Ensemble Risk Assessment in Support of the 2016 NEO Science Definition Team

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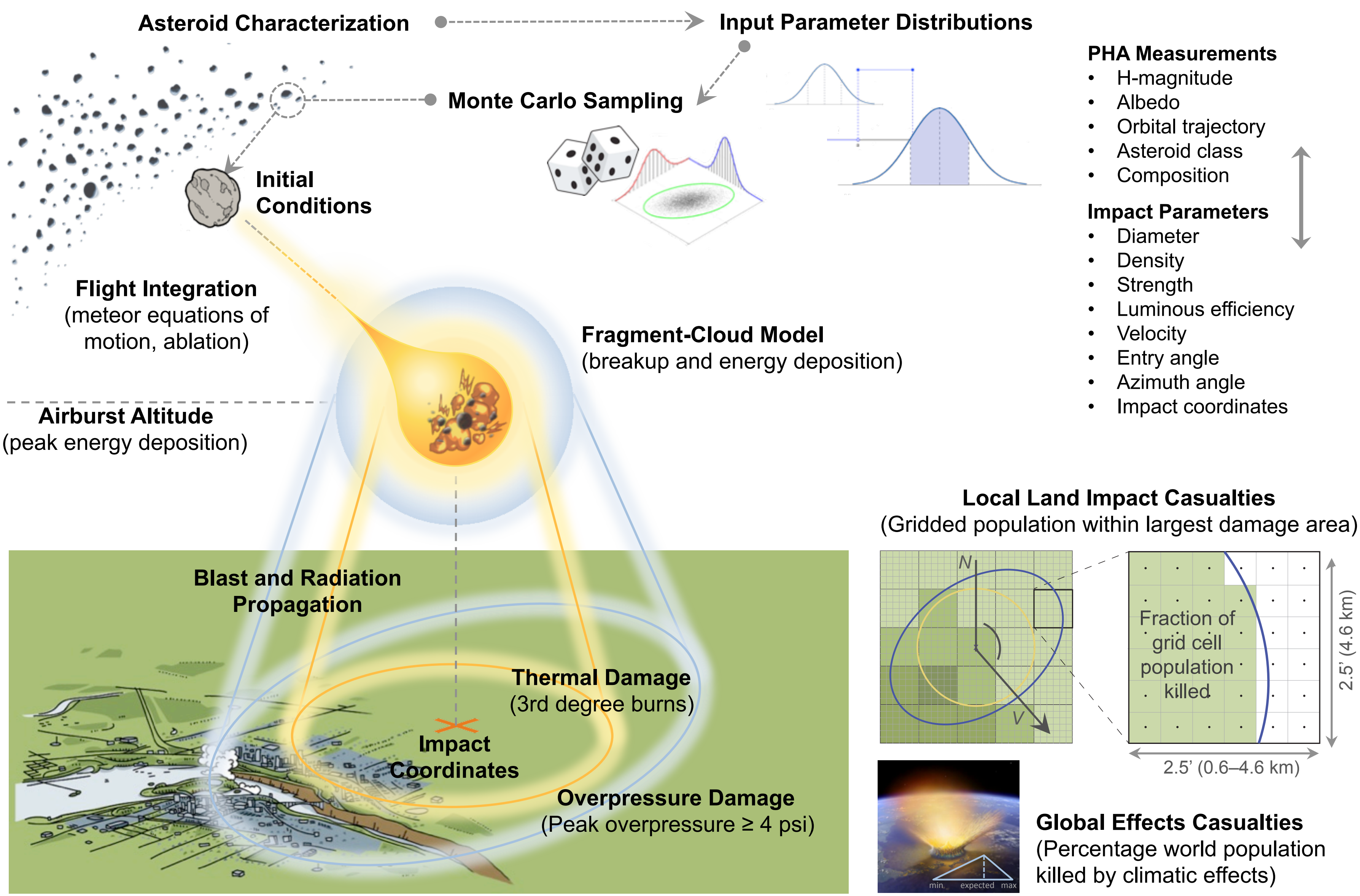
Probabilistic Asteroid Impact Risk Model



