8th Planetary Defence Conference 2023, Vienna, Austria

Predicting the Consequences of NEO Impacts on Earth

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06.04.2023 robert.luther@mfn.berlin Project P3-NEO-XXVIII

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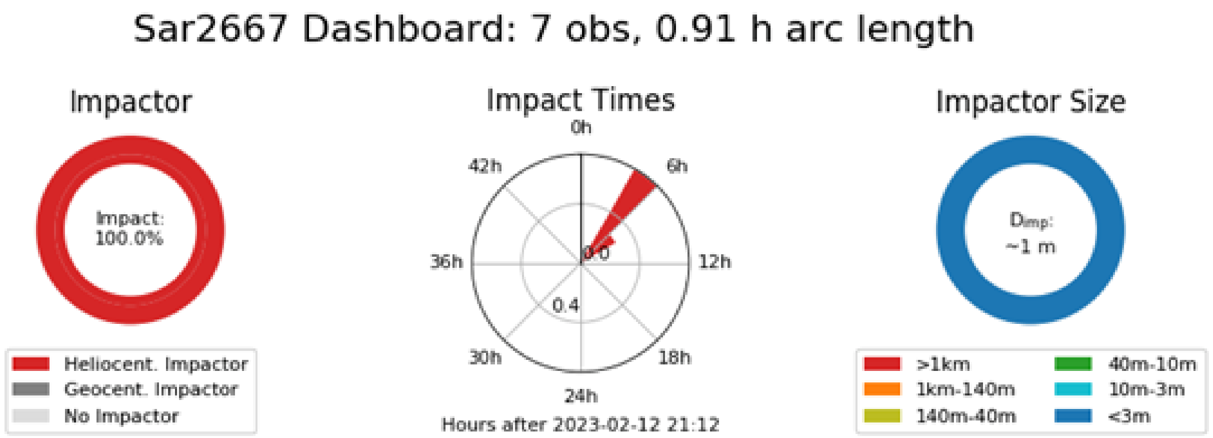
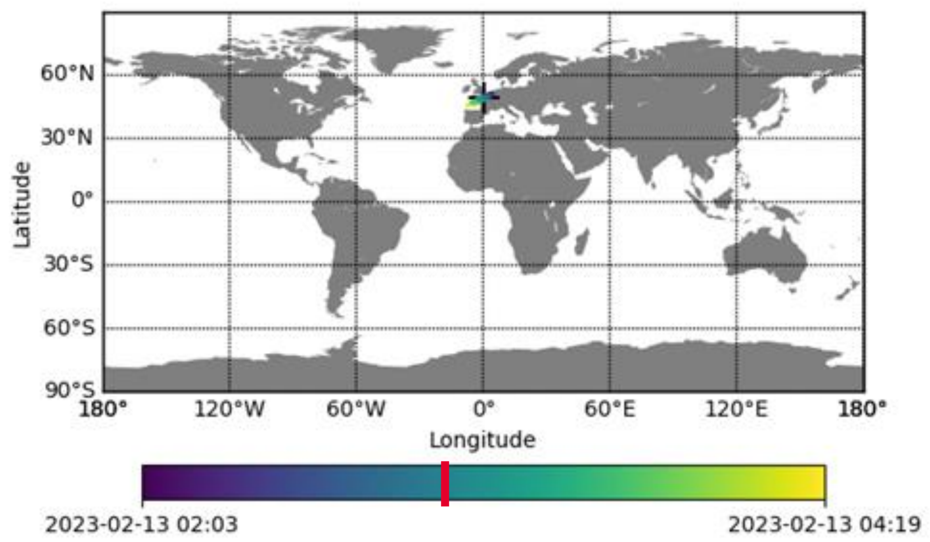
Short Notice Impact Warnings

– 12.02.2023: 7th meteoroid discovered before impact

→ ~6 h warning time



First impact assessment by ESA's tool Meerkat as reported at 21:33 UTC. Credit: ESA / PDO



First impact corridor by ESA's tool Meerkat as reported at 21:33 UTC. Credit: ESA / PDO

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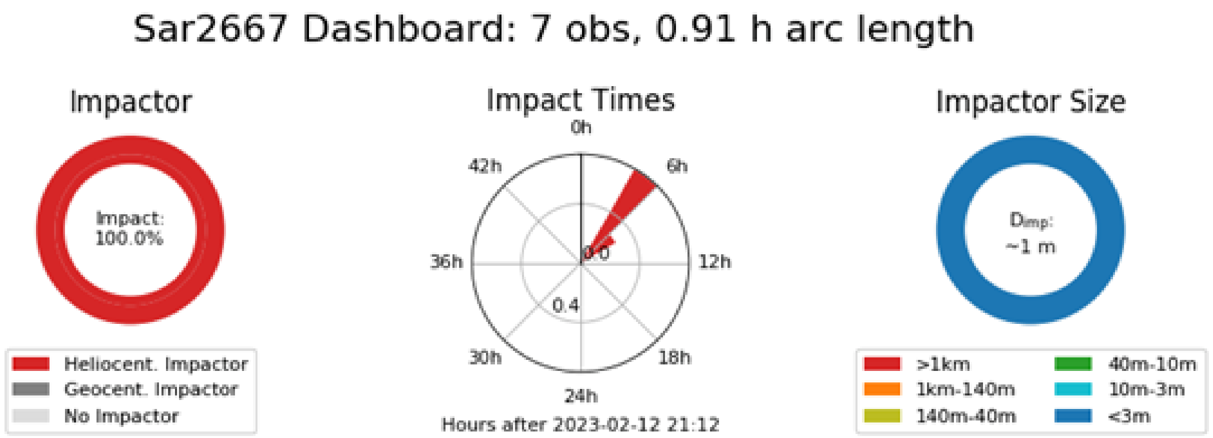
→ accurate impact effects need to be calculated in short time for emergency agencies



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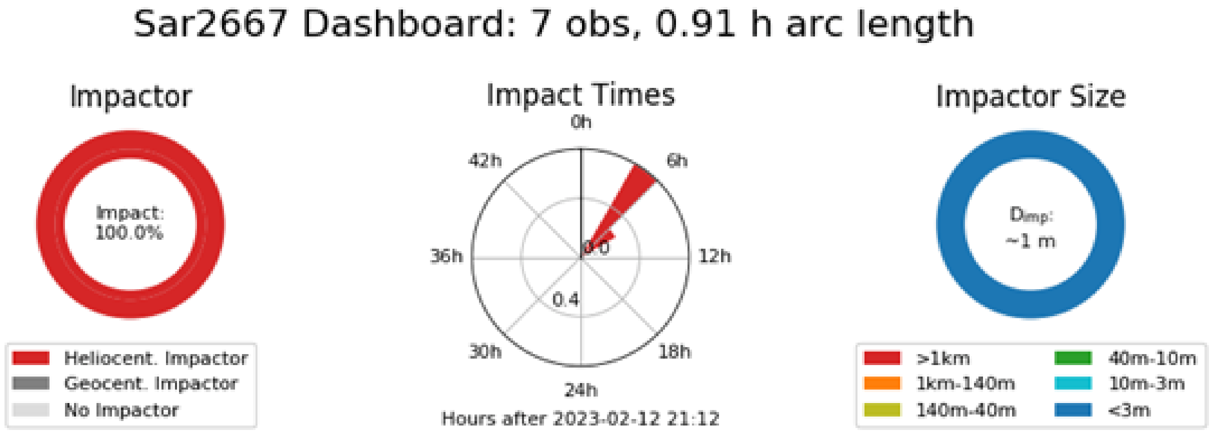
Combine fast **parameterisations** with database of **shock physics code** calculations



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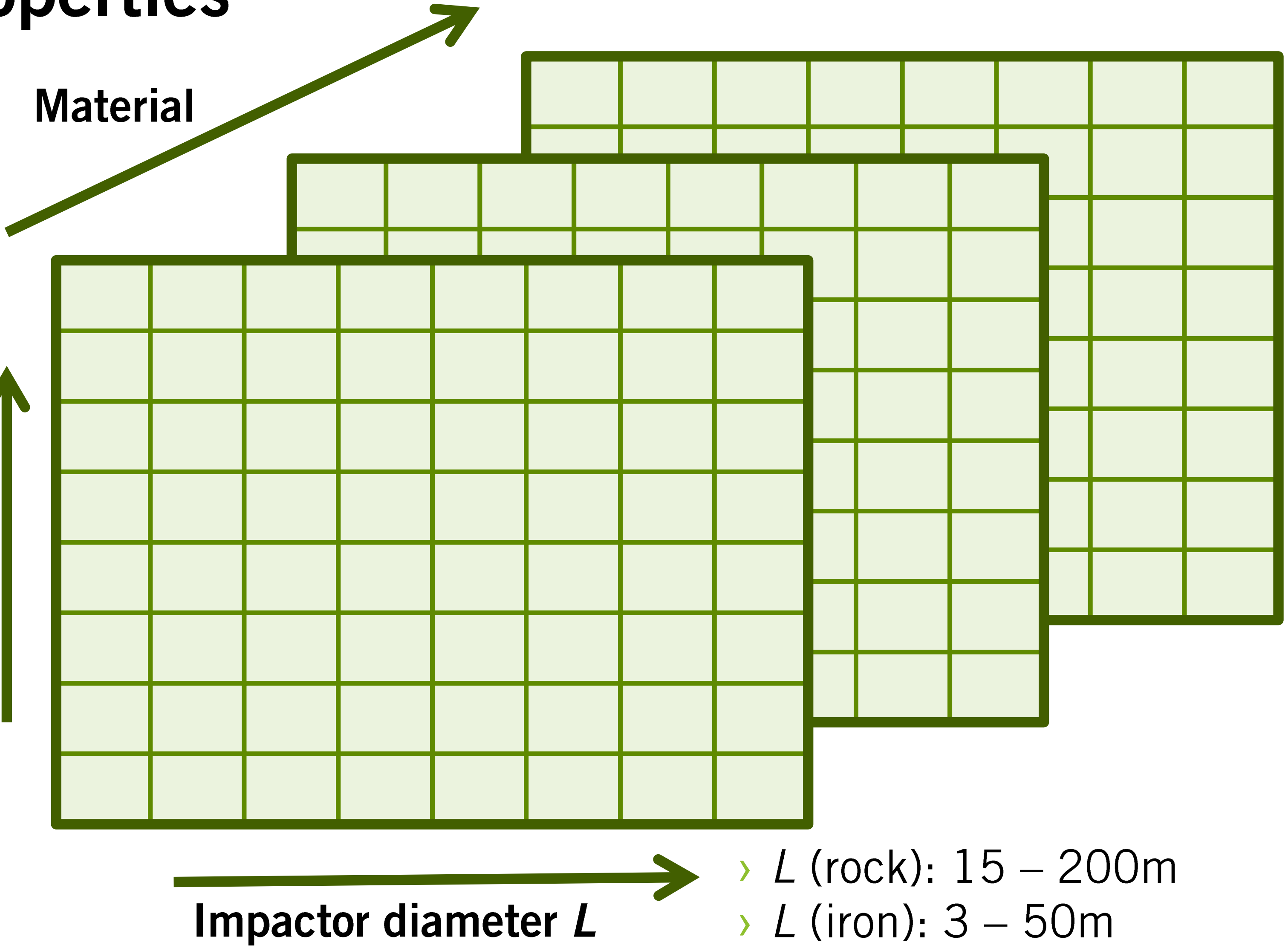
Impactor Properties



