Airburst-Generated Tsunami by Various Coupling Mechanisms

SAND2017-4941C

Mark Boslough
Sandia National Laboratories

Vasily Titov
NOAA Center for Tsunami Research

2017 IAA Planetary Defense Conference

Tokyo, Japan, May 15-19, 2017

This project was funded by NASA, NNSA, and NOAA

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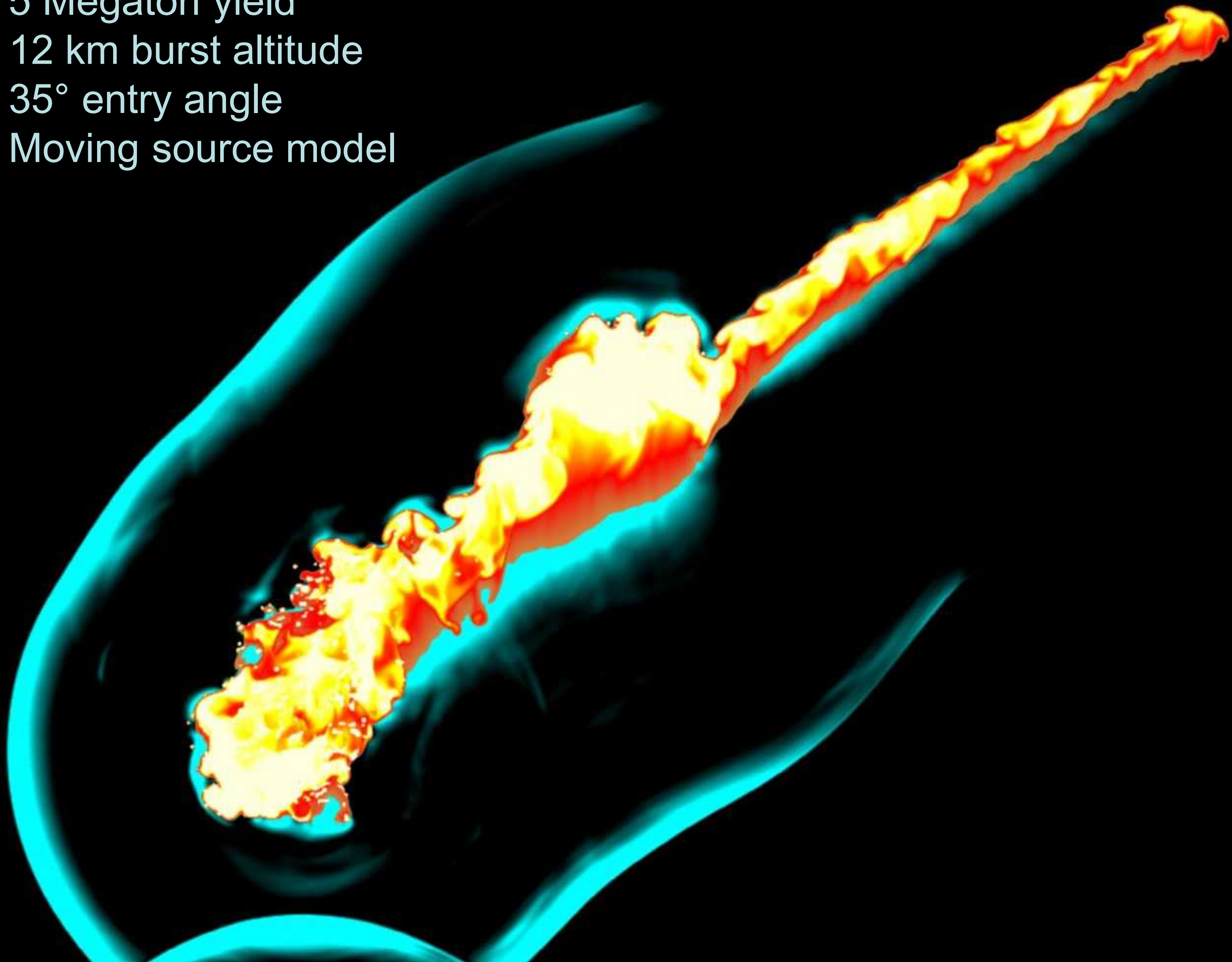
Outline

1. Review: Airburst-generated “meteotsunami”
2. Proposed coupling mechanisms:
   - Blast wave and rarefaction
   - Expanding toroidal vortices
   - Plume ejection and collapse
3. Air blast coupling from large impact

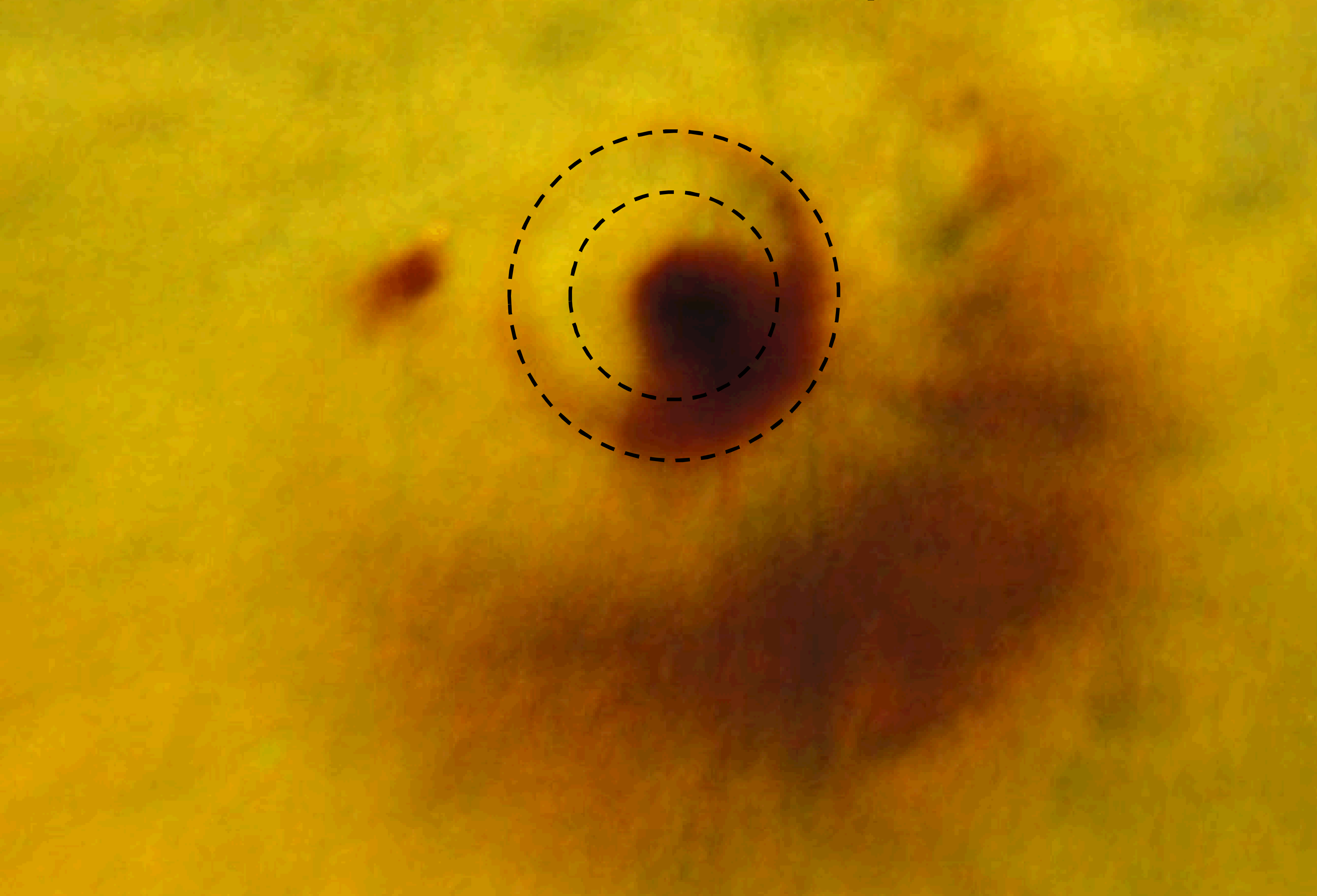
1. Review: Airburst “meteotsunami”