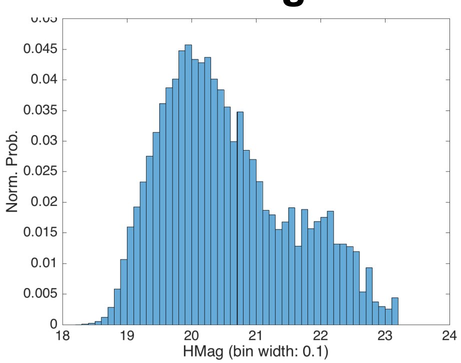
Risk Assessment: Changes Since 2003

- A Monte Carlo risk model is used to assess risk on a scenario-by-scenario basis.
- Scenario parameters, including the trajectory and impactor characteristics, are sampled from uncertainty distributions for each scenario.
- Assessment of each scenario uses a new fragment-cloud model for the simulation of the atmospheric entry trajectory and breakup.
- Blast overpressure damage is considered for a range of overpressure levels and is based on simulations for large impact energies.
- Thermal radiation is also considered as an impact effect that can cause ground damage.
- The tsunami model has been updated to incorporate local topography and distributed world population, and is assessed for each ocean impact scenario.

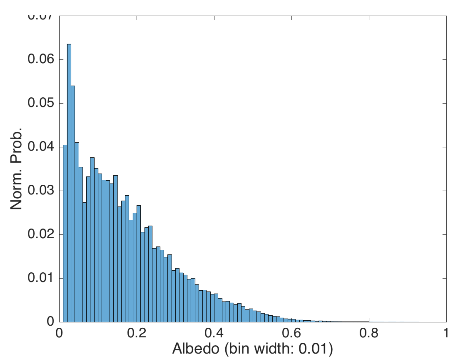
Impact Parameters

- **Diameter:** fixed diameter bins (in increments of 10m, 50m, 100m, and 1000m)
- **Albedo:** sampled from NEOWISE distribution (used to assign class)
- **H-magnitude:** computed from fixed size and sampled albedo (not used here)
- **Velocity:** sampled/computed from orbital parameters/dynamics (range of 11.3-69.6 km/s, mean of 20.2 km/s in current scenario set)
- **Entry angle:** 0 – 90° (sinusoidal weighting toward 45°)
- **Latitude/Longitude:** distributed evenly over full globe (latitude weighted toward equator for even surface area distribution)
- **Azimuth angle:** 0 – 360°, uniform (irrelevant for circular damage areas)