Velocity $\vec{v}(|\vec{v}|, \vartheta)$

- v: 11.2 – 40 km/s
- ϑ: 15 – 90°

Material

- C-type
- S-type (Fragmented or Lithified)
- M-type (Fragmented or Intact)

- *L* (rock): 15 – 200m
- *L* (iron): 3 – 50m

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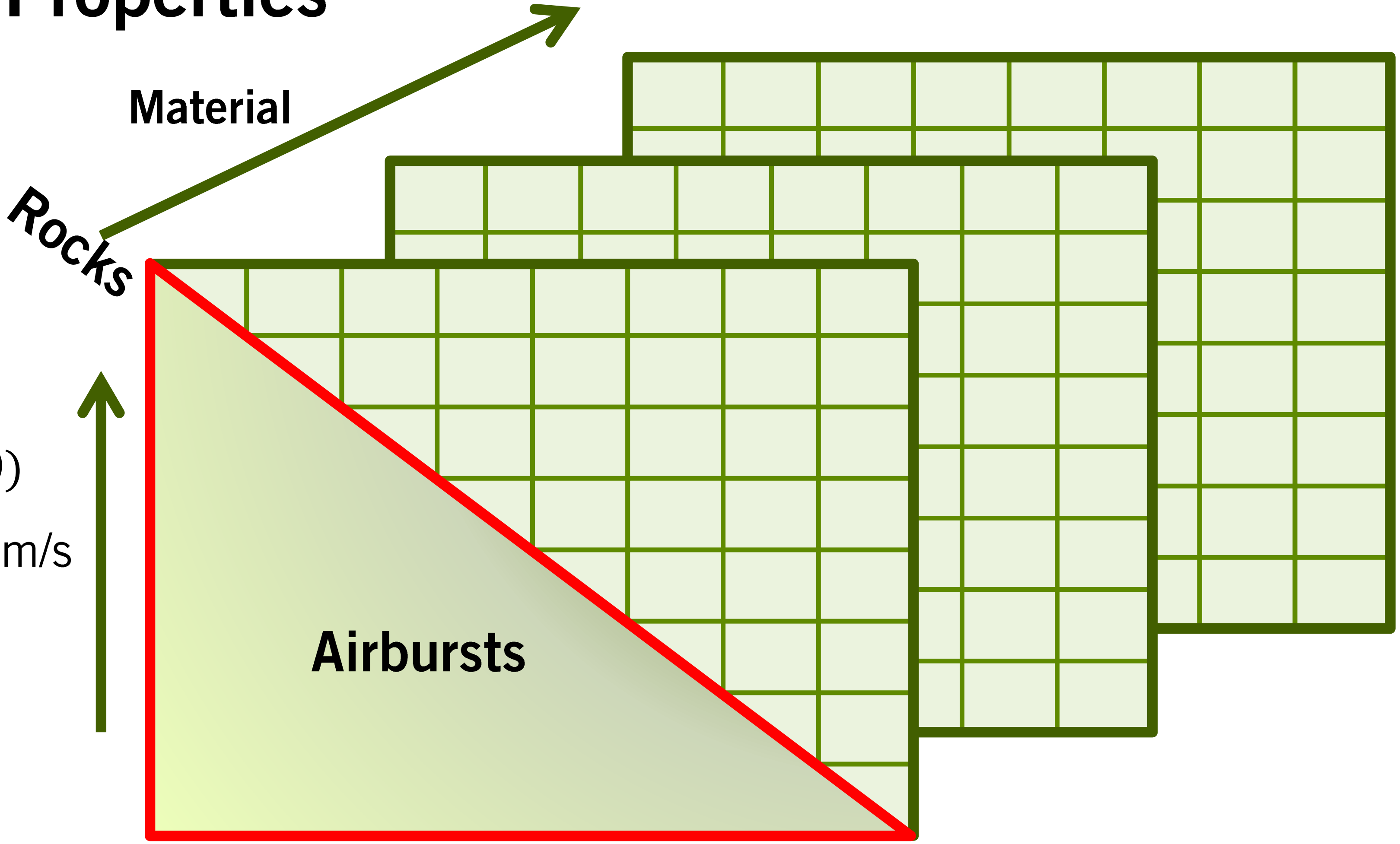

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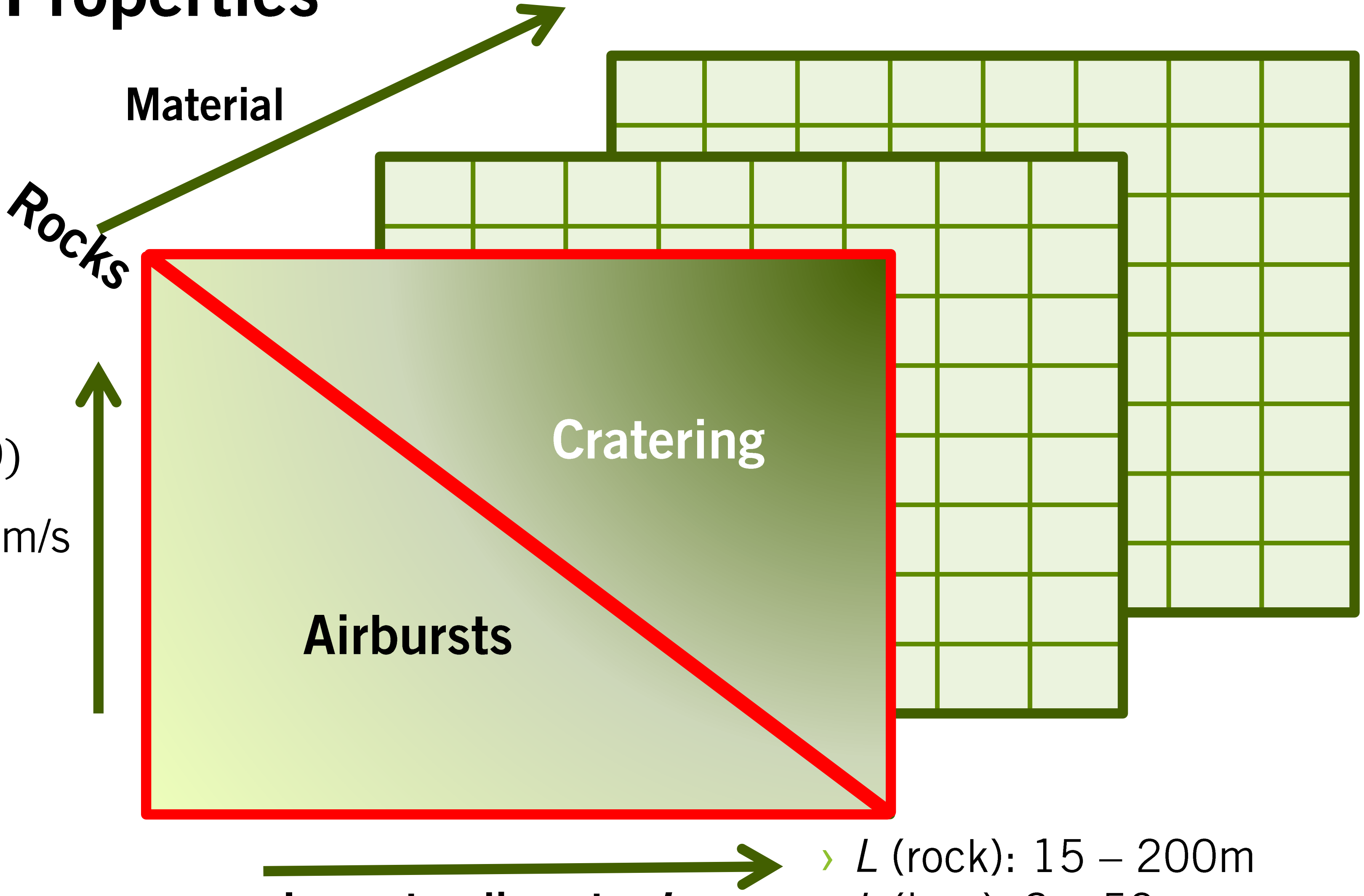

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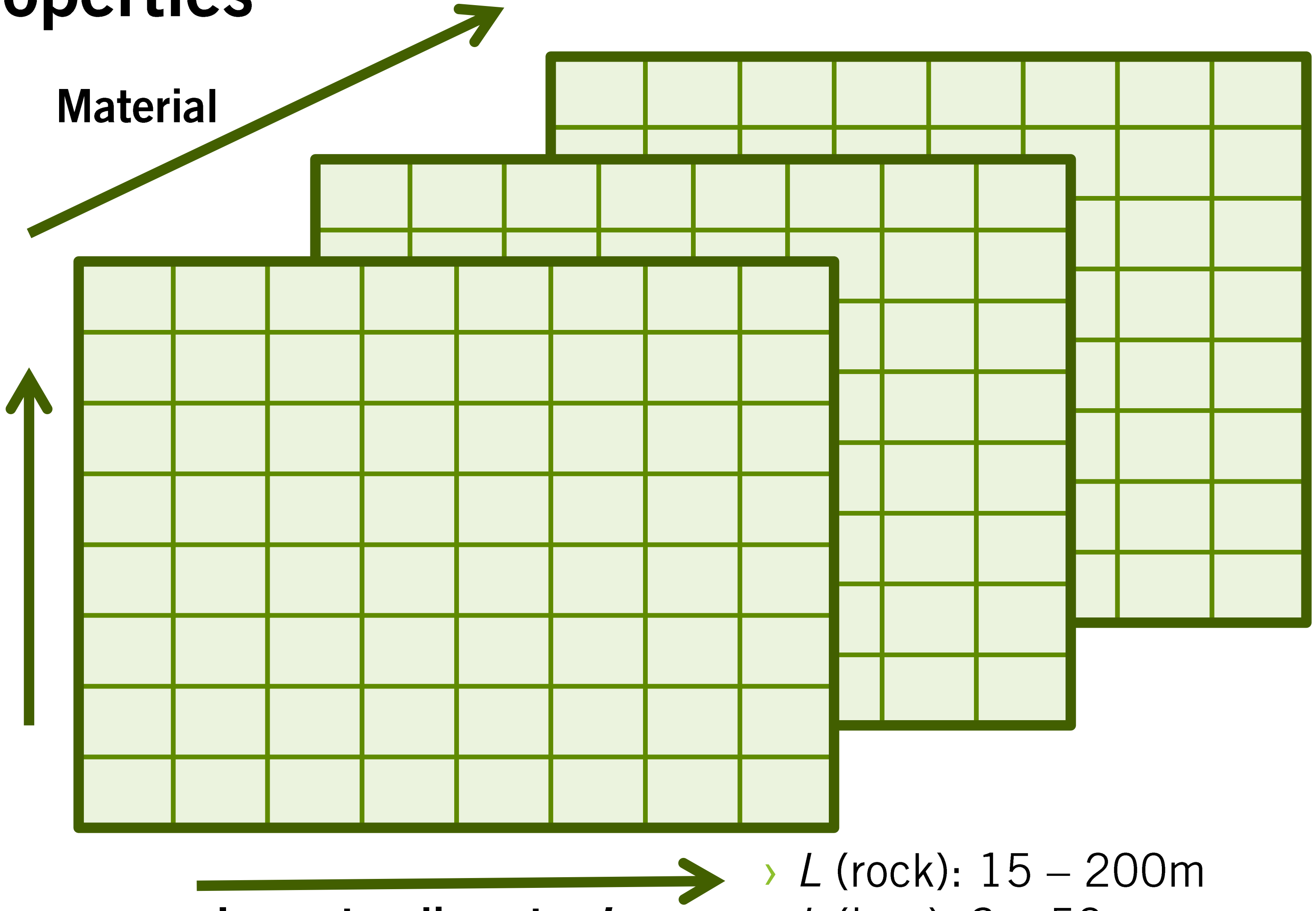