Tunguska

- 5 Megaton yield
- 12 km burst altitude
- 35° entry angle
- Moving source model

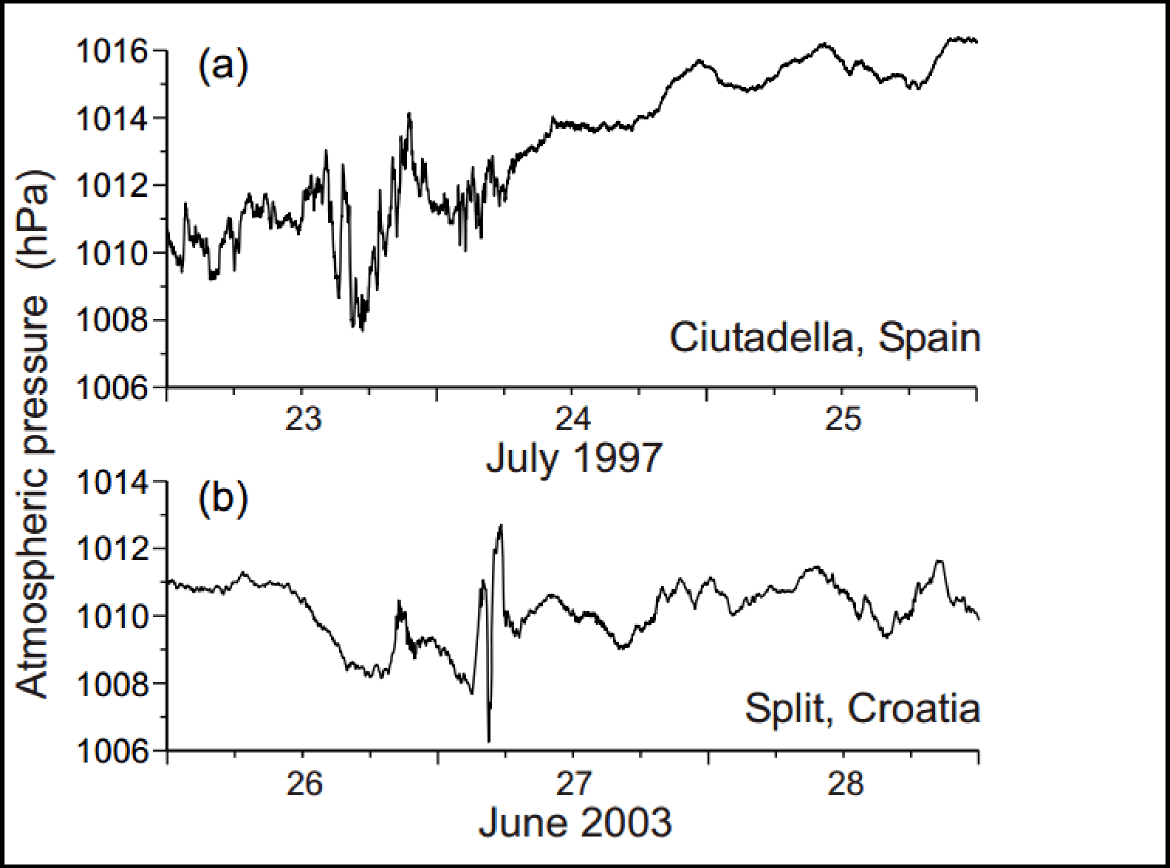


“Tsunami” on Jupiter

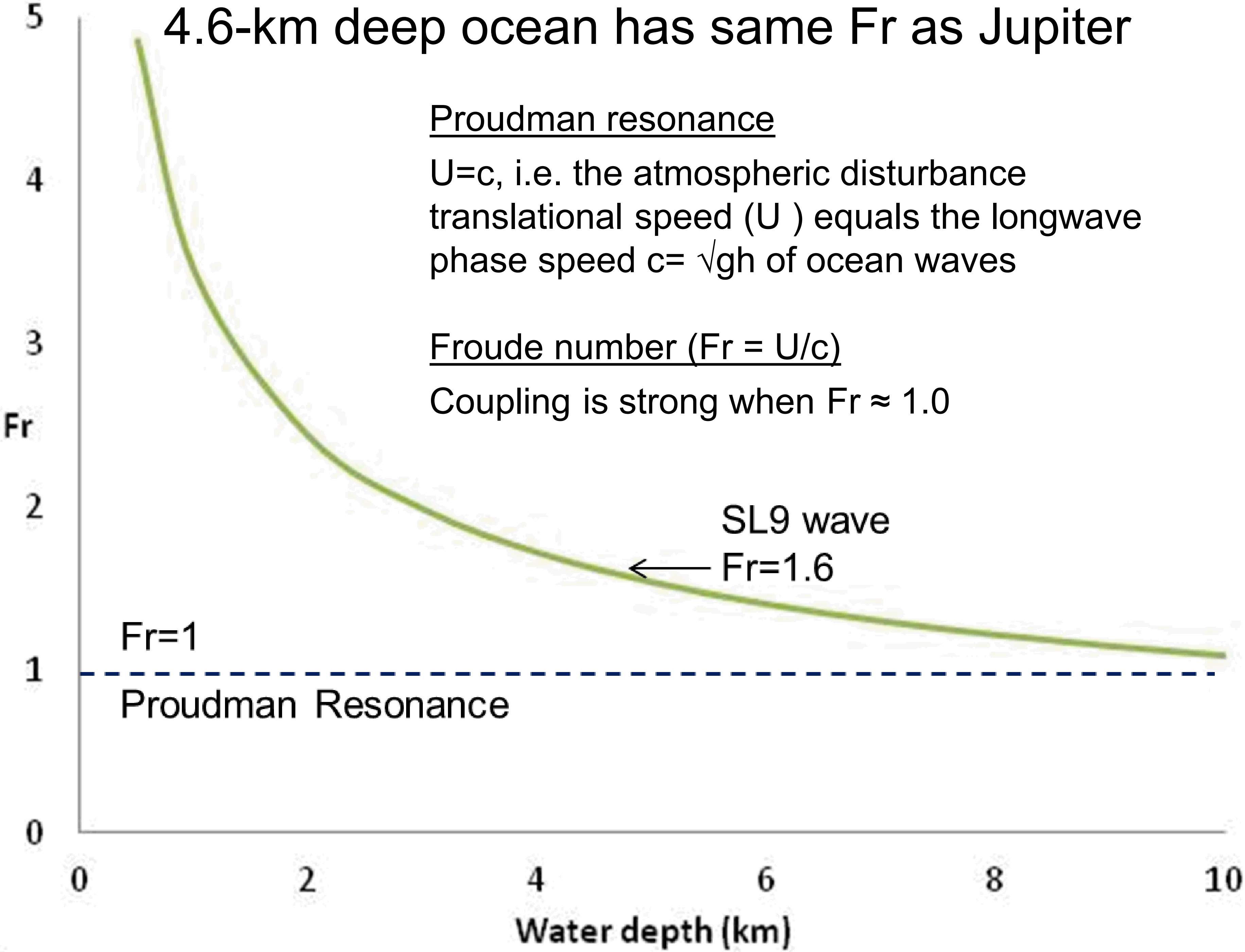


S. Monserrat et al.,
"Meteotsunamis: atmospherically induced destructive ocean waves in the tsunami frequency band."
Nat. Hazards Earth Syst. Sci., 6, 1035–1051, 2006

"…even during the strongest events, the atmospheric pressure oscillations at these scales typically reach only a few hPa that correspond only to a few cm of sea level change."



4.6-km deep ocean has same Fr as Jupiter



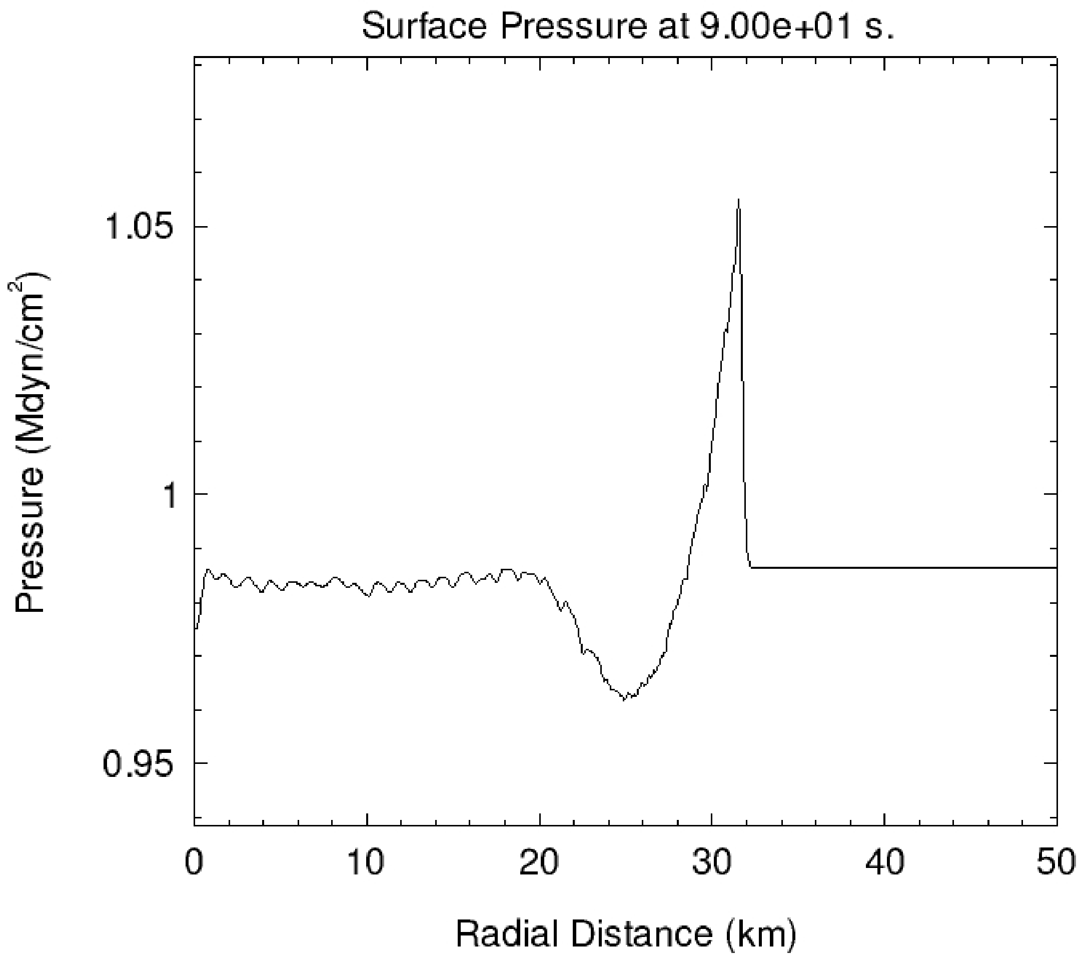
2. Proposed coupling mechanisms

- Blast and rarefaction waves
- Expanding toroidal vortices
- Plume ejection and collapse

2. Proposed coupling mechanisms

- **Blast and rarefaction waves**
- Expanding toroidal vortices
- Plume ejection and collapse