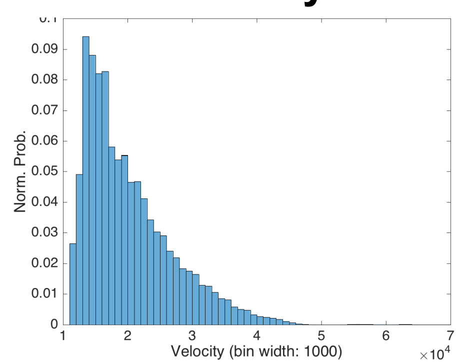
H-mag



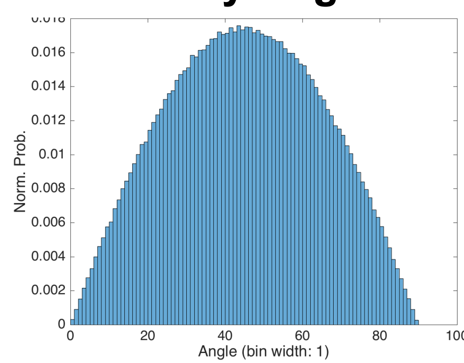
Albedo



Velocity



Entry Angle



Compositional Parameters

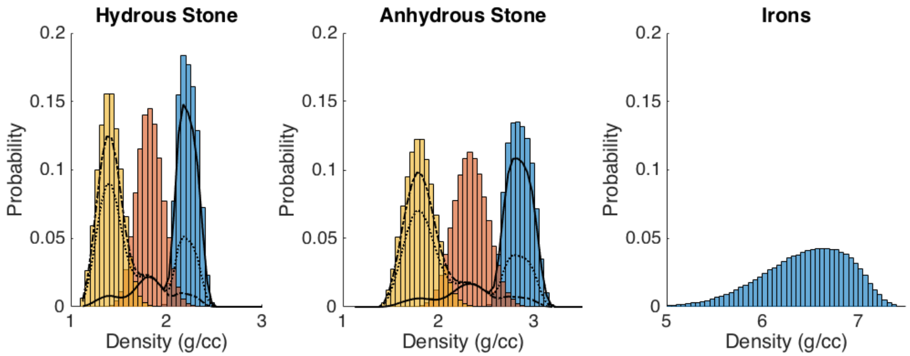
- Type-based base density distributions with structure-based porosity distributions:
  - Base material densities: clipped normal distributions based on compositional type
  - Porosity: clipped normal distributions based on structural type.
  - Sampled base material density reduced by sampled porosity to obtain overall density.
- Compositional types:
  - Anhydrous stone (albedo > 0.1): 60%
  - Hydrous stone (albedo ≤ 0.1): 35%
  - Iron (no albedo correlation): 5%
- Size-dependent structural types:
  - 15% fractured for all sizes
  - D=20m: 5% rubble pile, 80% coherent
  - D>200m: 80% rubble pile, 5% coherent
  - Scaled logarithmically between 20-200m
- Strength parameters:
  - Breakup strength sampled uniformly between 0.1-2.0 MPa for stones.
  - Strength scaling exponent α = 0.1 for hydrous, 0.2 for anhydrous
  - Irons assumed non-breaking

Density Distributions by Compositional Type

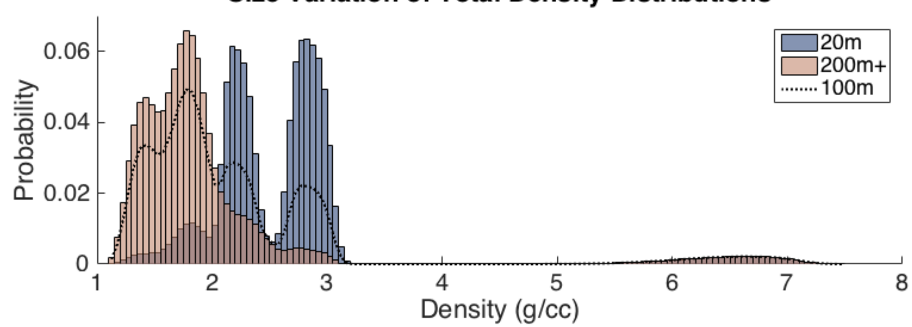
Type	Abundance	Mean	Std. Dev.	Min	Max
Hydrous Stone:	35%	1.9	0.58	1.1	2.5
Anhydrous Stone:	60%	2.9	0.54	1.4	3.2
Iron:	5%	7.0	0.6	1.8	7.5

Porosity Distributions by Structural Type

Structure	Abundance in type	Mean	Std. Dev.	Min	Max
Coherent Irons:	100%	5%	2%	0%	10%
Coherent Stones:	80-5% (20-200+ m)	5%	2%	0%	50%
Fractured Stones:	15%	22%	5%	0%	50%
Rubble Stones:	5-80% (20-200+ m)	40%	5%	0%	50%