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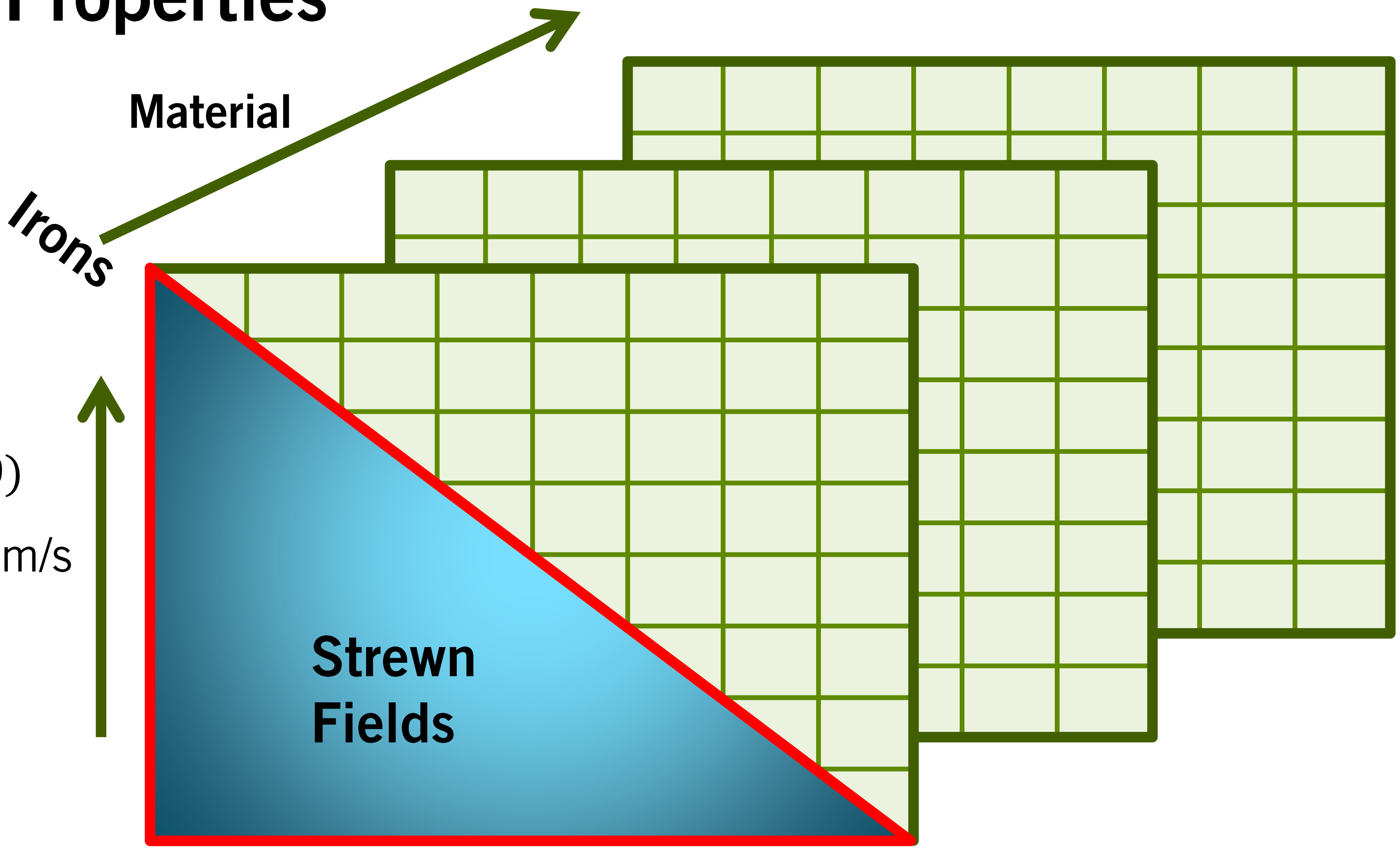

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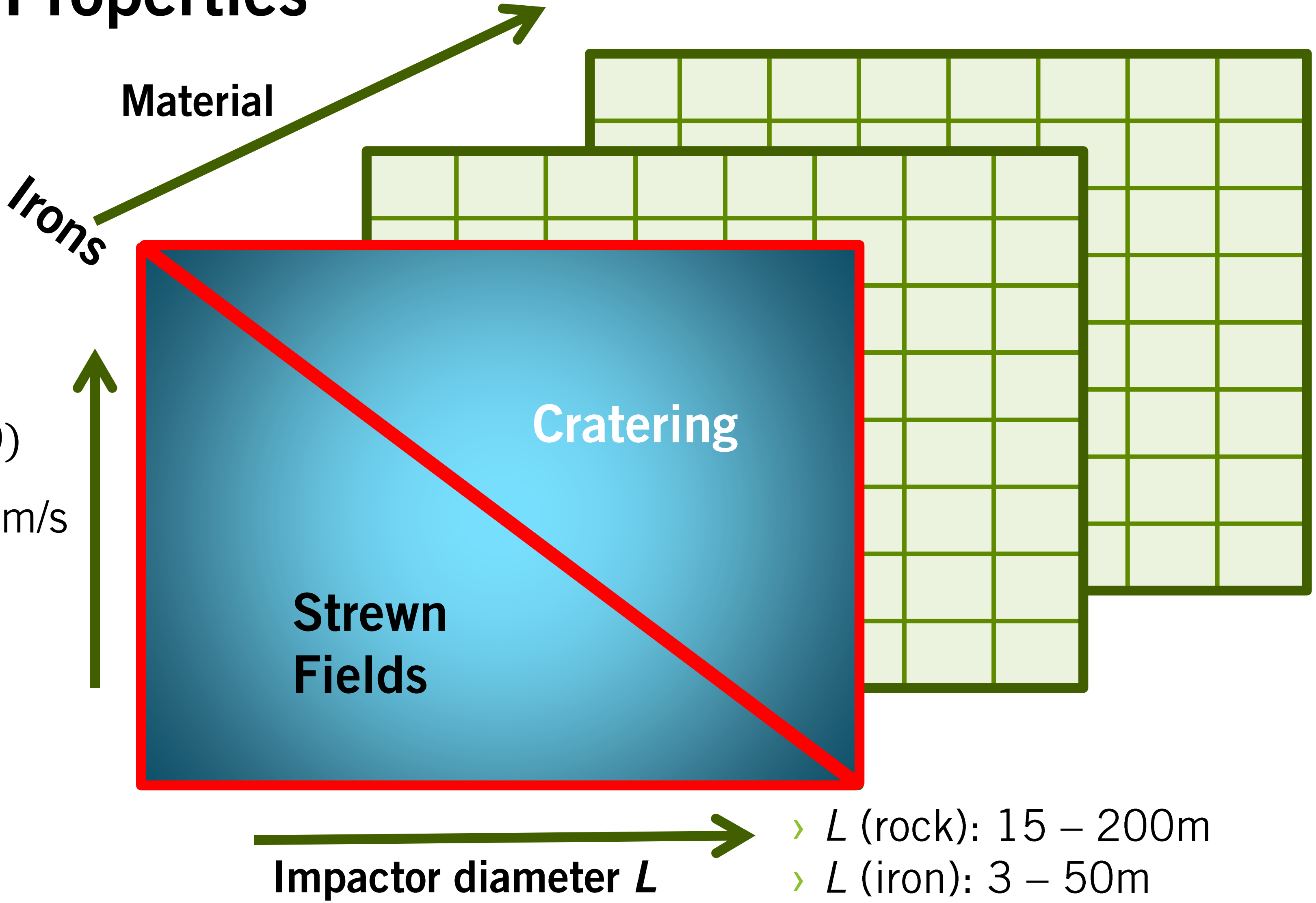