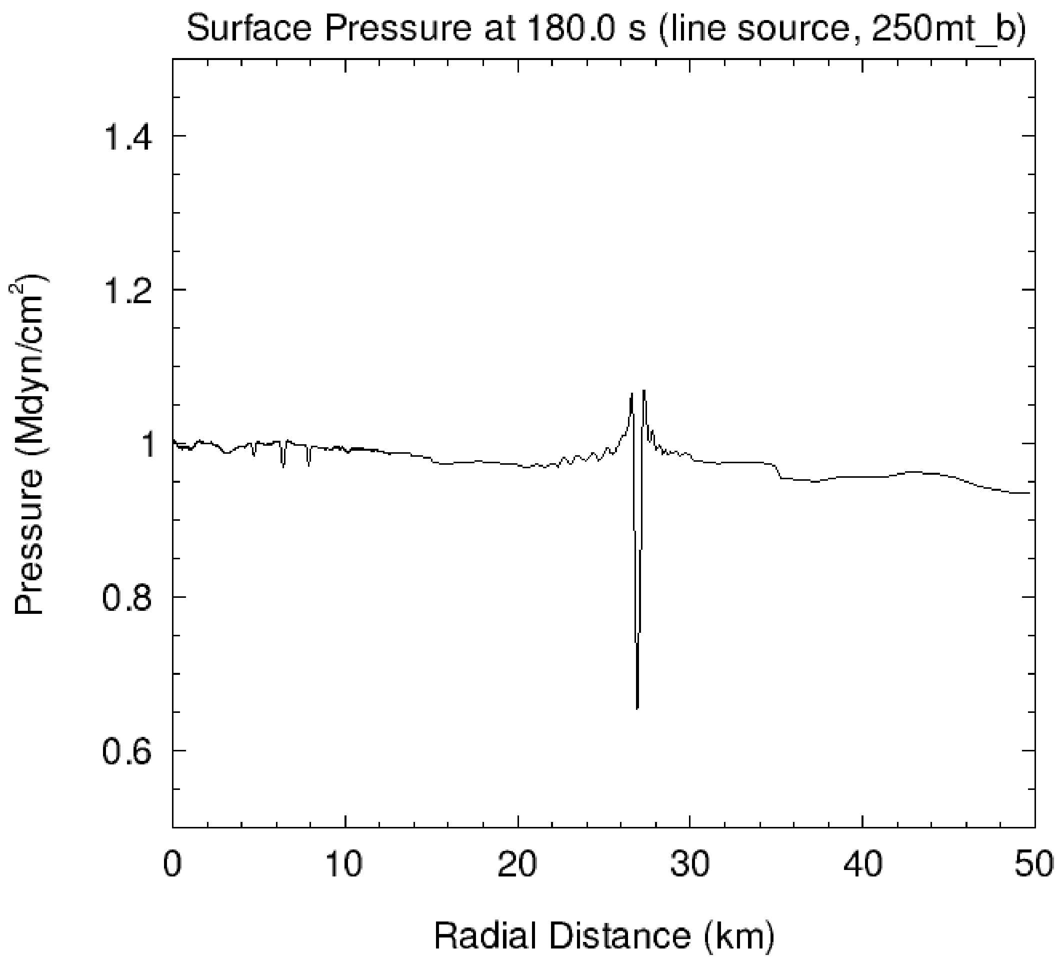
Blast and rarefaction waves



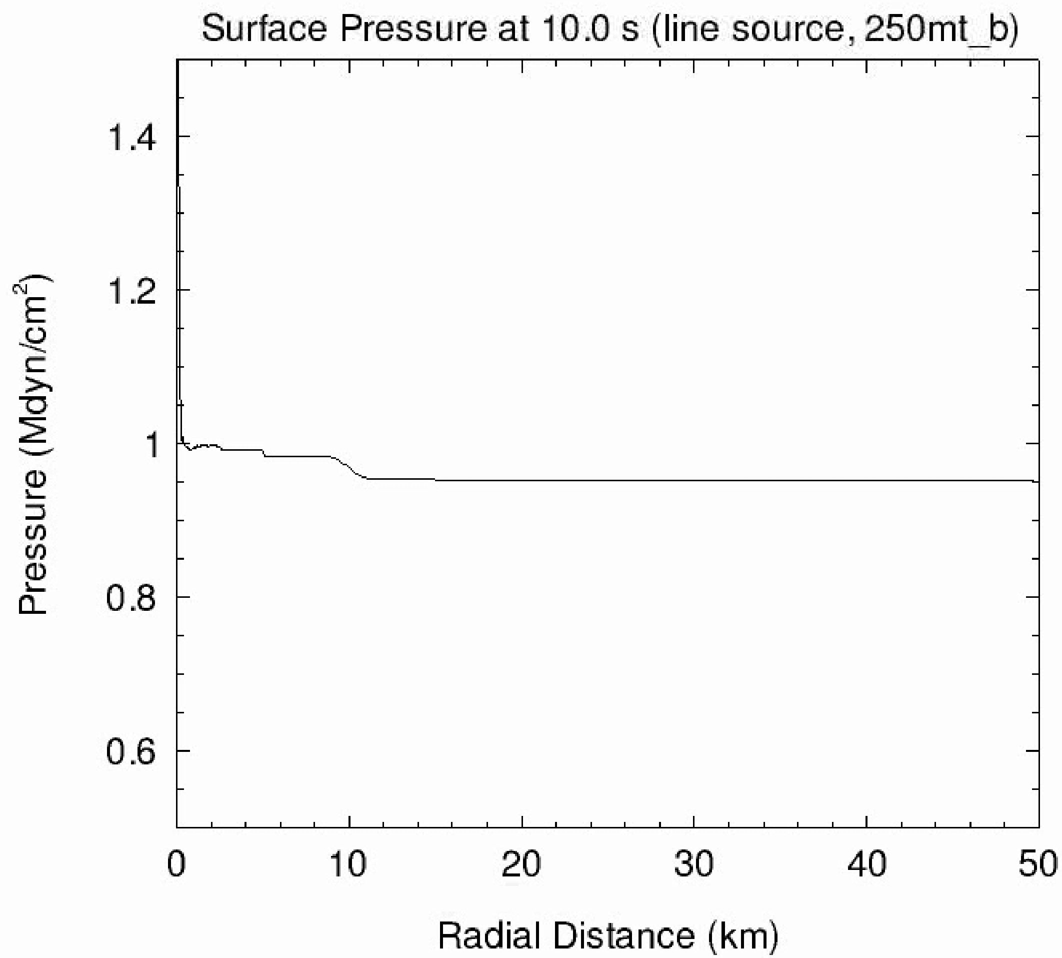
2. Proposed coupling mechanisms

- Blast and rarefaction waves
- **Expanding toroidal vortices**
- Plume ejection and collapse

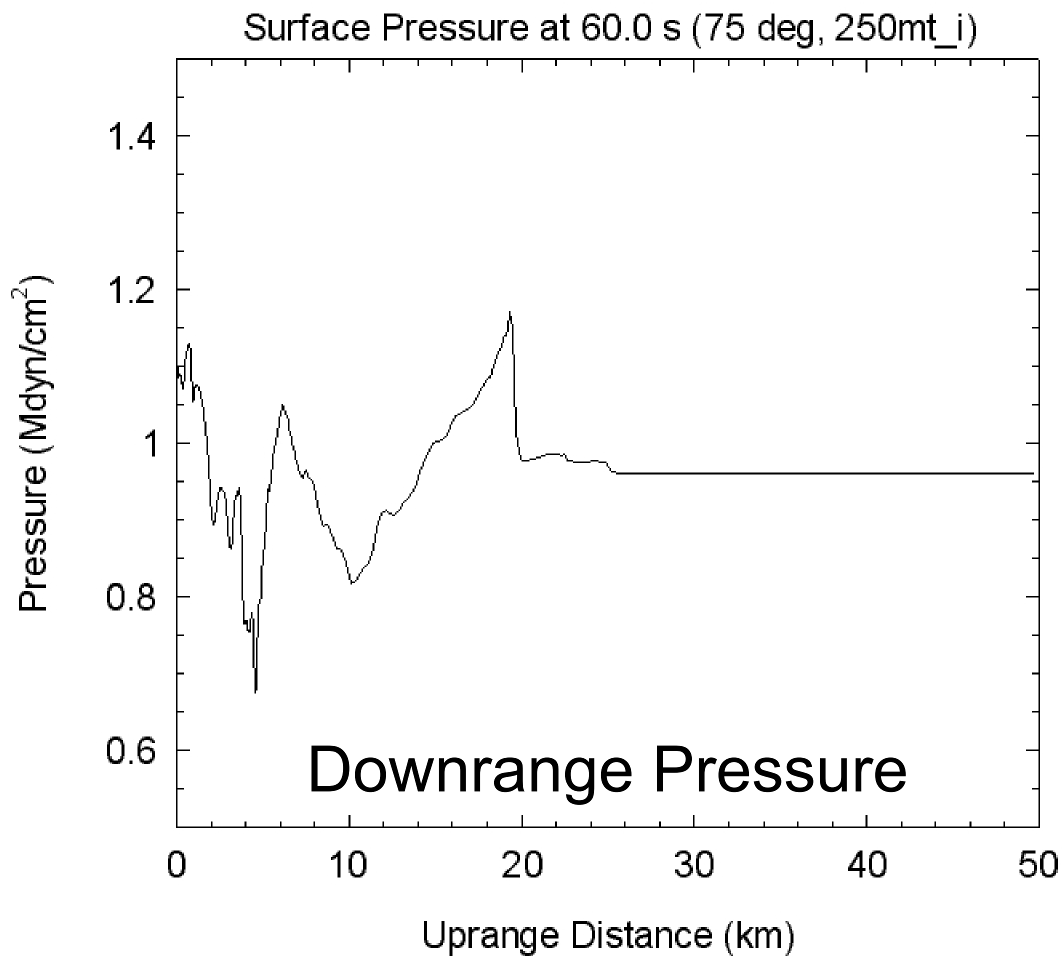
Expanding Toroidal Vortices



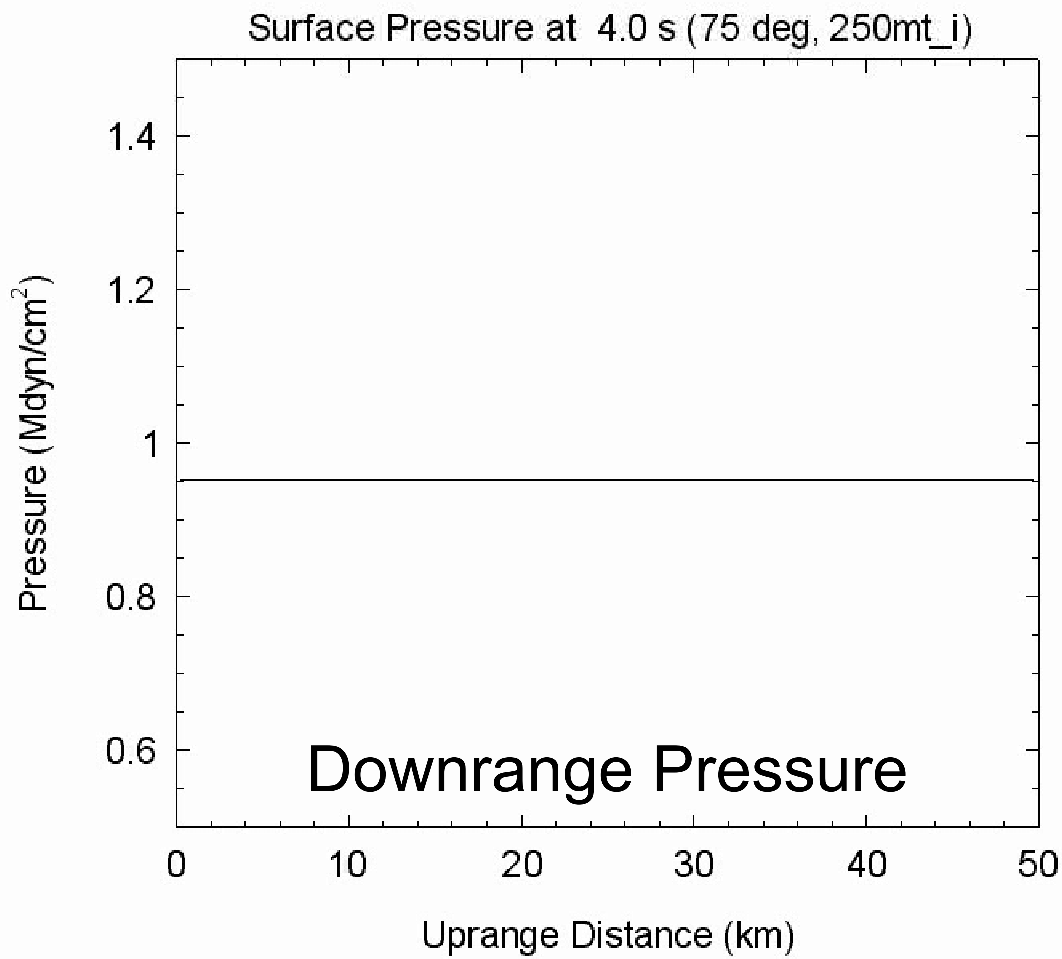
Pressure history movie (b): 250mt 2dc maxl=5 ~31m 90° Edep<100 km