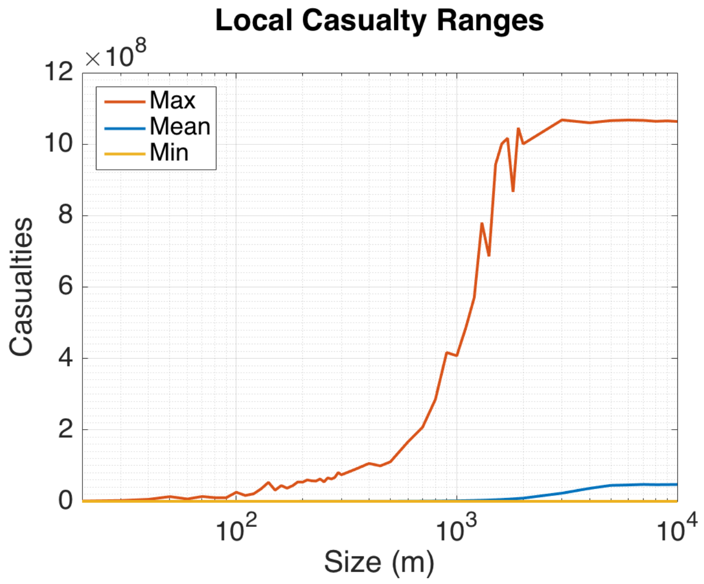


Size Variation of Total Density Distributions

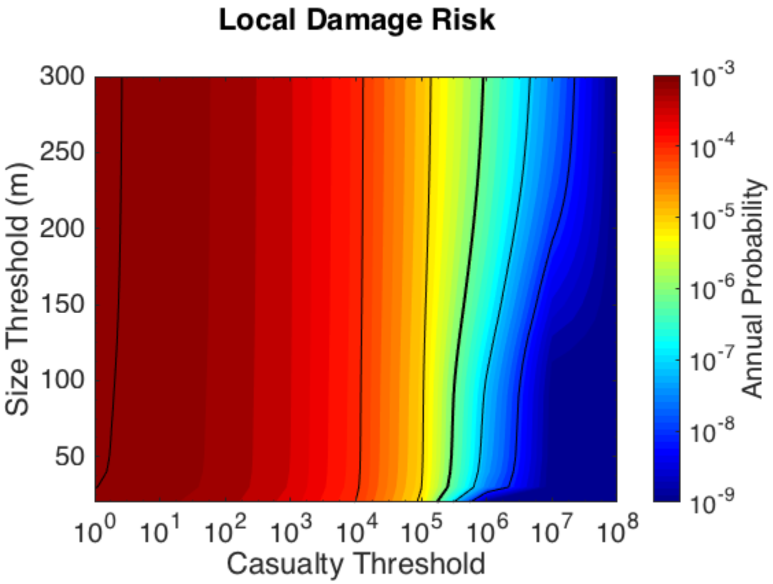


Local Damage

- Blast overpressure and thermal radiation evaluated based on energy deposition curve
- Larger of the the two damage areas used for casualty calculation



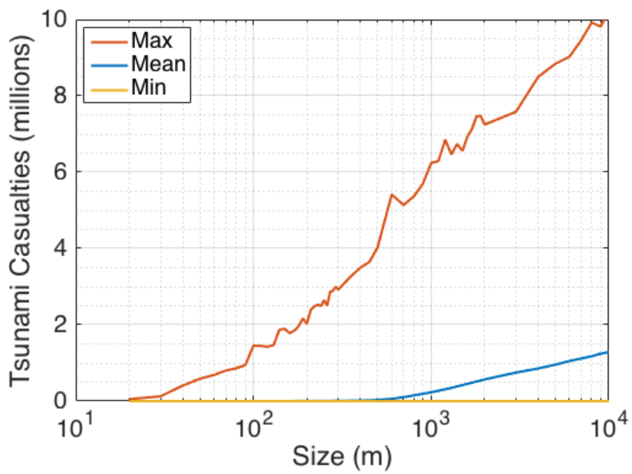
Range of local impact consequences- simulation min, mean, and max



