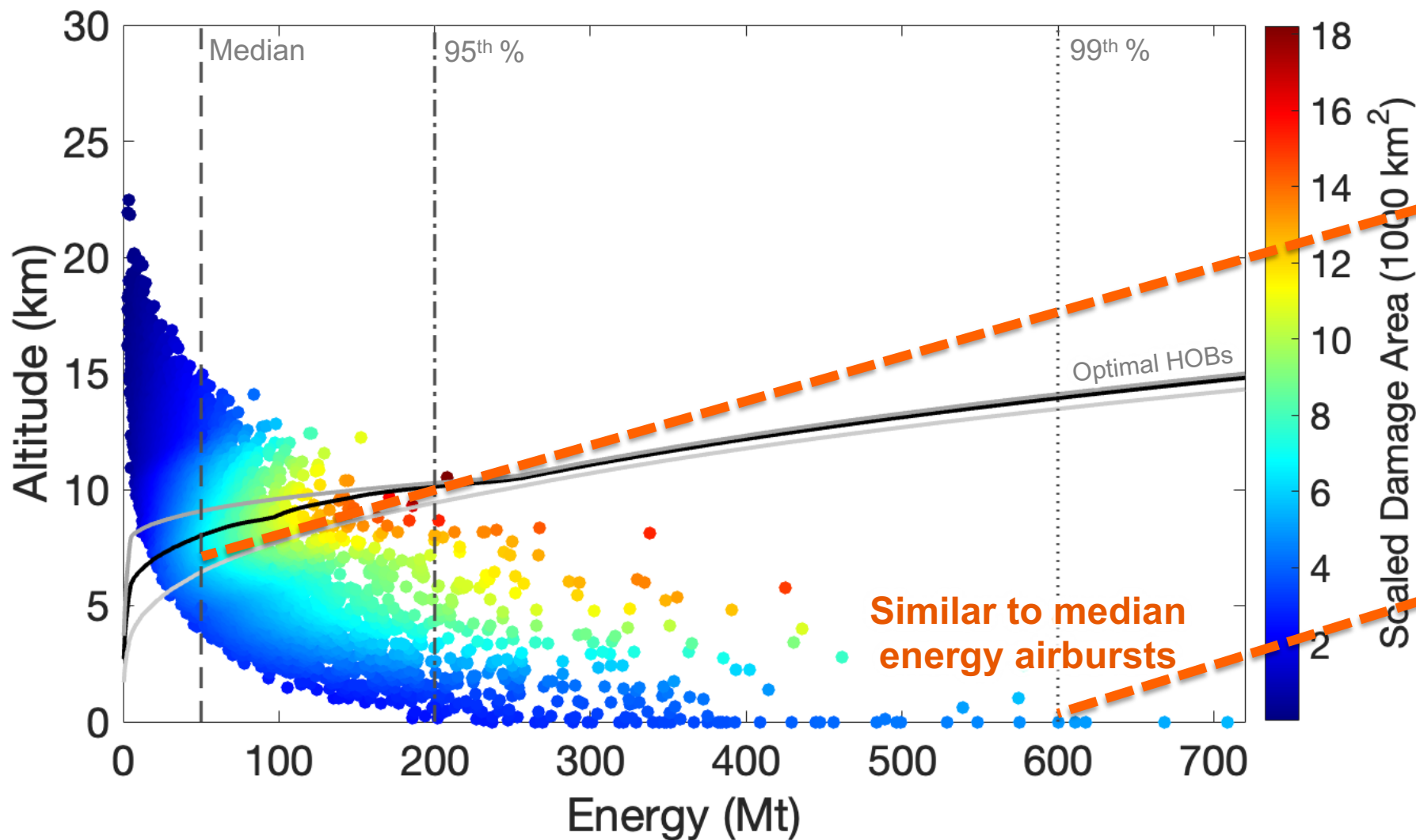


200 Mt ground impact

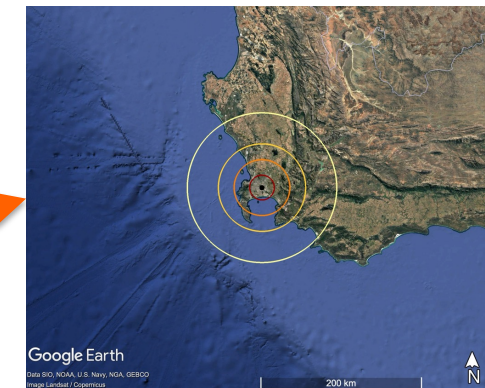




# Airburst & Total Blast Damage Trends for Steep Entry (Cape Town)



50 Mt at 7 km altitude

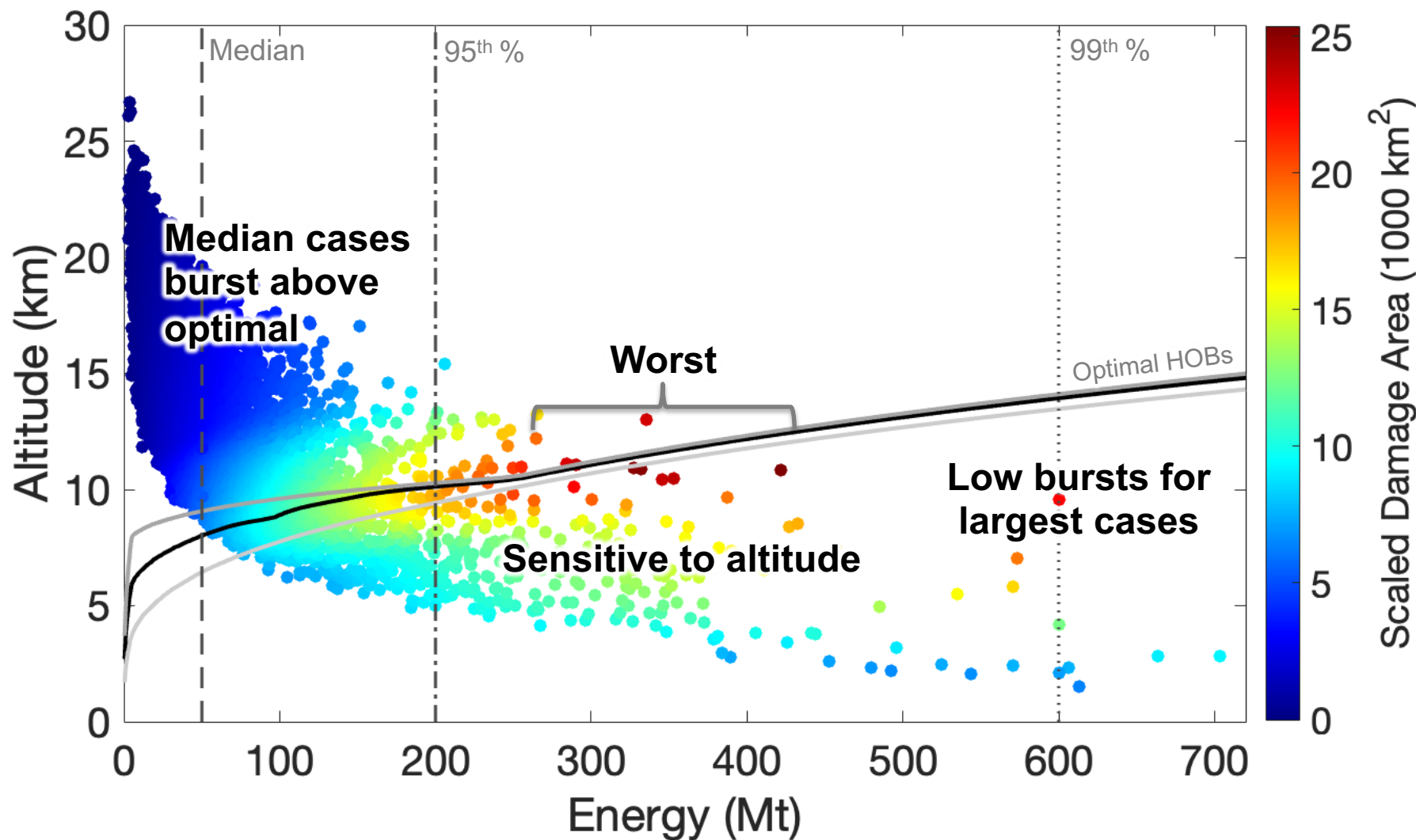


600 Mt ground impact





# Airburst & Total Blast Damage Trends for Moderate Entry (Athens)

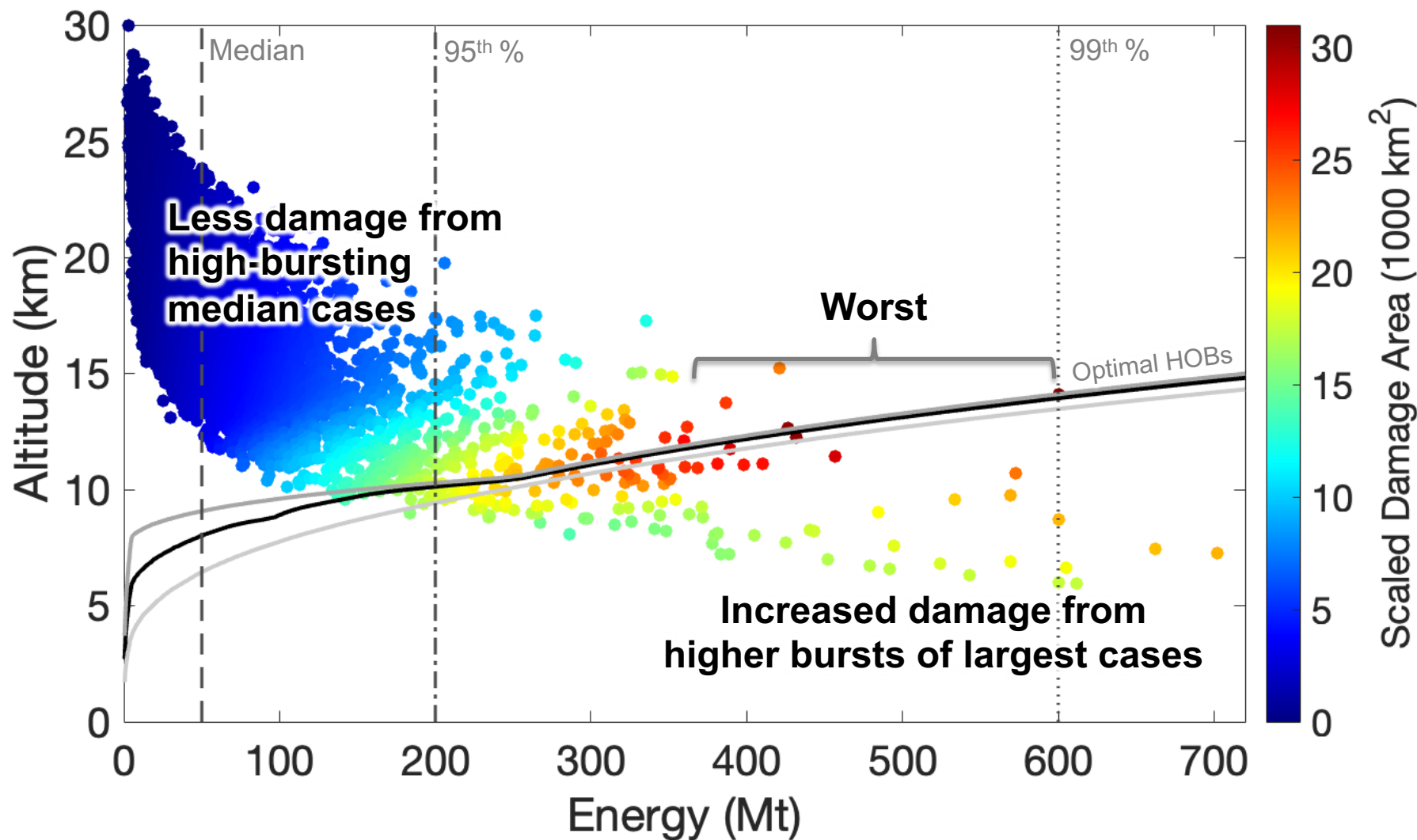