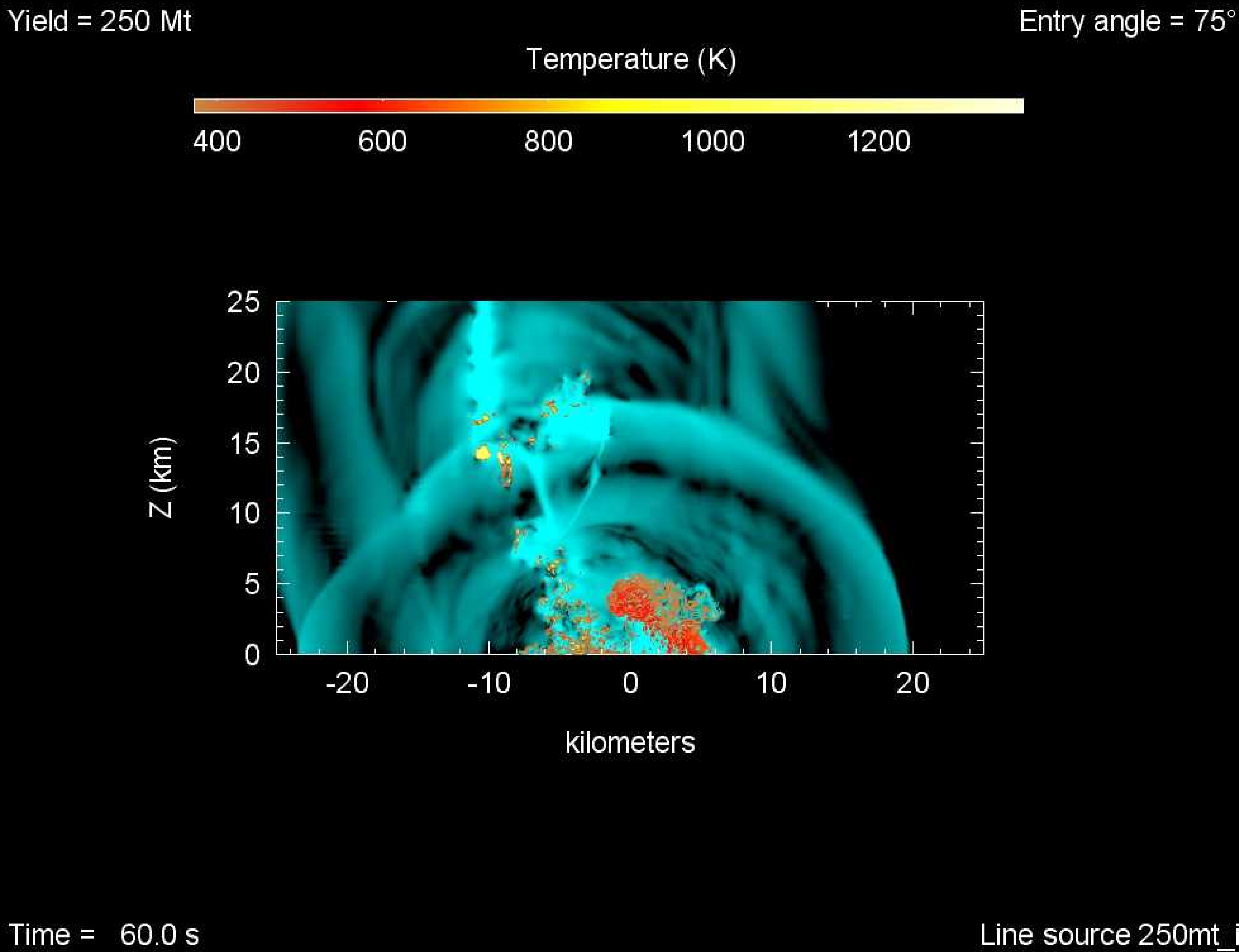
Pressure history movie (i): 250mt 2dc maxl=5 ~31 m 75° Edep<26 km



Pressure history movie (i): 250mt 2dc maxl=5 ~31 m 75° Edep<26 km



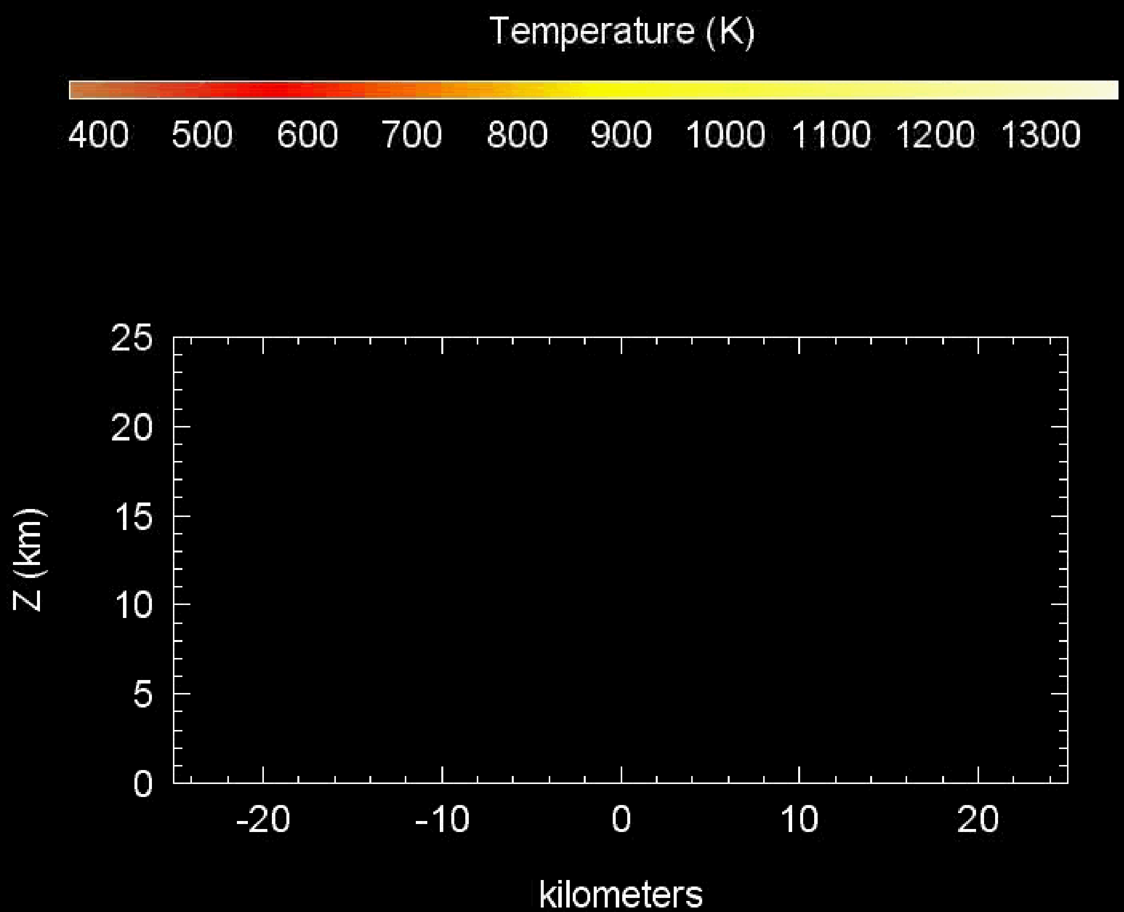
Cross-section movie (i): 250mt 2dc maxl=5 ~31 m 75° Edep<26 km