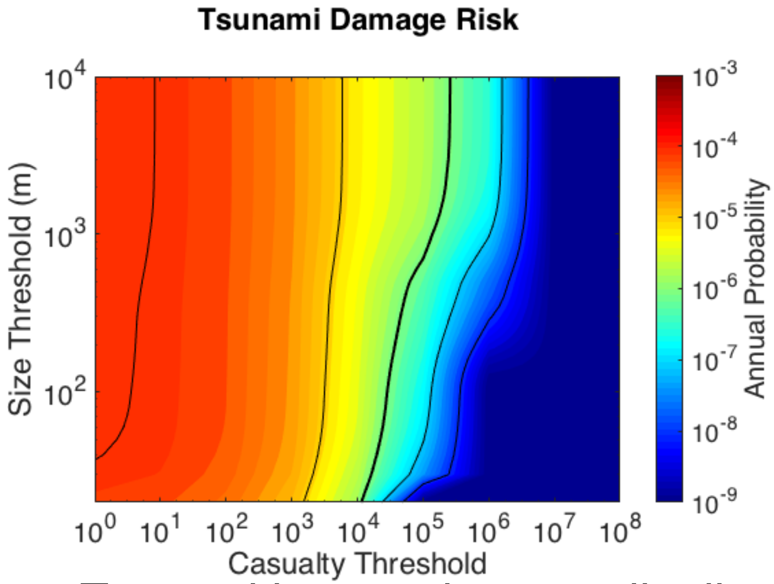
Local impact damage distributions- colors represent probability per year

Tsunami Damage

- Fraction of the kinetic energy remaining at the surface used to determine the initial ocean cavity size
- Wave propagation and inundation based on modified Chesley and Ward model
  - Each impact scenario was evaluated
  - Inundation takes into consideration human population and coastal topography



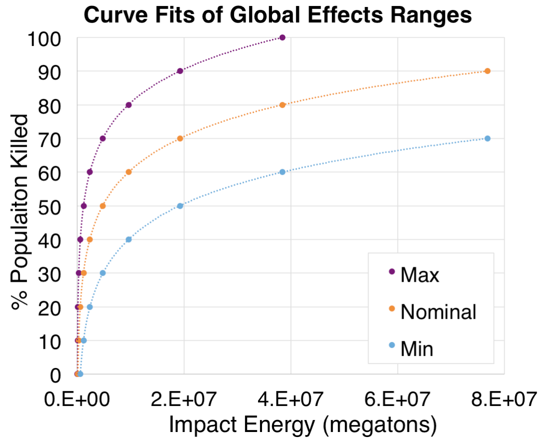
Range of tsunami impact consequences- simulation min, mean, and max