## Moderate entry trends:

- Median energies mostly burst above optimal
- Worst damage from ~300–400 Mt cases at high altitudes
- Partial low bursts of largest cases increases their damage



# Airburst & Total Blast Damage Trends for Shallow Entry (St. Petersburg)



## Shallow entry trends:

- Effective burst altitudes of largest cases rise closer to optimal HOBs
- Worst damage from high-altitude ~400–600 Mt cases

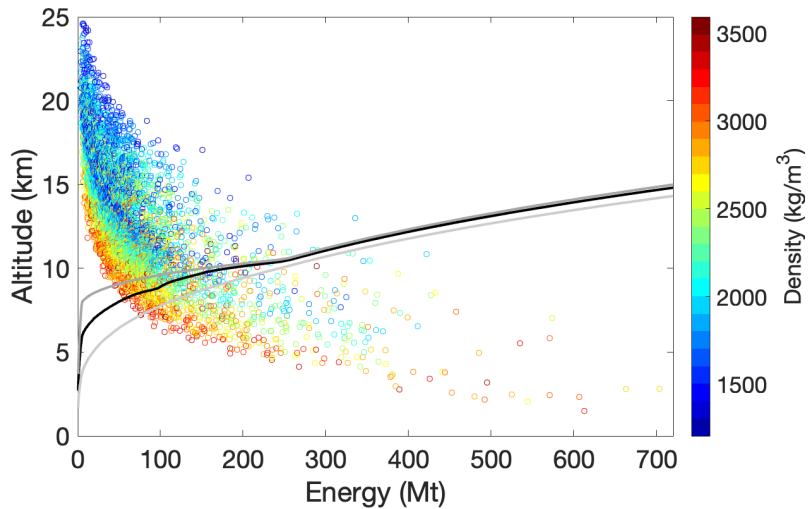


# Sensitivity to Entry & Airburst Modeling

Airburst altitude sensitivity means uncertain asteroid properties and breakup modeling parameters can notably influence damage trends for specific cases