Cross-section movie (i): 250mt 2dc maxl=5 ~31 m 75° Edep<26 km

Yield = 250 Mt

Entry angle = 75°

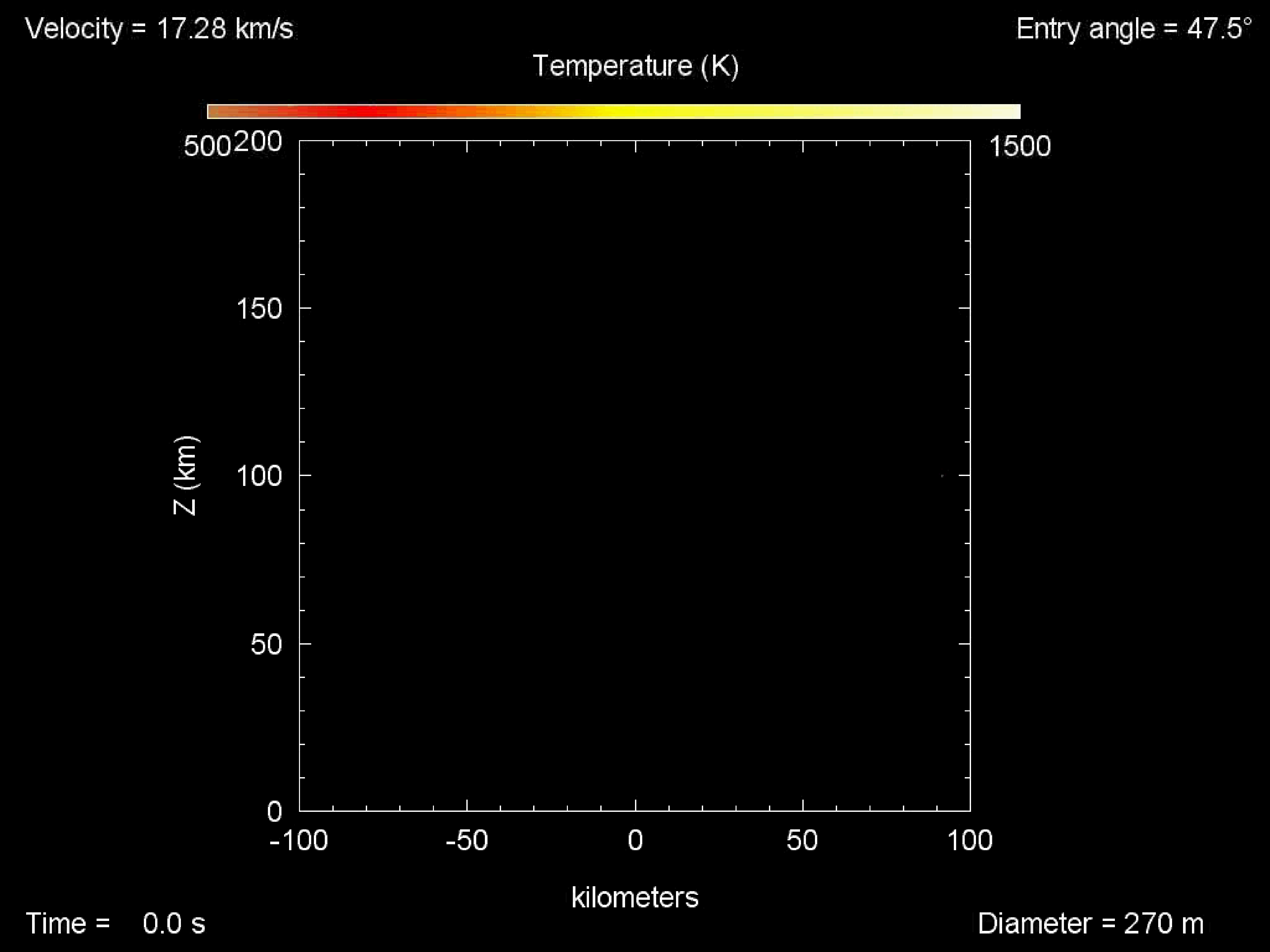


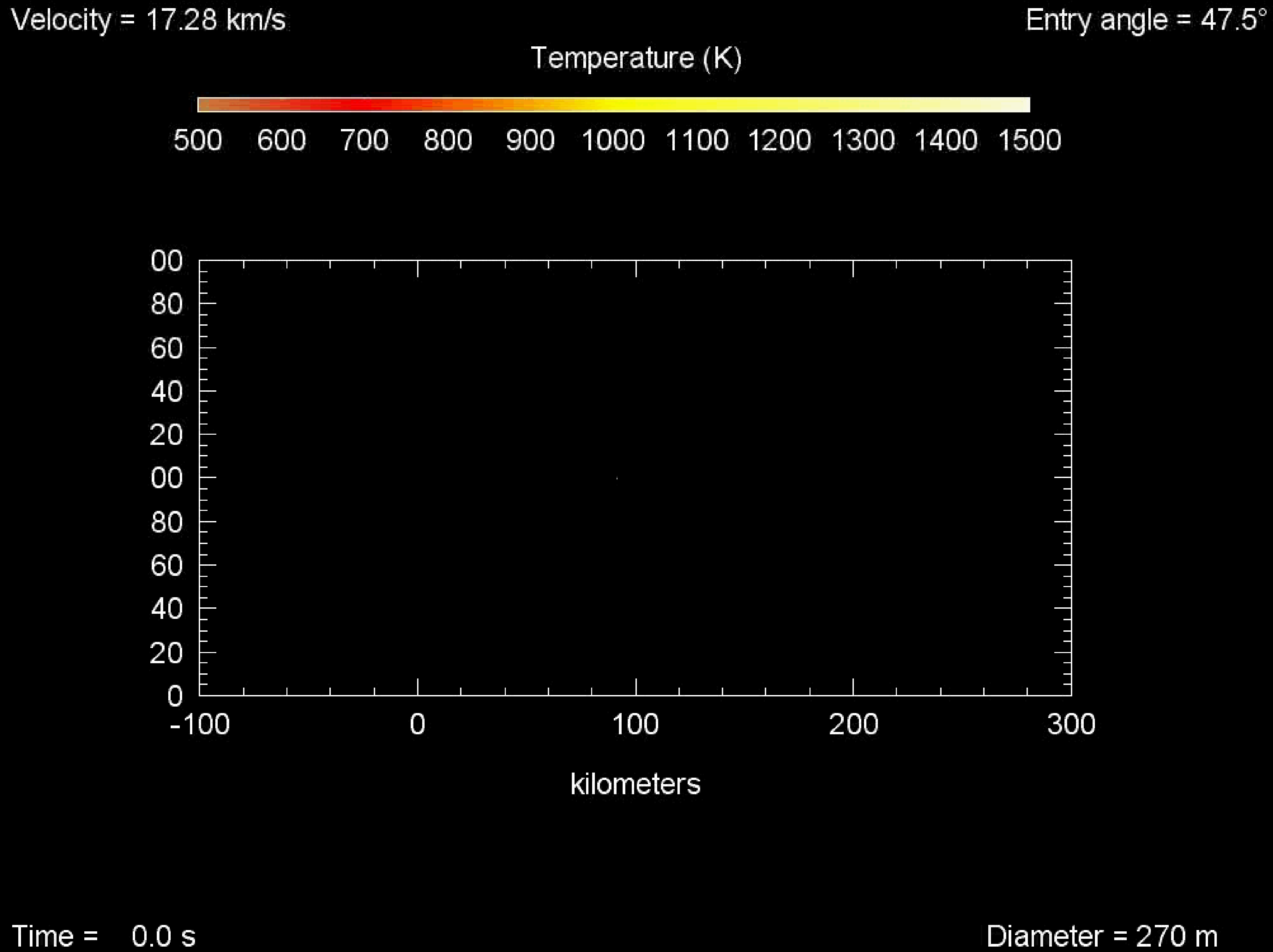
Time = 4.0 s

Line source 250mt_i

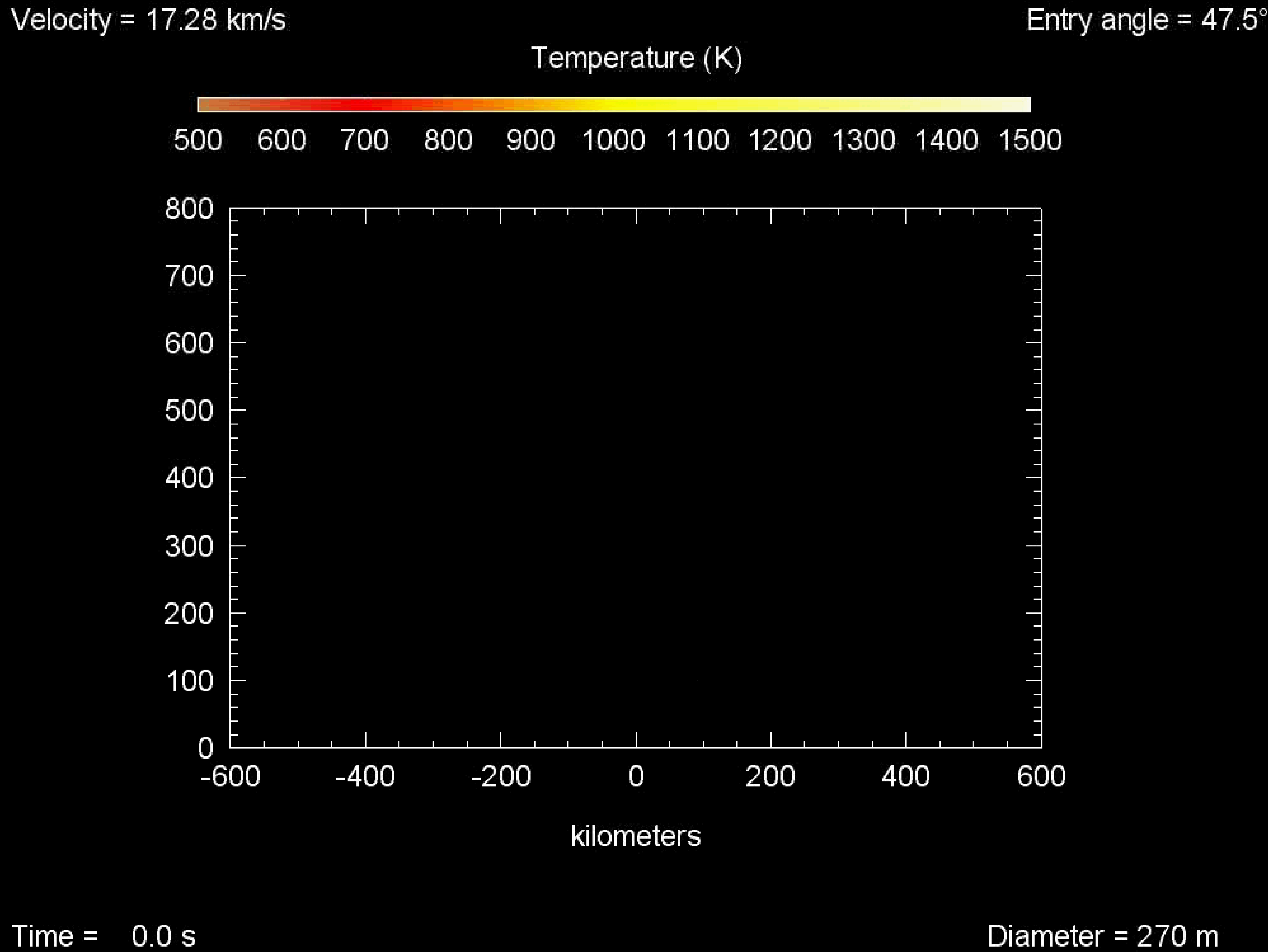
2. Proposed coupling mechanisms

- Blast and rarefaction waves
- Expanding toroidal vortices
- **Plume ejection and collapse**

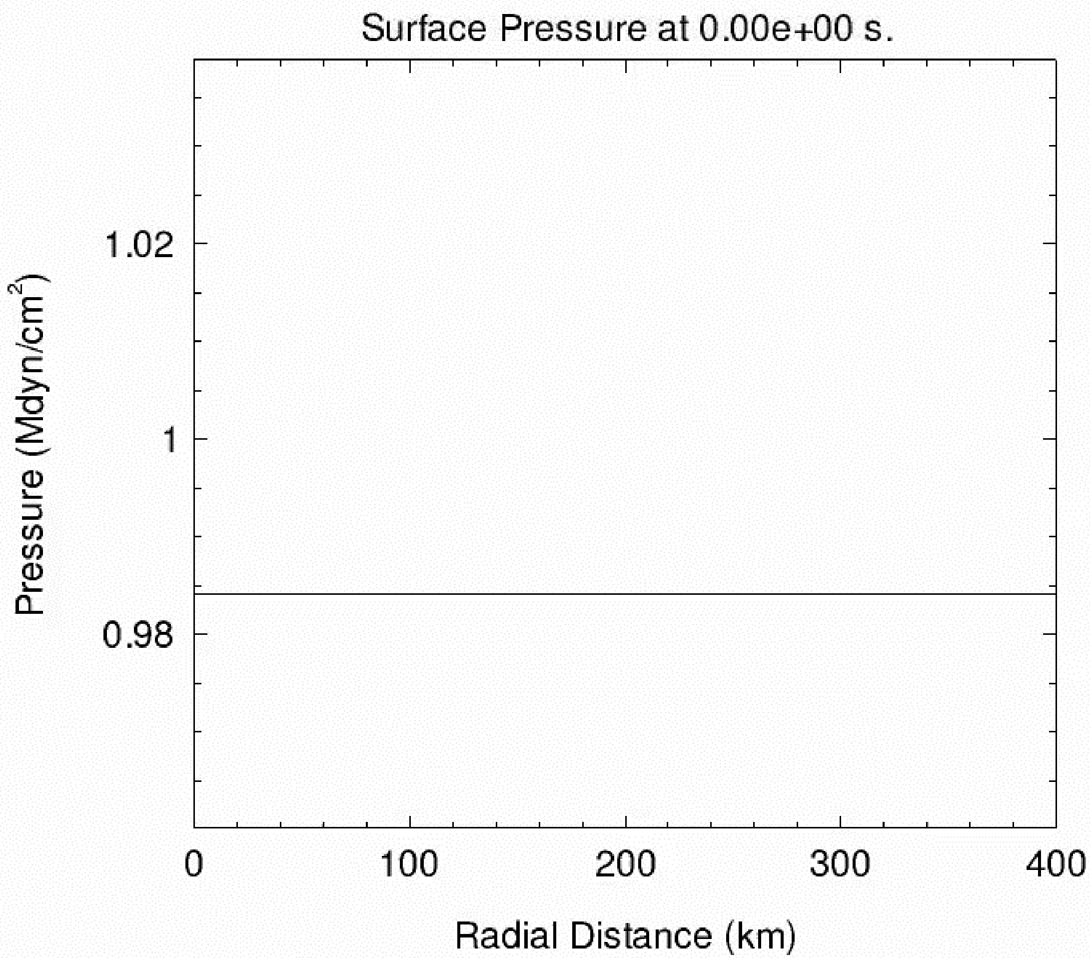

Velocity = 17.28 km/s
Entry angle = 47.5°
Temperature (K)
500
1500
200
150
100
50
0
Z (km)
-100
-50
0
50
100
kilometers
Time = 0.0 s
Diameter = 270 m