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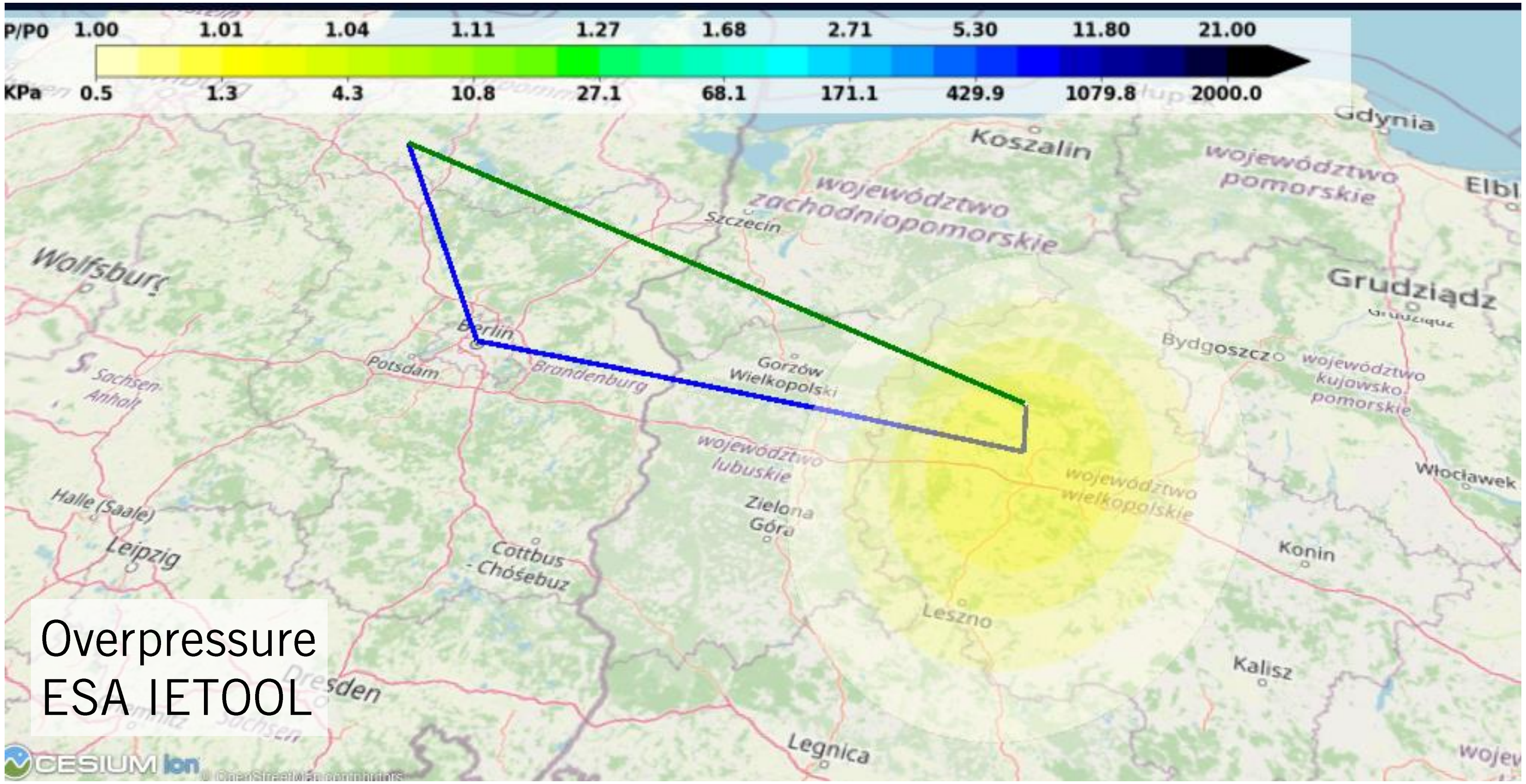
Impact Effects



Chelyabinsk type event:
$\boldsymbol{L}$ = 19m, $\boldsymbol{v}$ = 19 km/s, $\boldsymbol{\vartheta}$ = 18°, rocky asteroid

Atmospheric Effects

› Overpressure

› Wind speeds

› Thermal radiation

Impact Effects:

› Cratering

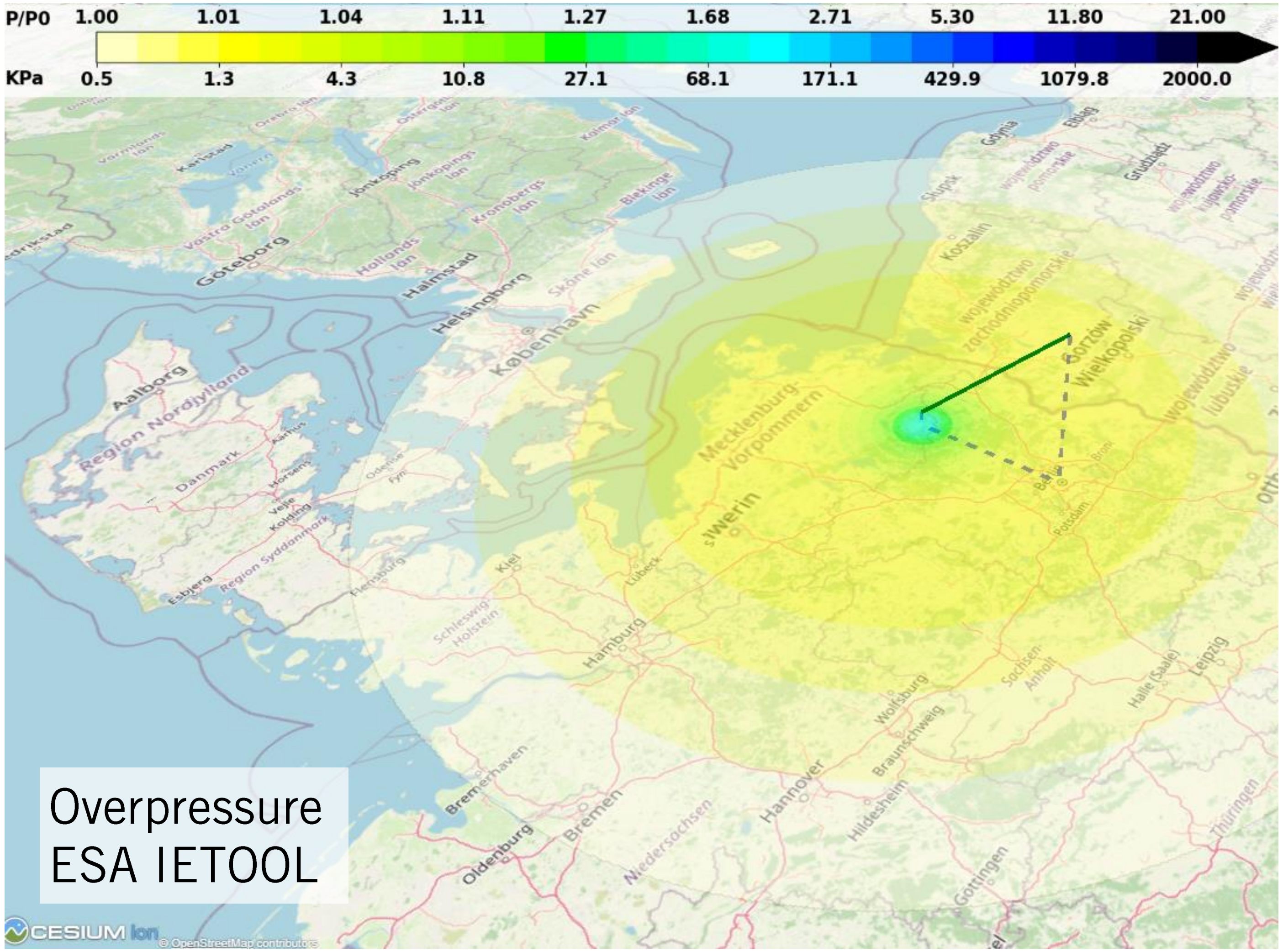
› Crater ejecta emplacement

› Strewn field size (meteorite & crater fields)

Software Testing Examples

› Airburst regime: Tunguska


Plekhanov: Tunguska



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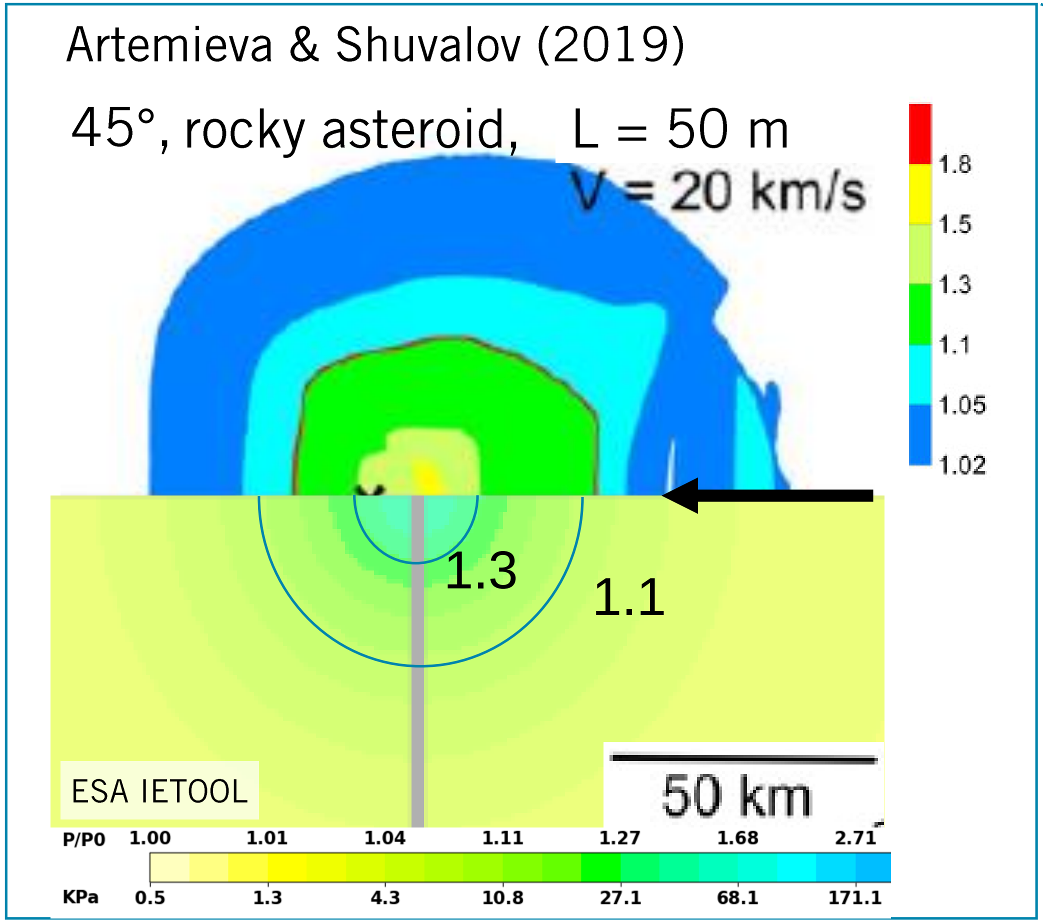
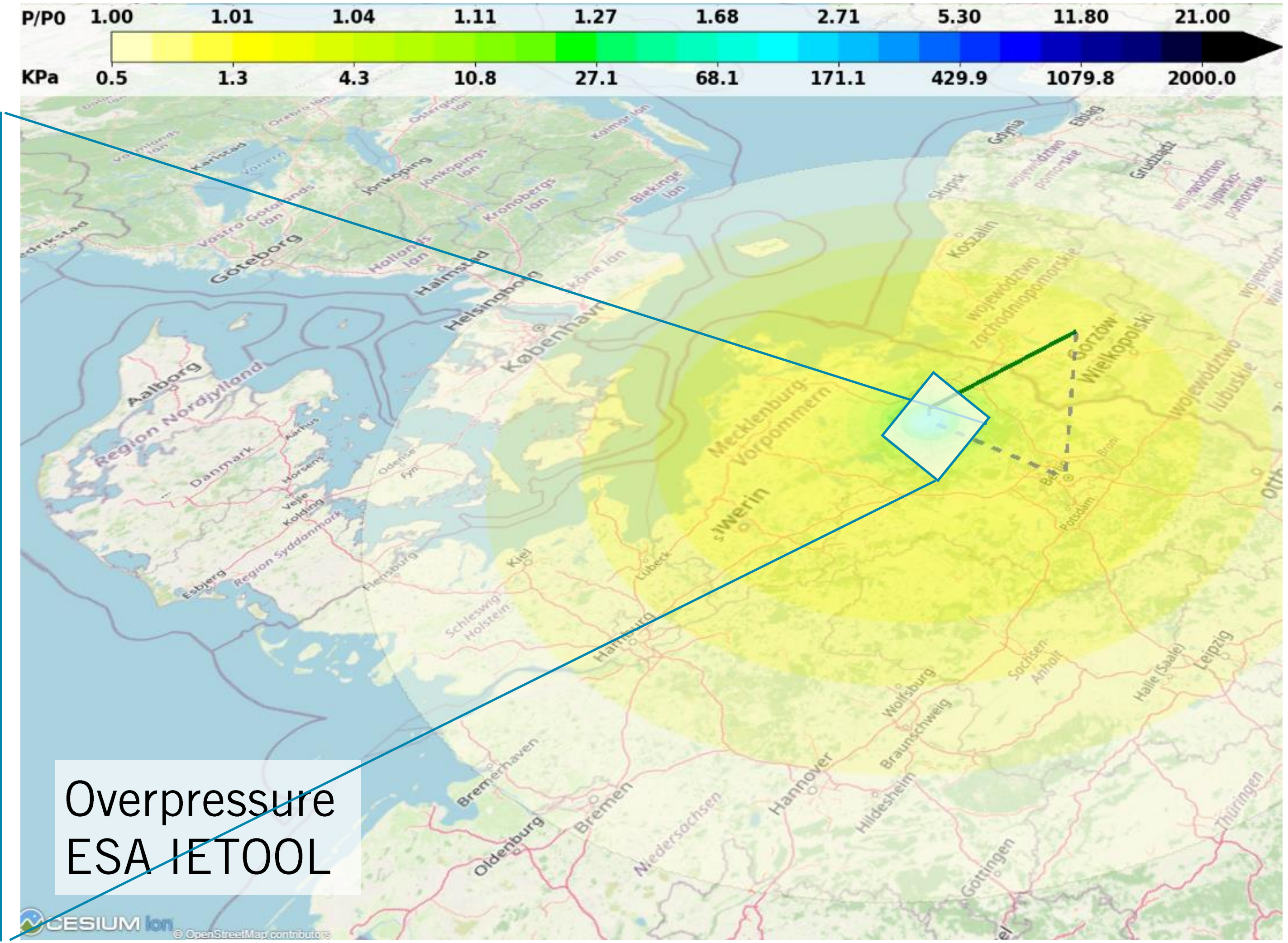