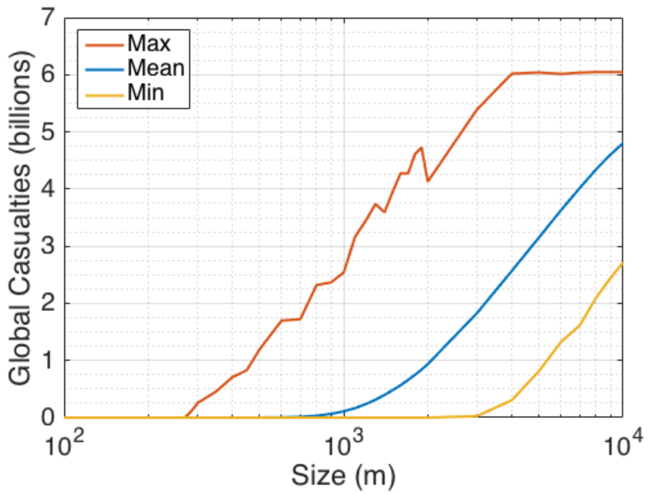


Tsunami impact damage distributions- colors represent probability per year

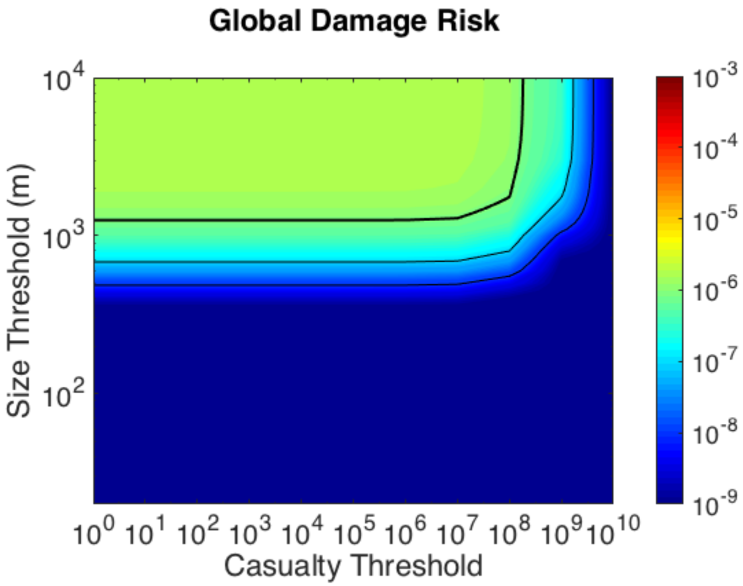
Global Effects

- Global effects model from 2003 re-factored based on kinetic energy
- Triangular uncertainty distribution used to model the percentage of global population effected as a function of impact energy



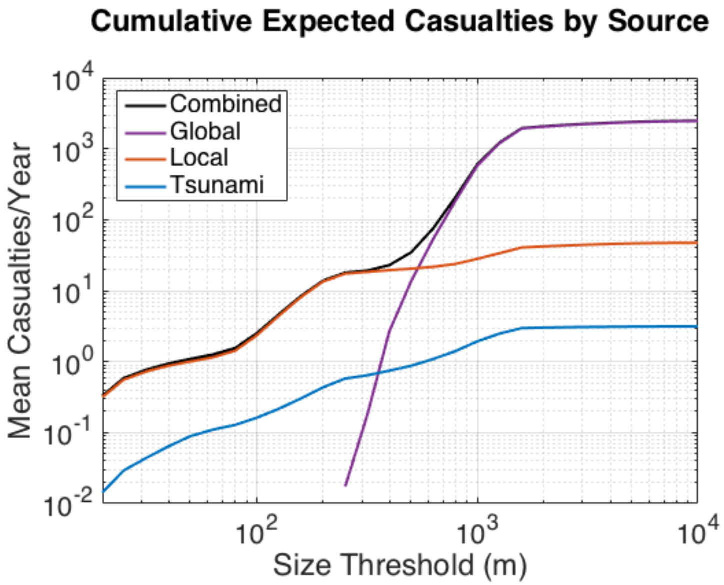


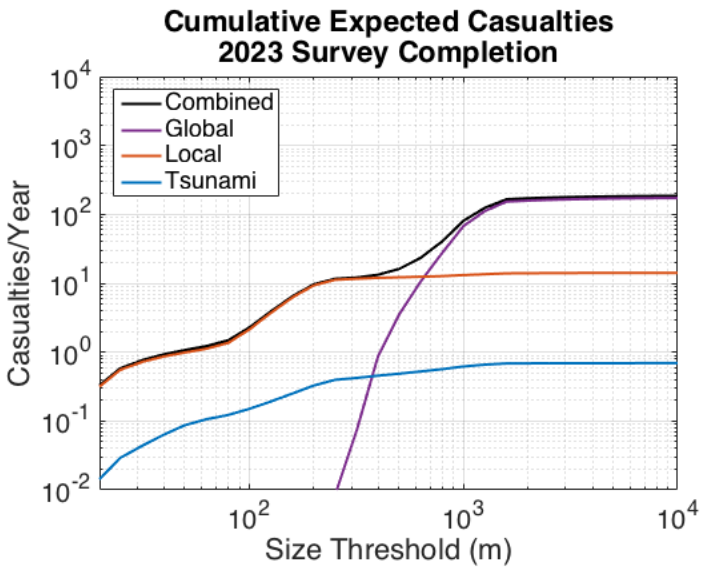
Range of global impact consequences- simulation min, mean, and max



Global impact damage distributions- colors represent probability per year

Combined Results





Cumulative expected casualties/yr due to the total estimated PHO population.

Results assuming current discovery rates up to 2023.

Risk Results Summary

- Total nominal risk from PHO impact = 2500 casualties/year
  - Dominated by global effects of large objects
- Risk associated with undiscovered PHO (2023) = 180 casualties/year
- Nominal remaining risk:
  - 10 casualties/year for land impact
  - <1 casualties/year for water impact
  - 170 casualties/year for remaining global effects