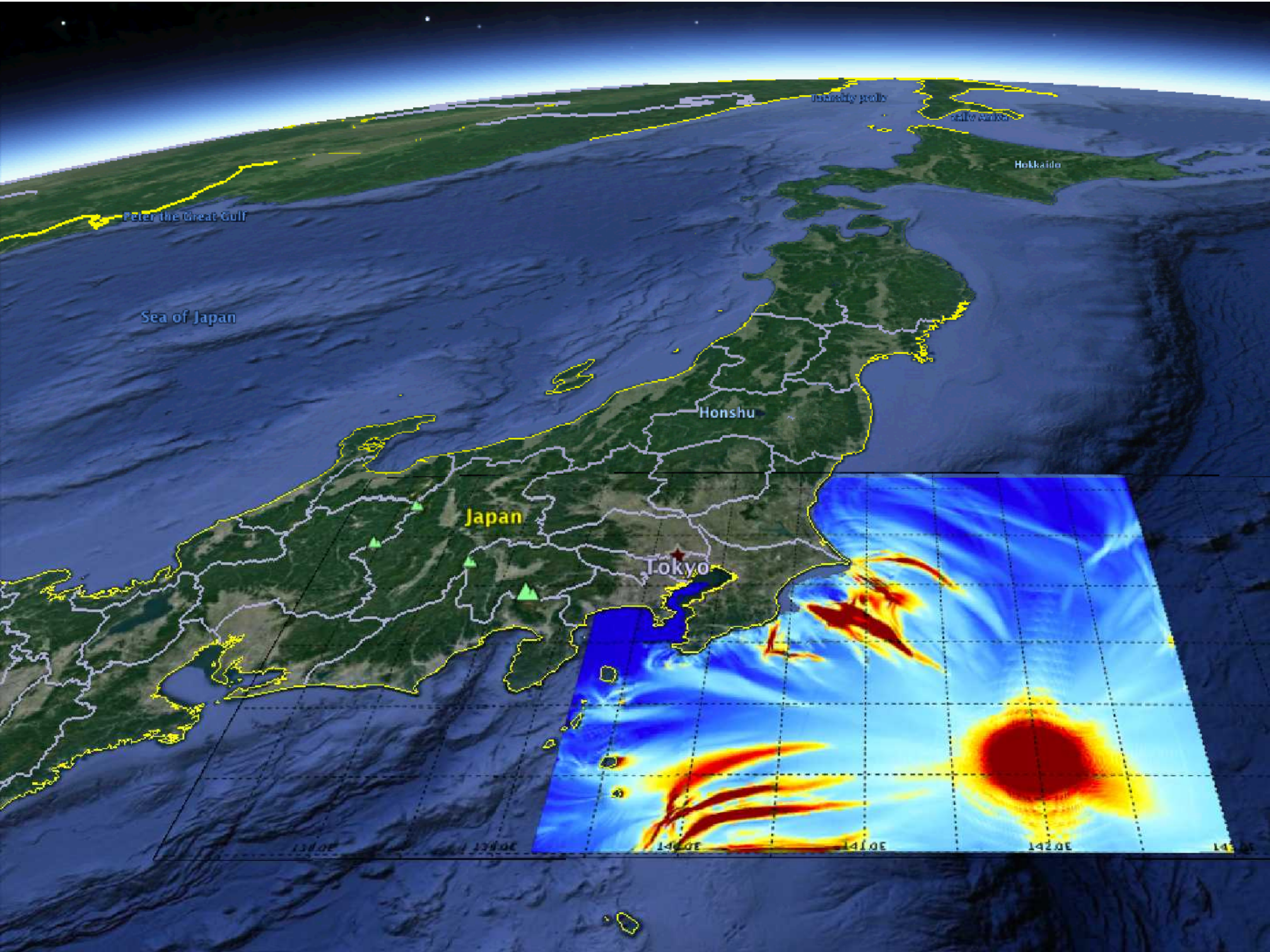
Velocity = 17.28 km/s
Entry angle = 47.5°
Temperature (K)
500 600 700 800 900 1000 1100 1200 1300 1400 1500
00
80
60
40
20
00
80
60
40
20
0
-100 0 100 200 300
kilometers
Time = 0.0 s
Diameter = 270 m



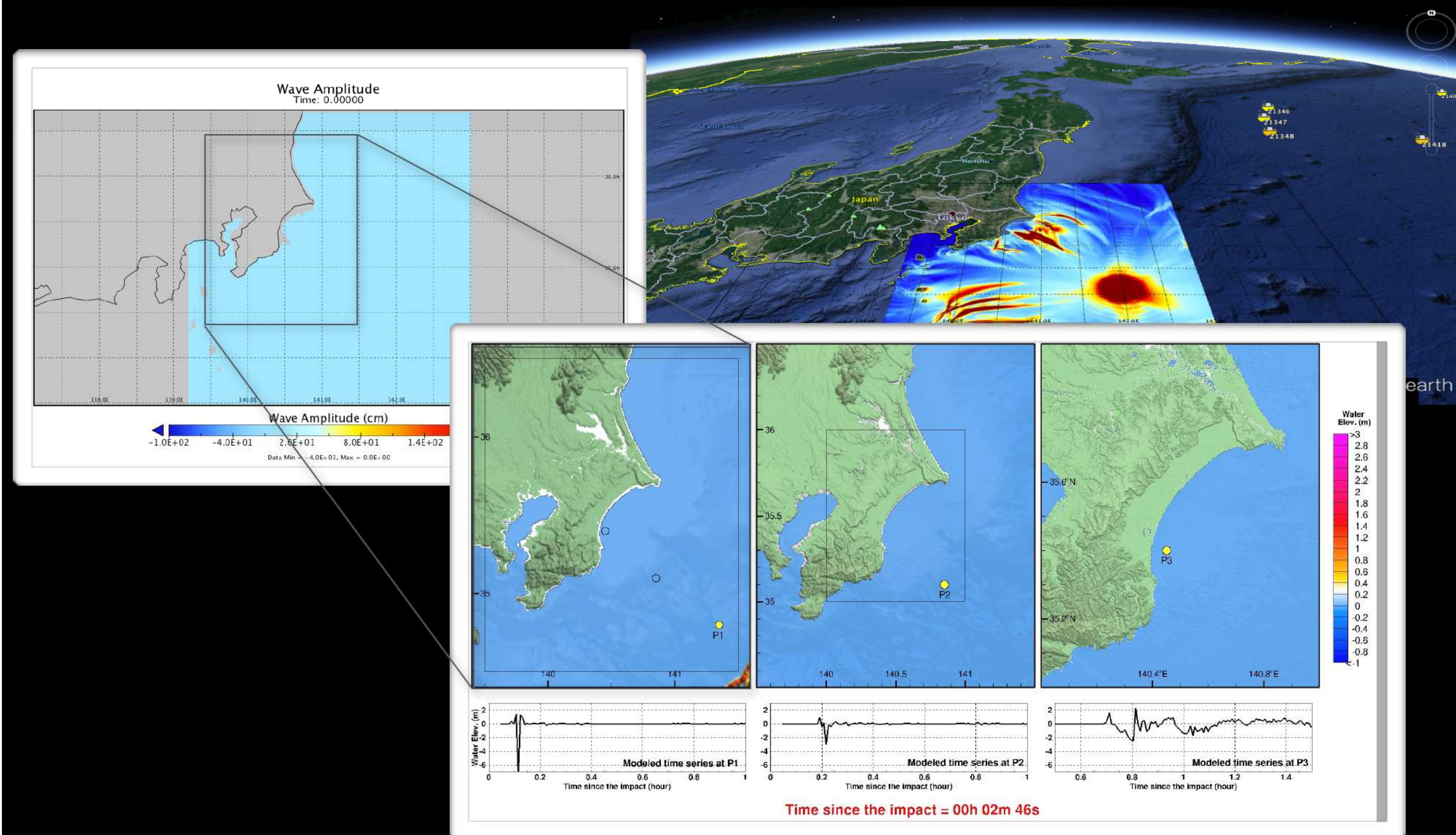
Velocity = 17.28 km/s
Entry angle = 47.5°
Temperature (K)
500 600 700 800 900 1000 1100 1200 1300 1400 1500
800
700
600
500
400
300
200
100
0
-600 -400 -200 0 200 400 600
kilometers
Time = 0.0 s
Diameter = 270 m

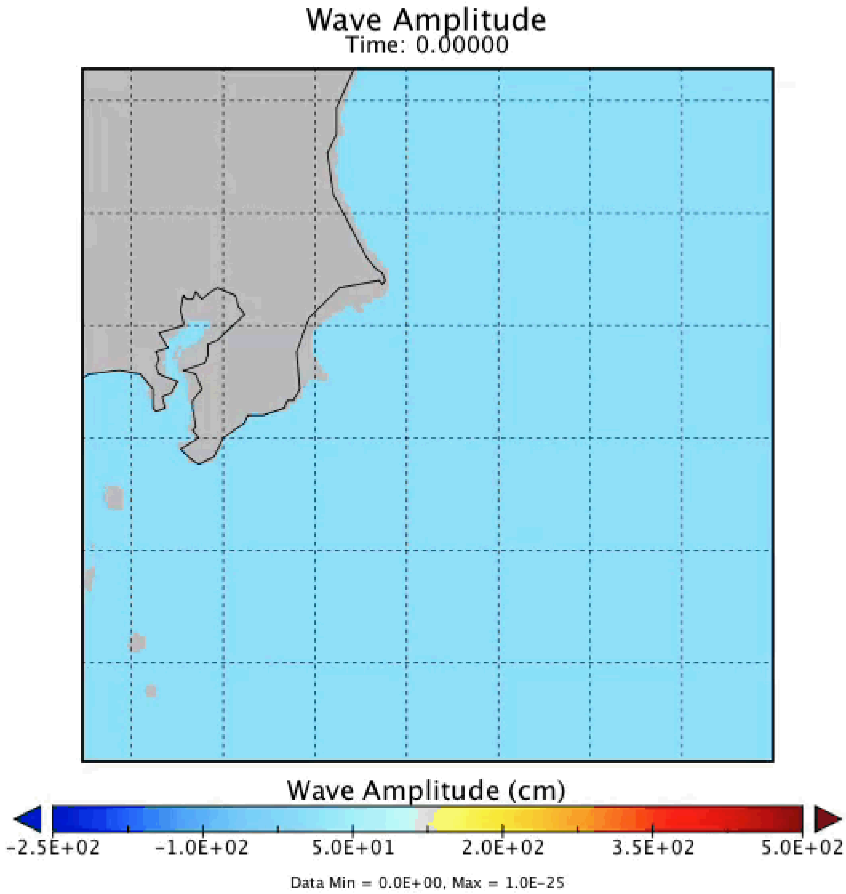

Surface Pressure at 0.00e+00 s.
Pressure (Mdyn/cm^2)
1.02
1
0.98
0
100
200
300
400
Radial Distance (km)