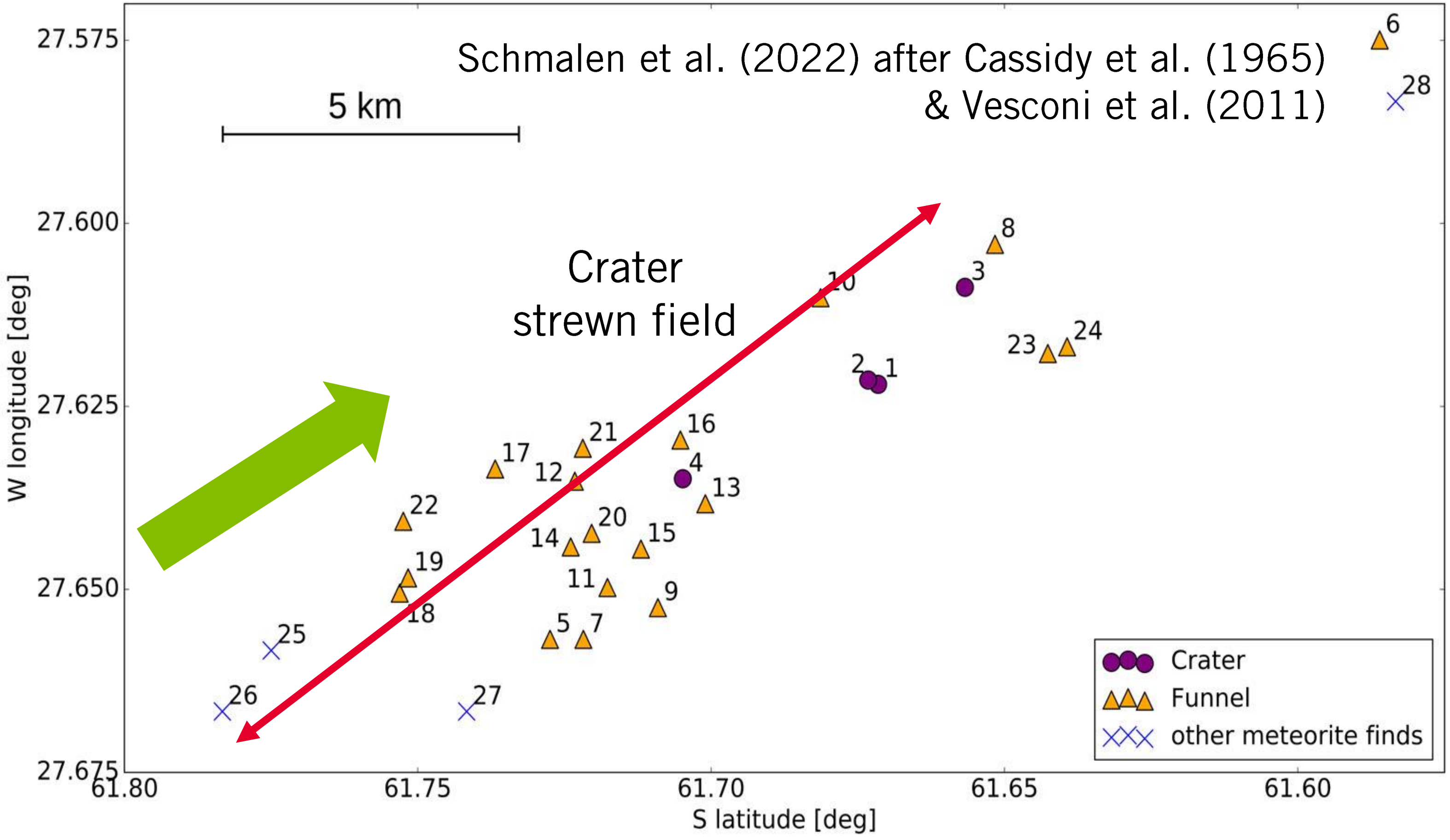
Software Testing Examples

- Strewn field regime: Campo del Cielo
- Length: 14 km
- (funnels & craters)
- main craters $D = 70\text{-}110$ m

recent reconstruction:

- atmospheric entry & funnel/crater formation by Schmalen et al. (2022) & Luther et al. (in submission)

Iron asteroid, v=14.5 km/s, L=12.8 m, ϑ=16.5°



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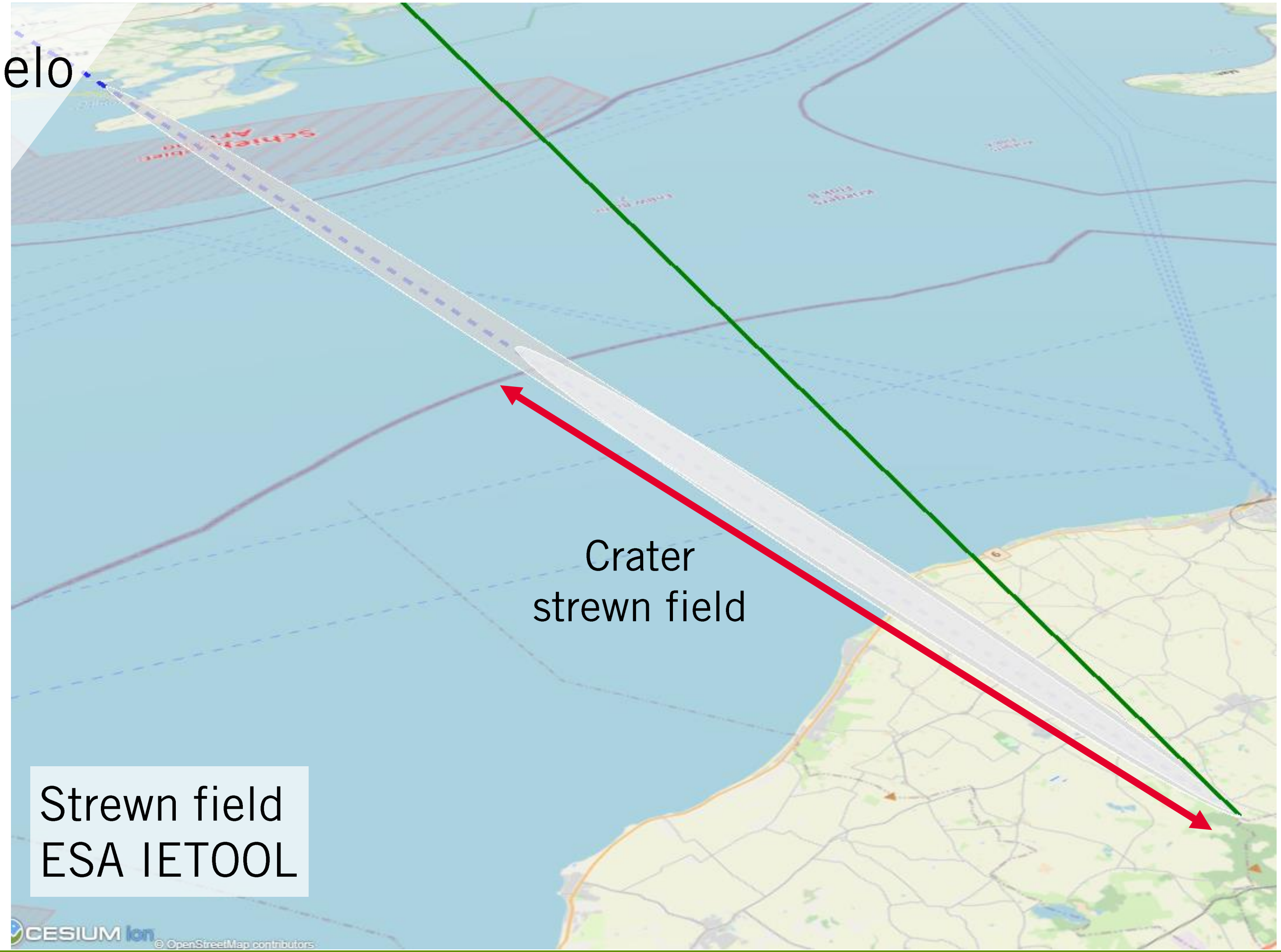
Tool results:

- Length: 19.6 km
- *D* = 220 m



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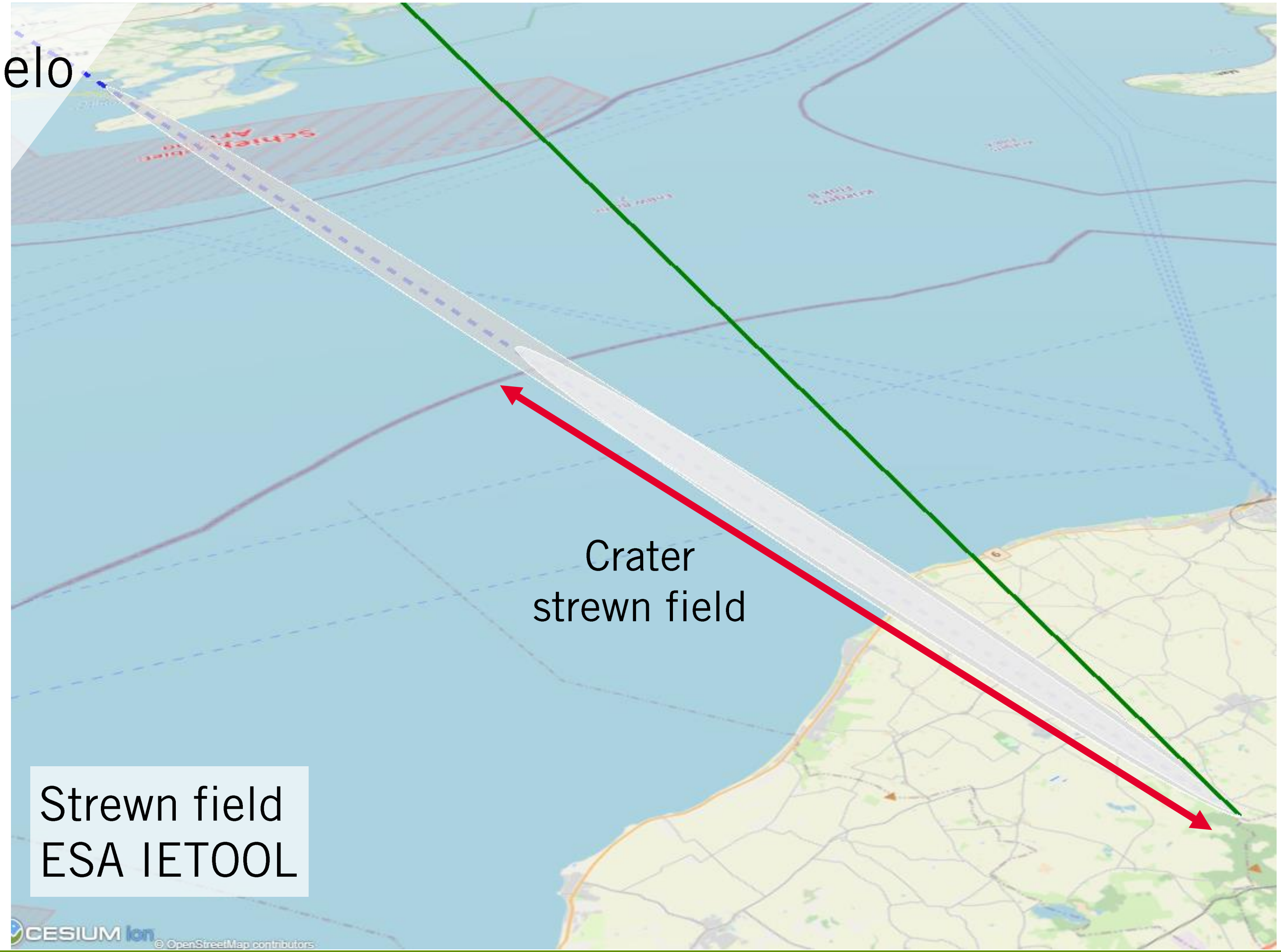
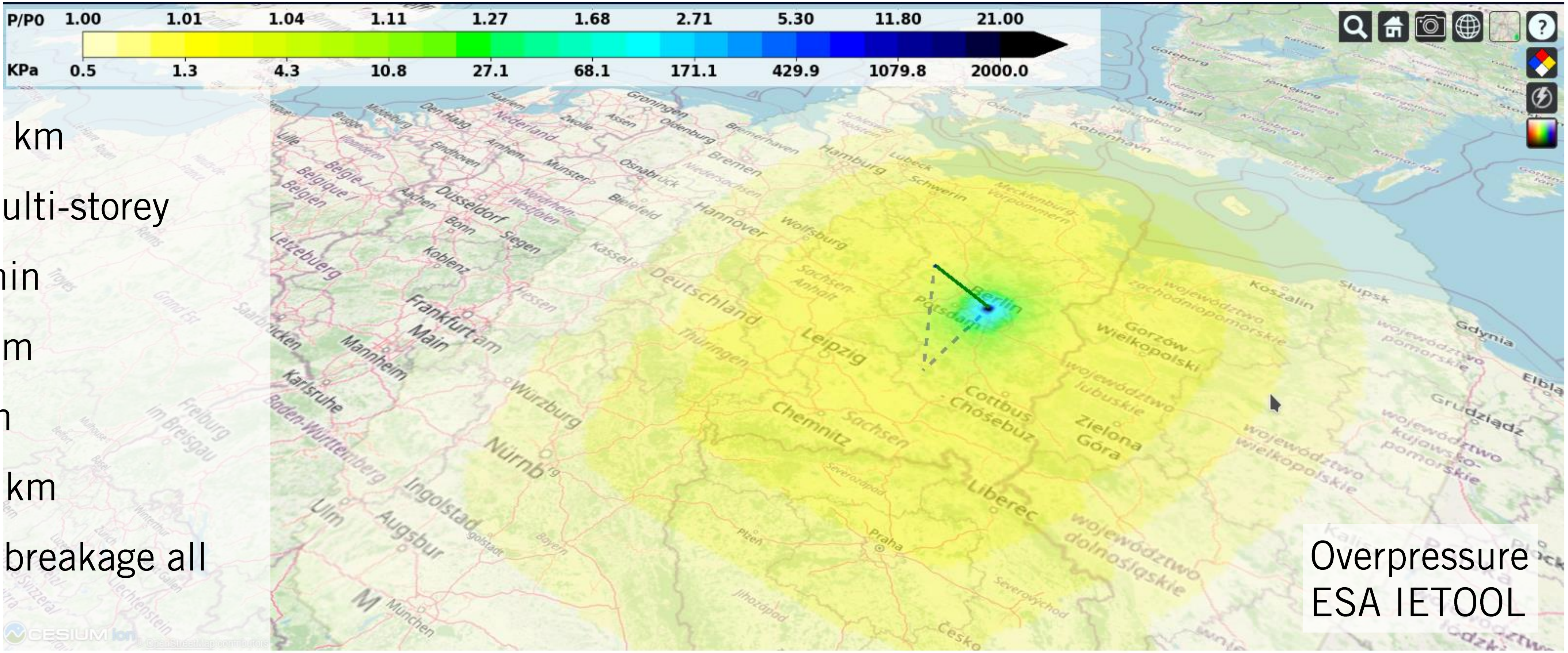
Sufficient agreement & reasonable overprediction



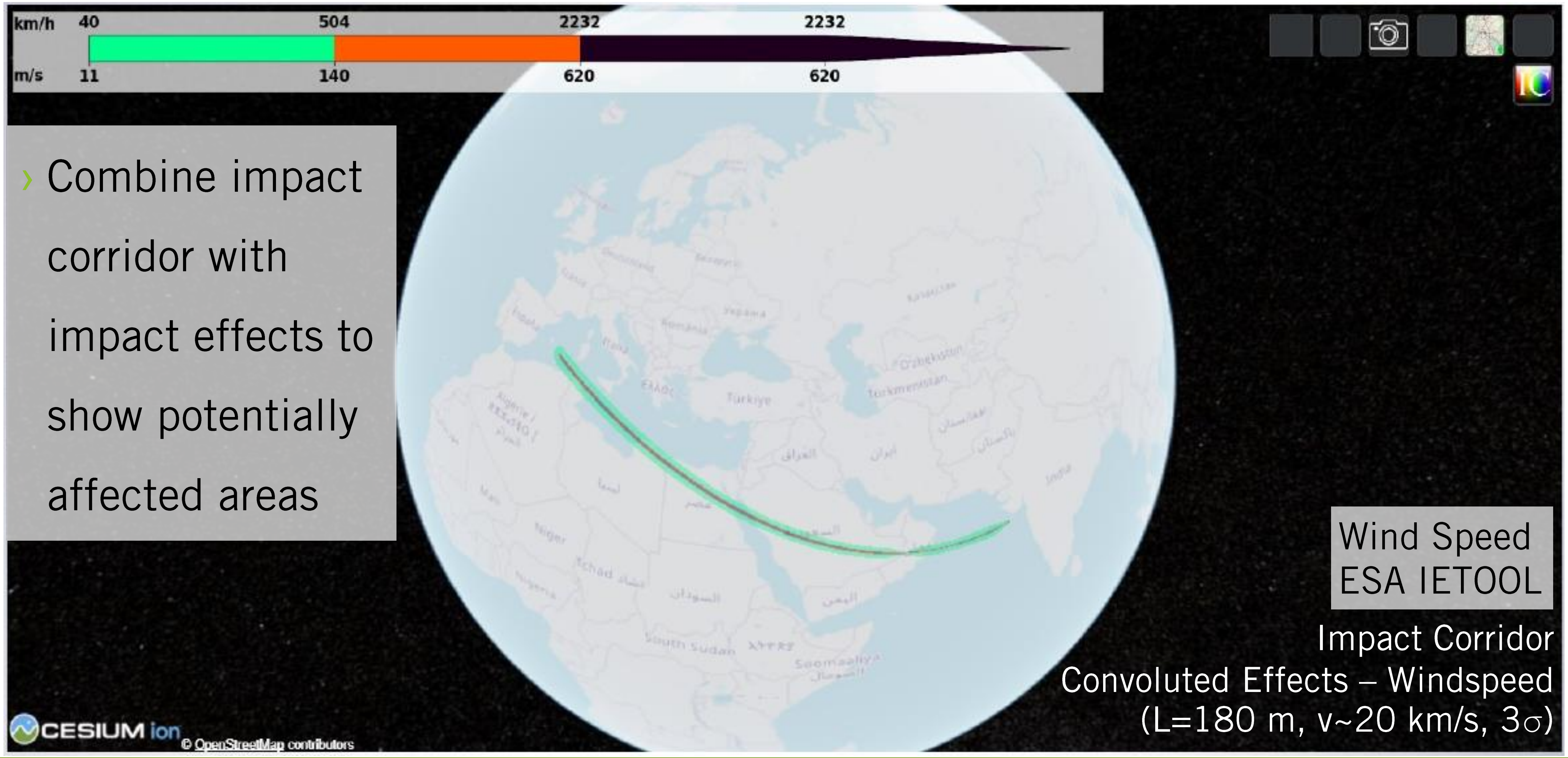
Application to a Dimorphos-sized asteroid