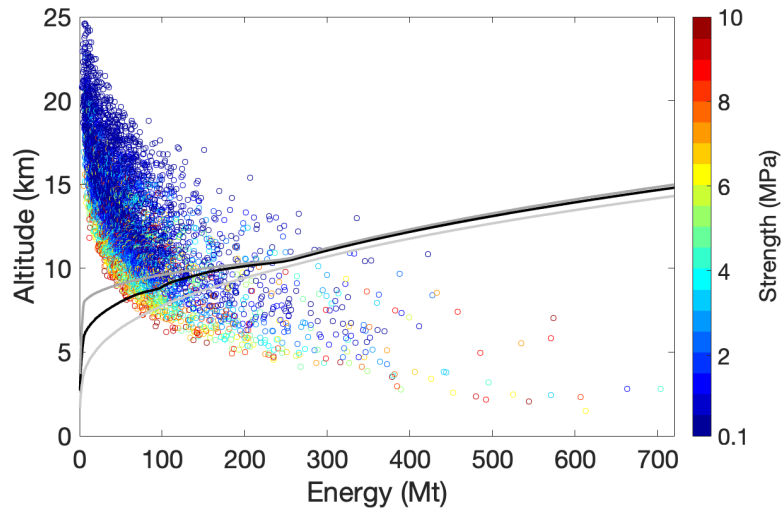
## Density

↓ Higher Density  
Lower bursts



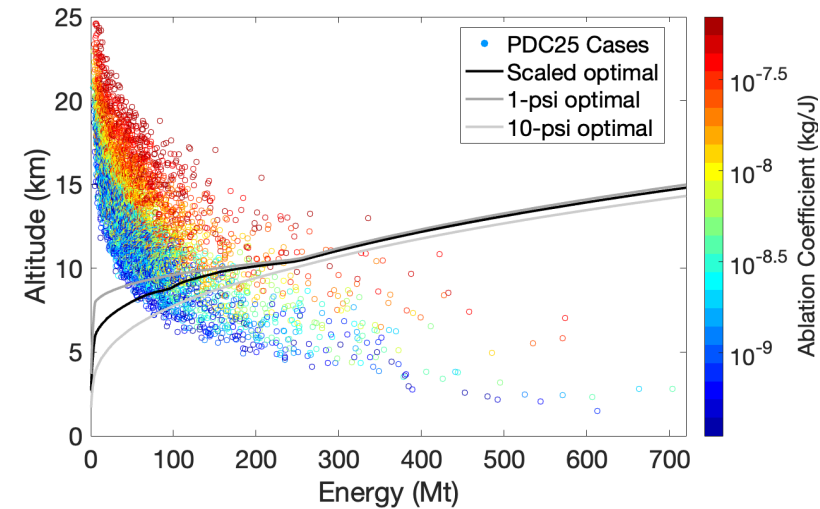
## Strength

↓ Highest strengths  
Lowest bursts



## Ablation

↑ Higher ablation  
Higher bursts





# Summary

- Blast damage estimates for the initial PDC25 scenario are sensitive to airburst altitude and HOB modeling factors
  - JWST constraints mean airburst variations are not swamped by greater asteroid size uncertainties
  - Airburst altitude ranges span optimal (worst-damage) HOBs for the potential asteroid energies
  - Entry angles along the corridor shift which sizes burst above, below, or near their optimal HOBs, affecting which sizes give the largest damage
- Blast modeling implications and future work
  - HOB models are better suited to evaluating potential damage ranges spanning airburst uncertainties than modeling specific damage cases
  - Point-source HOB approximations don't fully capture effects of high-energy entry columns and large ground-impacting cases
  - High-fidelity CFD simulations are being used to develop improved blast models that will better capture these effects (see talks by M. Aftosmis, W. Spurlock, D. Robertson)



# References

## Probabilistic Asteroid Impact Risk (PAIR) Model

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## Fragment-Cloud Model (FCM)

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