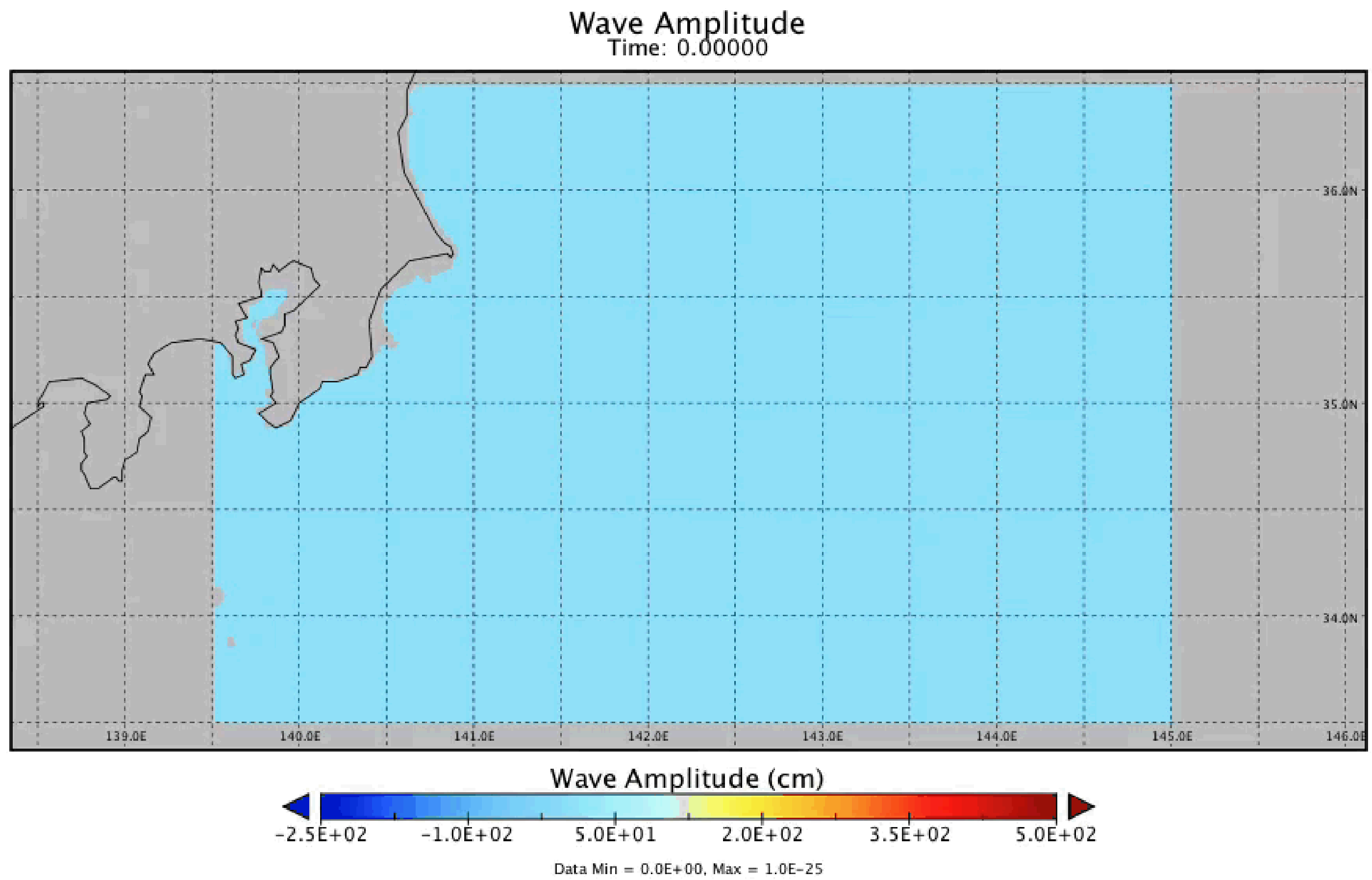
3. Air blast from large impact


Peter the Great Gulf
Hokkaido
Sea of Japan
Honshu
Japan
Tokyo
141.0E
142.0E

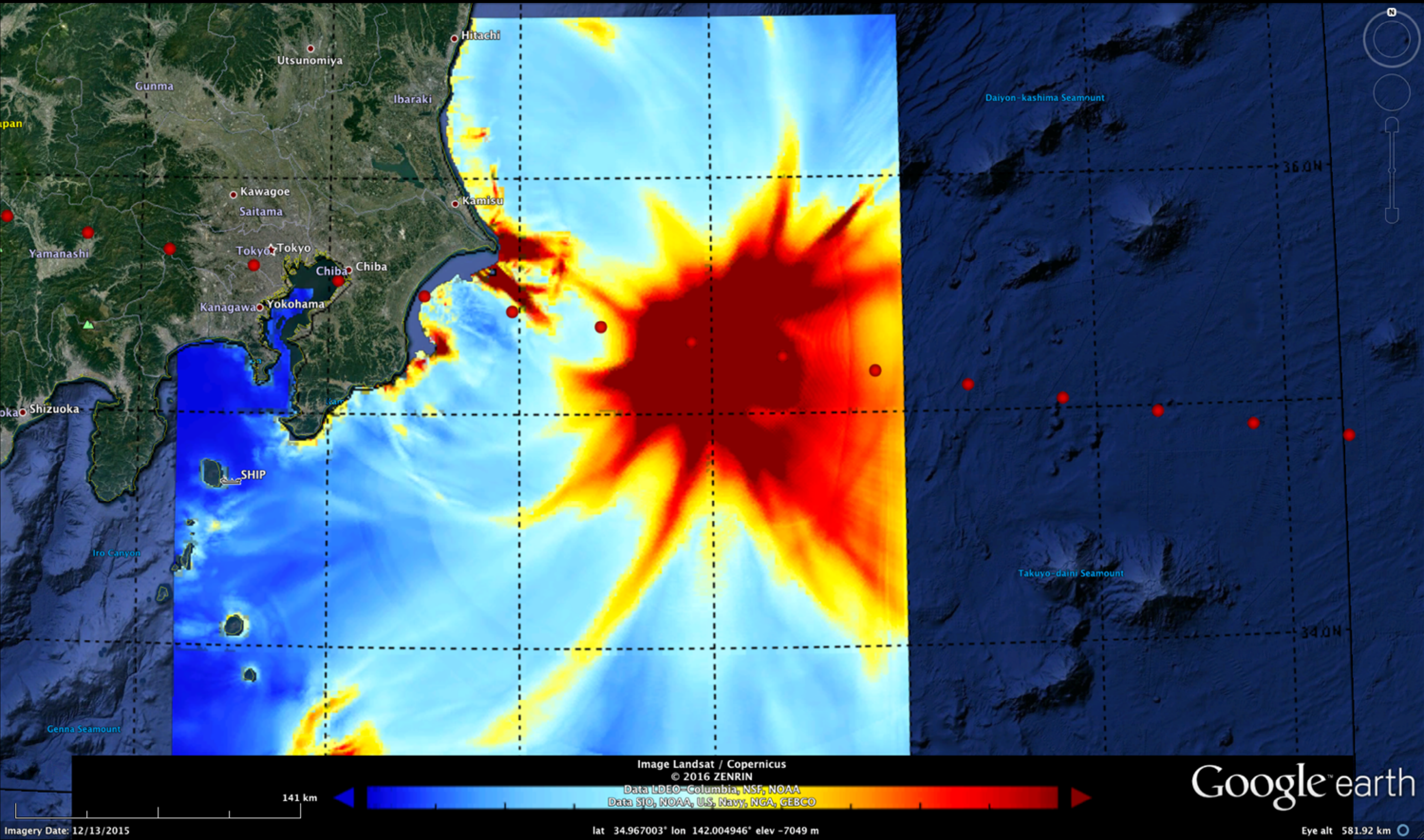
Source location sensitivities




Wave Amplitude
Time: 0.00000
Wave Amplitude (cm)
-2.5E+02
-1.0E+02
5.0E+01
2.0E+02
3.5E+02
5.0E+02
Data Min = 0.0E+00, Max = 1.0E-25

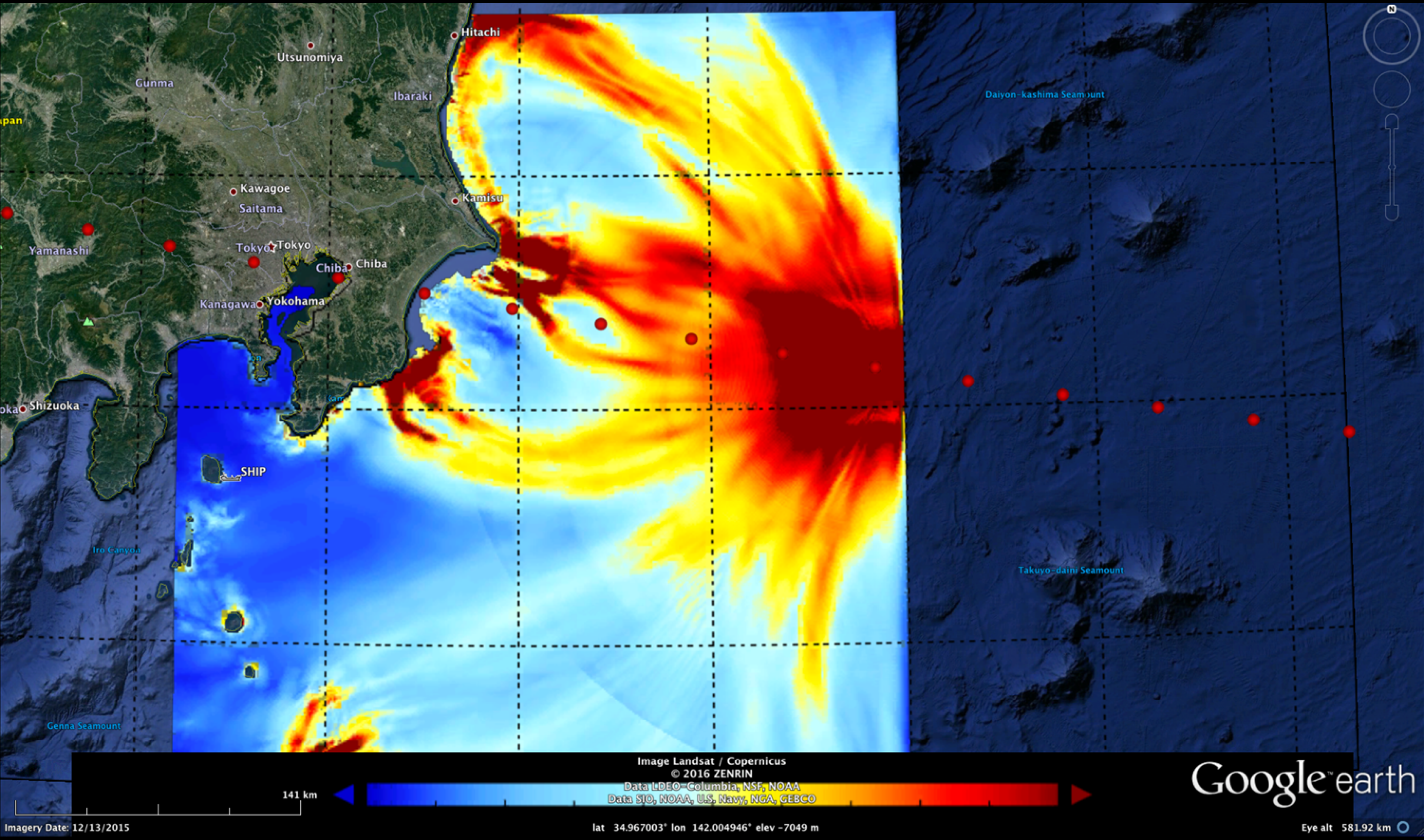

Wave Amplitude
Time: 0.00000
36.0N
35.0N
34.0N
139.0E
140.0E
141.0E
142.0E
143.0E
144.0E
145.0E
146.0E
Wave Amplitude (cm)
-2.5E+02
-1.0E+02
5.0E+01
2.0E+02
3.5E+02
5.0E+02
Data Min = 0.0E+00, Max = 1.0E-25