Rocky asteroid, v=20 km/s, L=170 m, ϑ=45°



- Crater of D~2 km
- Collapse of multi-storey buildings within 40 km x 25 km
- Treefall within ~90 km x 70 km
- window glass breakage all over Germany

Trajectory Uncertainties



- Combine impact corridor with impact effects to show potentially affected areas

Wind Speed
ESA IETOOL

Impact Corridor
Convoluted Effects – Windspeed
(L=180 m, v~20 km/s, 3σ)

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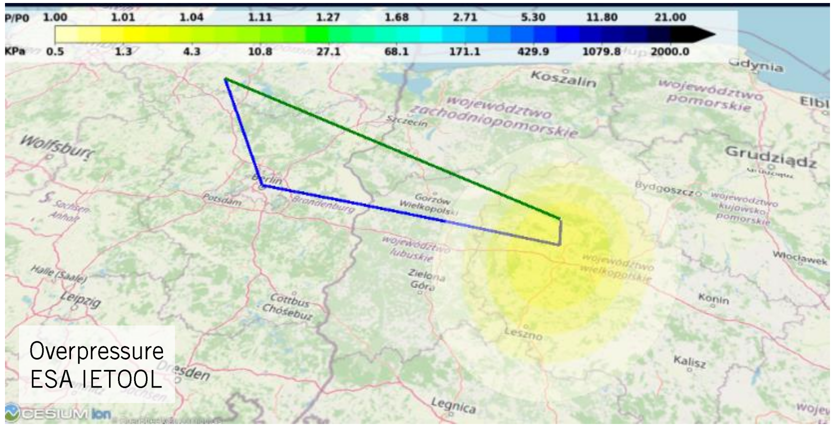
Conclusion



- We have developed a tool to do:
  - fast and accurate impact predictions for small asteroids (<50 m for irons, <200 m for rocks)
  - visualise impact effects and impact corridor on a map

  → tool is used by ESA experts to provide information for emergency agencies
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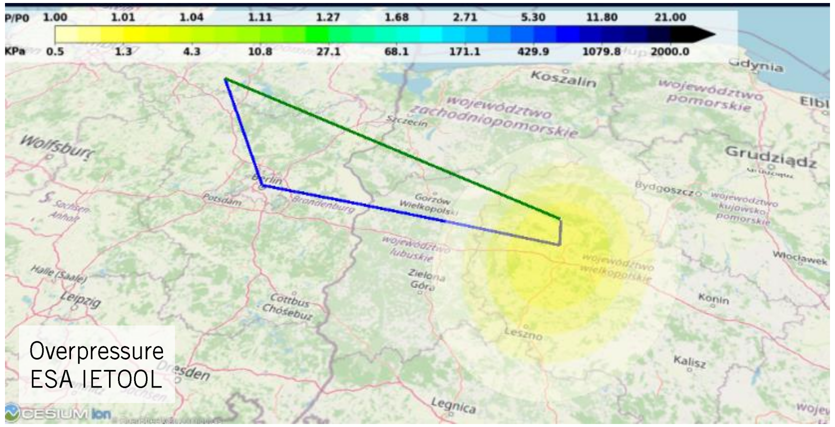

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Thank you for you attention!

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Thank you and Good Bye

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IETOOL Flow Chart - Irons

Computational module input:
v, *L*, *θ*, type

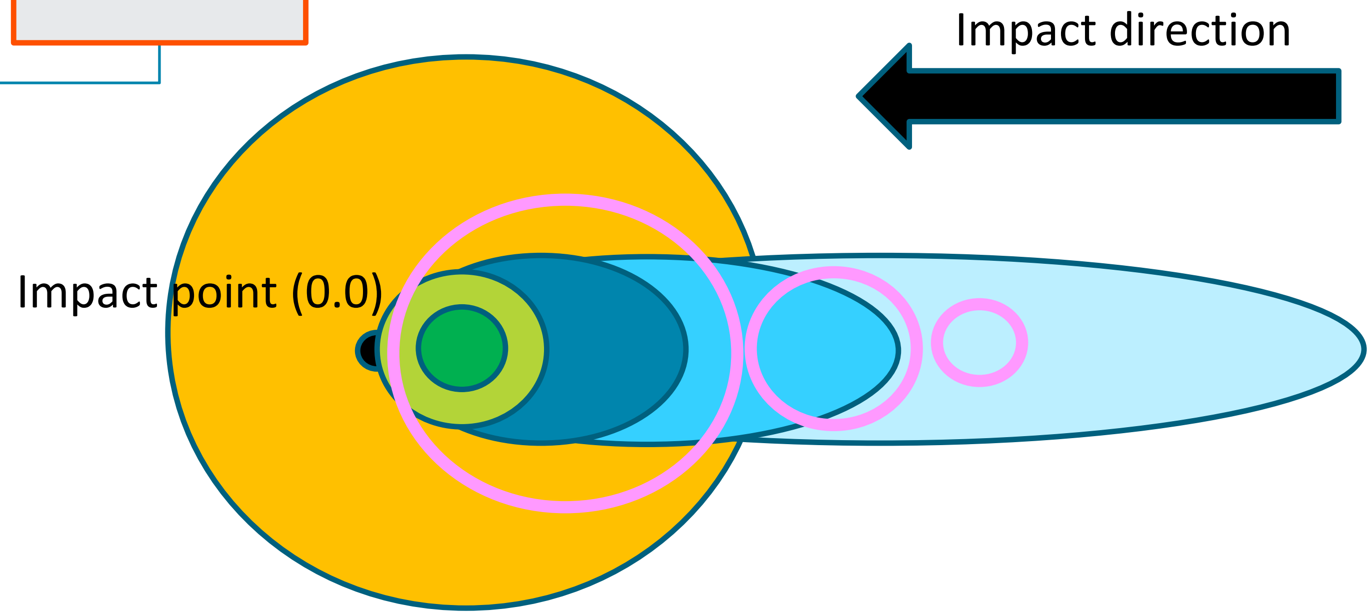
type → IRON → D>30 m

NO → modified Separate Fragment approach

YES → SOVA database

OUTPUT:
- Windspeed (crater & airburst)
- Overpressure (crater & airburst)
- Radiation
- Single maximum crater & ejecta
- strewn field size (craters)
- strewn field size (meteorites)

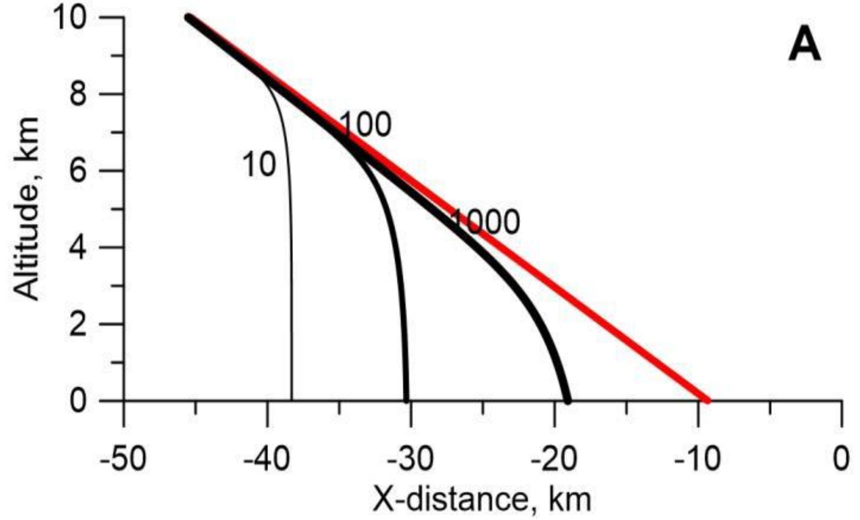
Updated approach

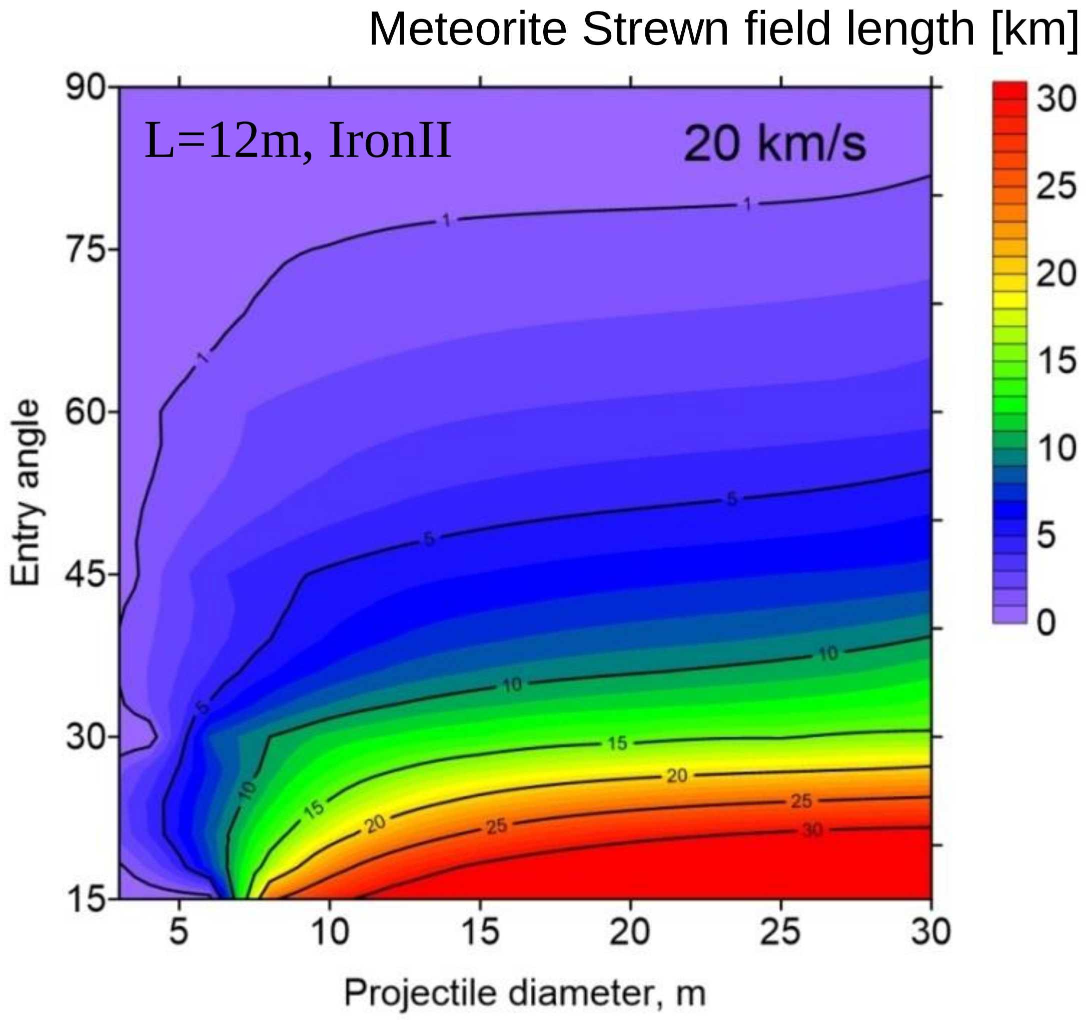


Small Irons: Strewn Field Size

Assumptions:

1. Consider separation into 3 fragments:
2. Largest crater forms by residual energy of largest fragment
3. Crater strewn field can be defined by descent of second fragment (1 ton or more)
4. Meteorite strewn field can be defined by descent of smallest fragment (10 kg or more)
5. Crater formation and meteorite finds occur most probably in the corresponding strewn field ellipses

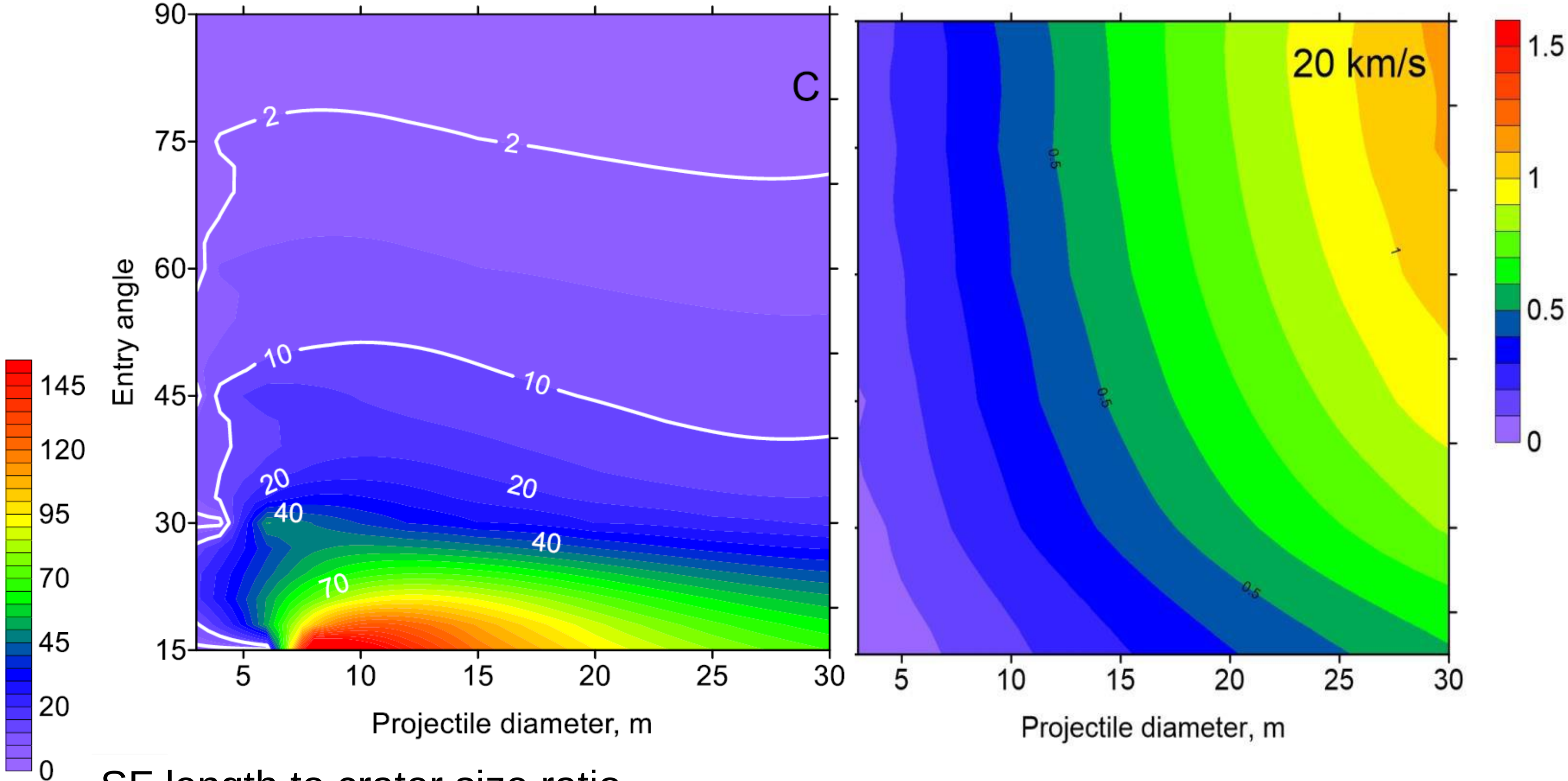




Small Irons: Strewn Field Size

- Size-velocity-angle of the largest fragment + scaling laws = crater size
- Double-triple crater size = ejecta blanket
- In observed SF craters are in the range of 10 – 300 m

Largest Crater & Ejecta [km]



SF length to crater size ratio

Small Irons: Airburst

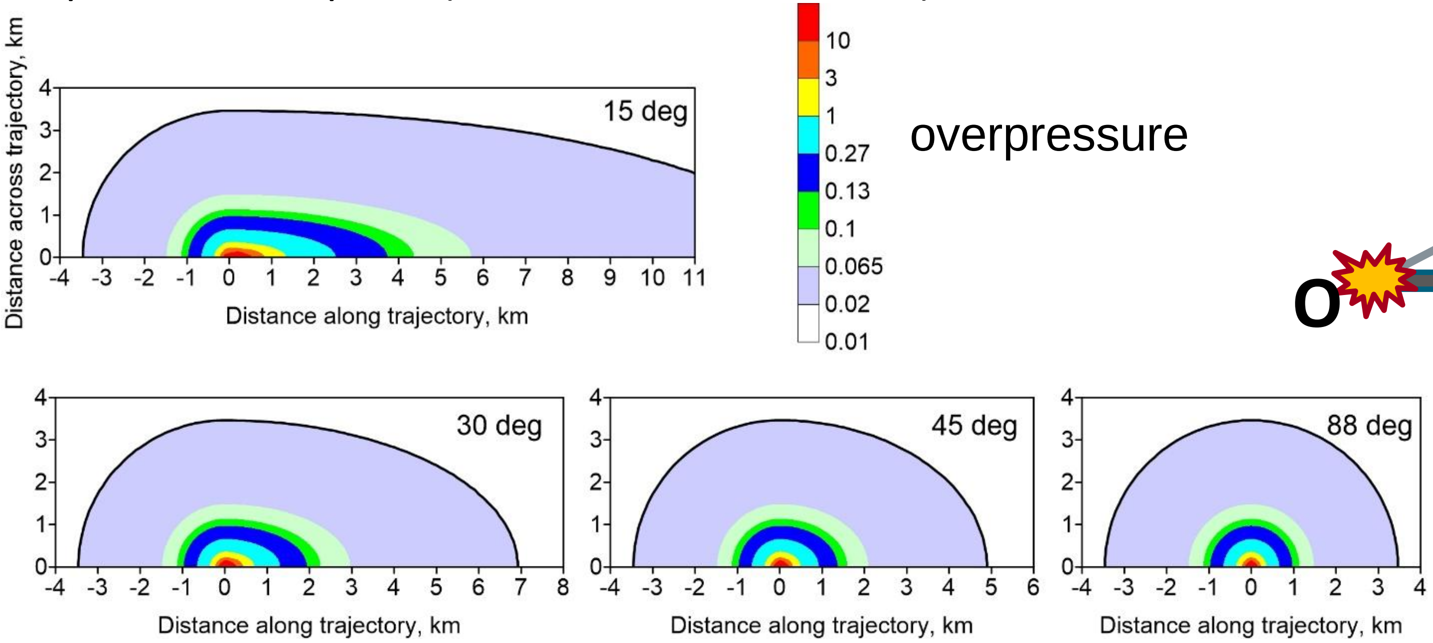
Assumptions:

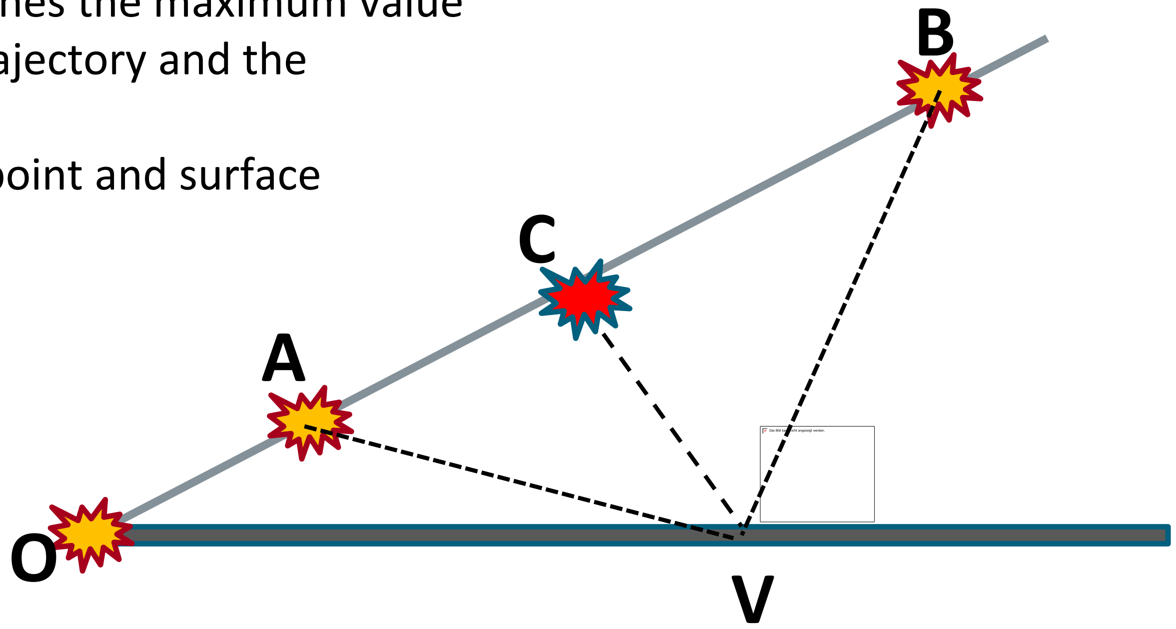
1. An airburst could happen at any point of the trajectory

2. There is no energy loss except at the burst point (i.e., no deceleration or ablation of meteoroid)

3. At any point **V** below the trajectory airburst overpressure reaches the maximum value if an airburst occurs at point **C** (shortest distance between the trajectory and the observer).

4. Overpressure at **V** point is a maximum between airburst at **C**-point and surface explosion at **O**- point (Collins et al. 2005, 2017).





Overpressure ($dP=P/P0 -1$) after a 1-kt asteroid entering the atmosphere at various angles.