Maximum wave heights
Impact on shore-side of Japan Trench



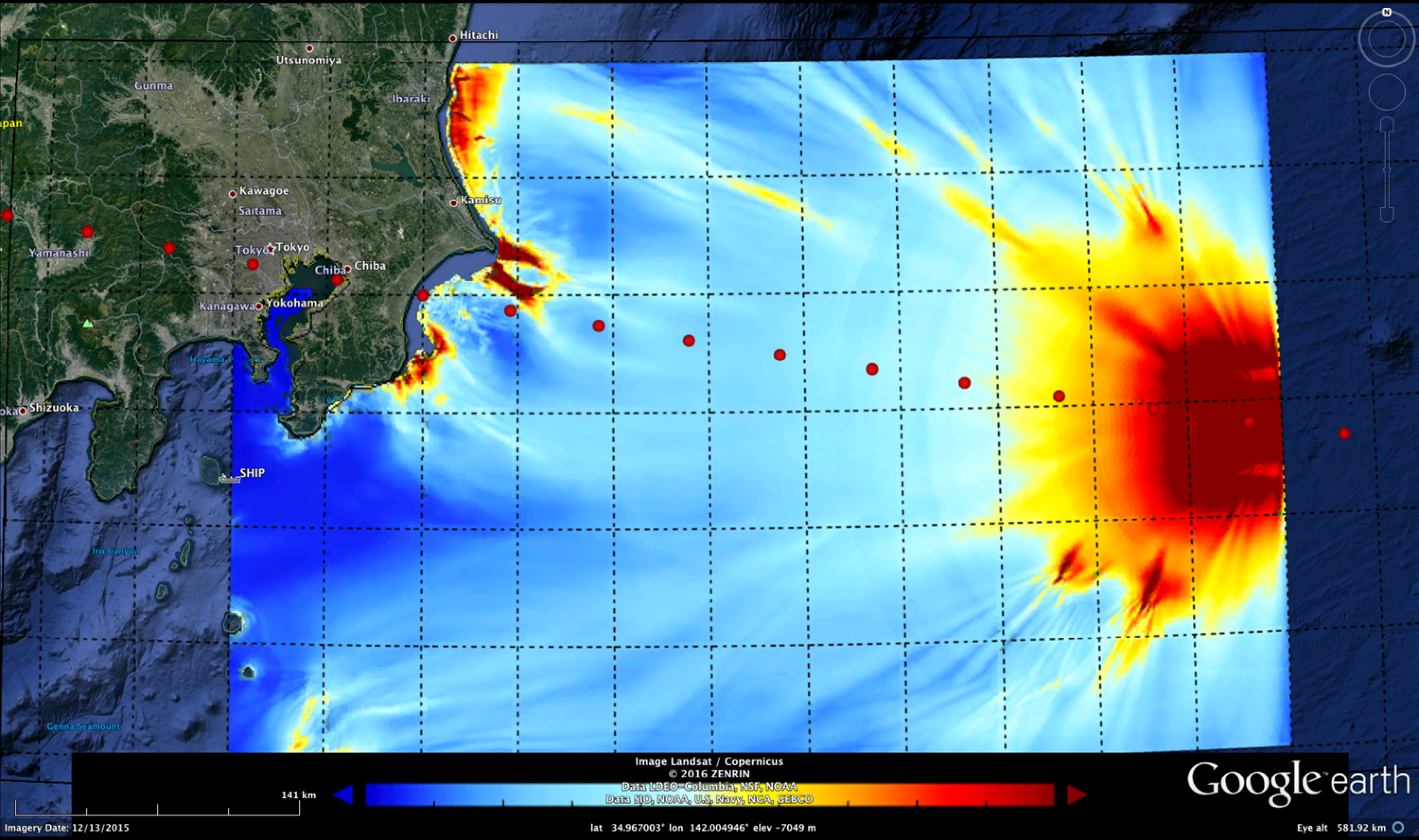
Max depth at shore = 25 m, Flooded area = 54.8 km^2

Maximum wave heights
Impact on offshore-side of Japan Trench



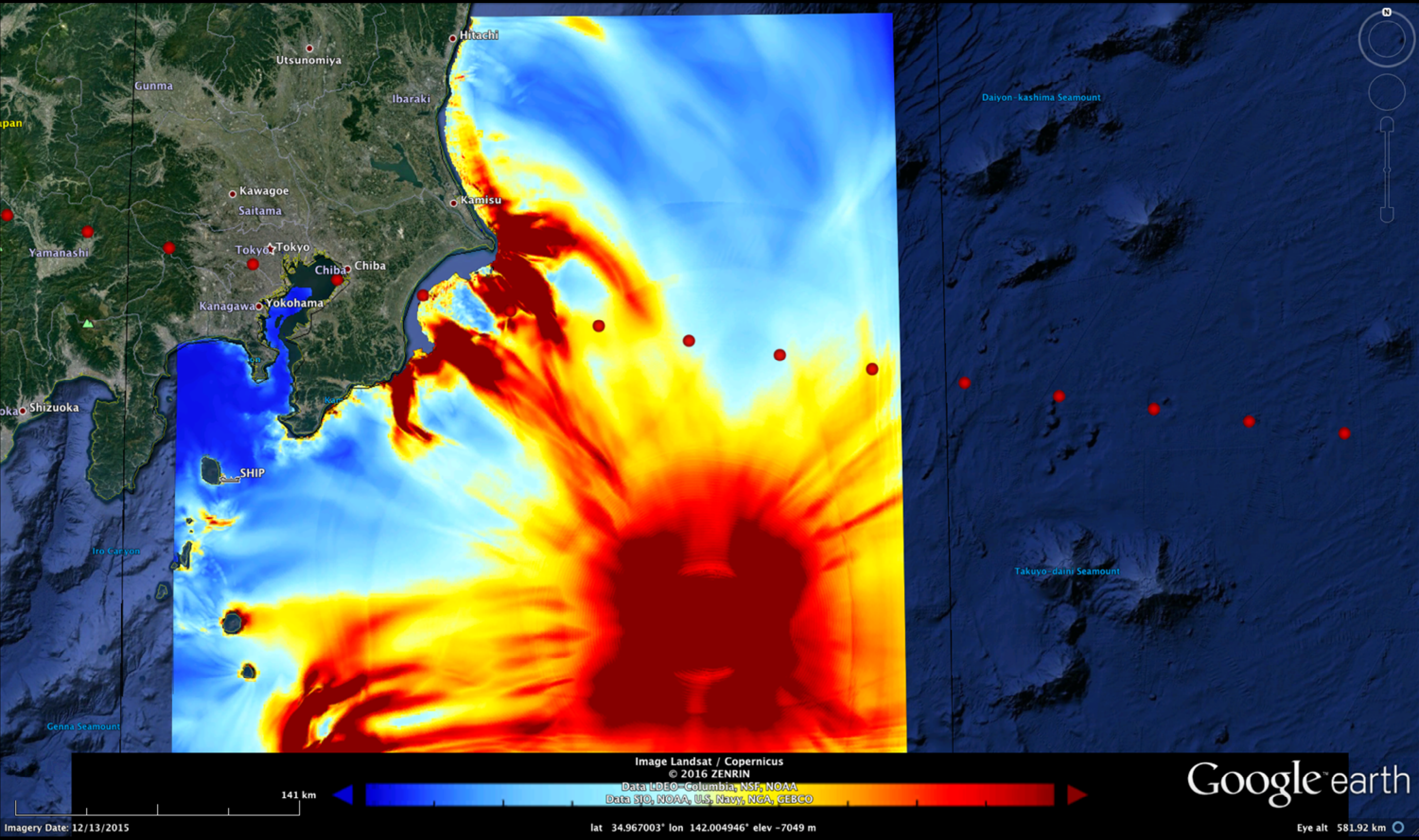
Max depth at shore = 29 m, Flooded area = 46.1 km^2

Maximum wave heights
Impact 400 km away in middle of oceanic plane



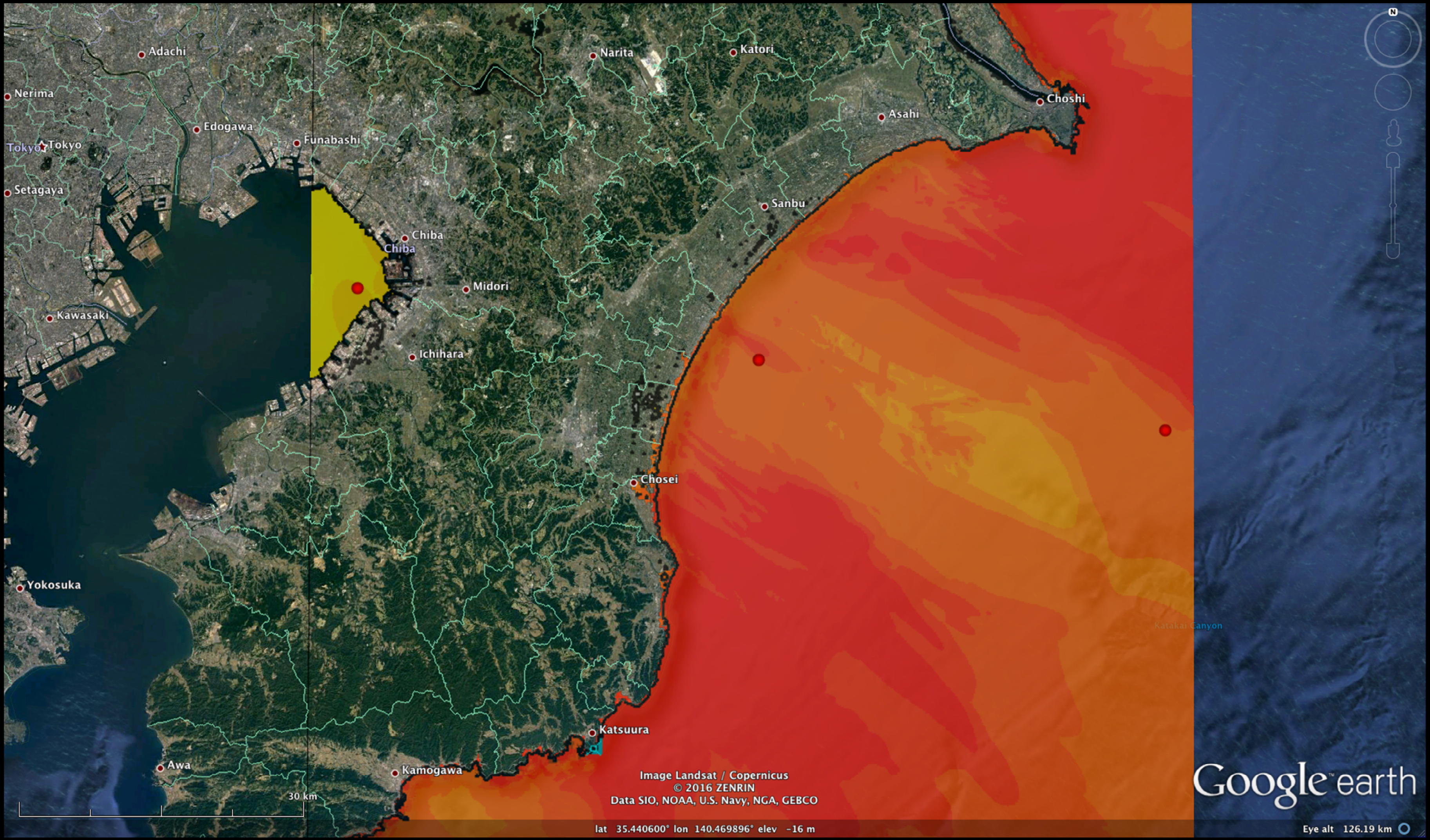
Max depth at shore = 25 m, Flooded area = 46.5 km^2

Maximum wave heights
Impact on depester part of Japan Trench

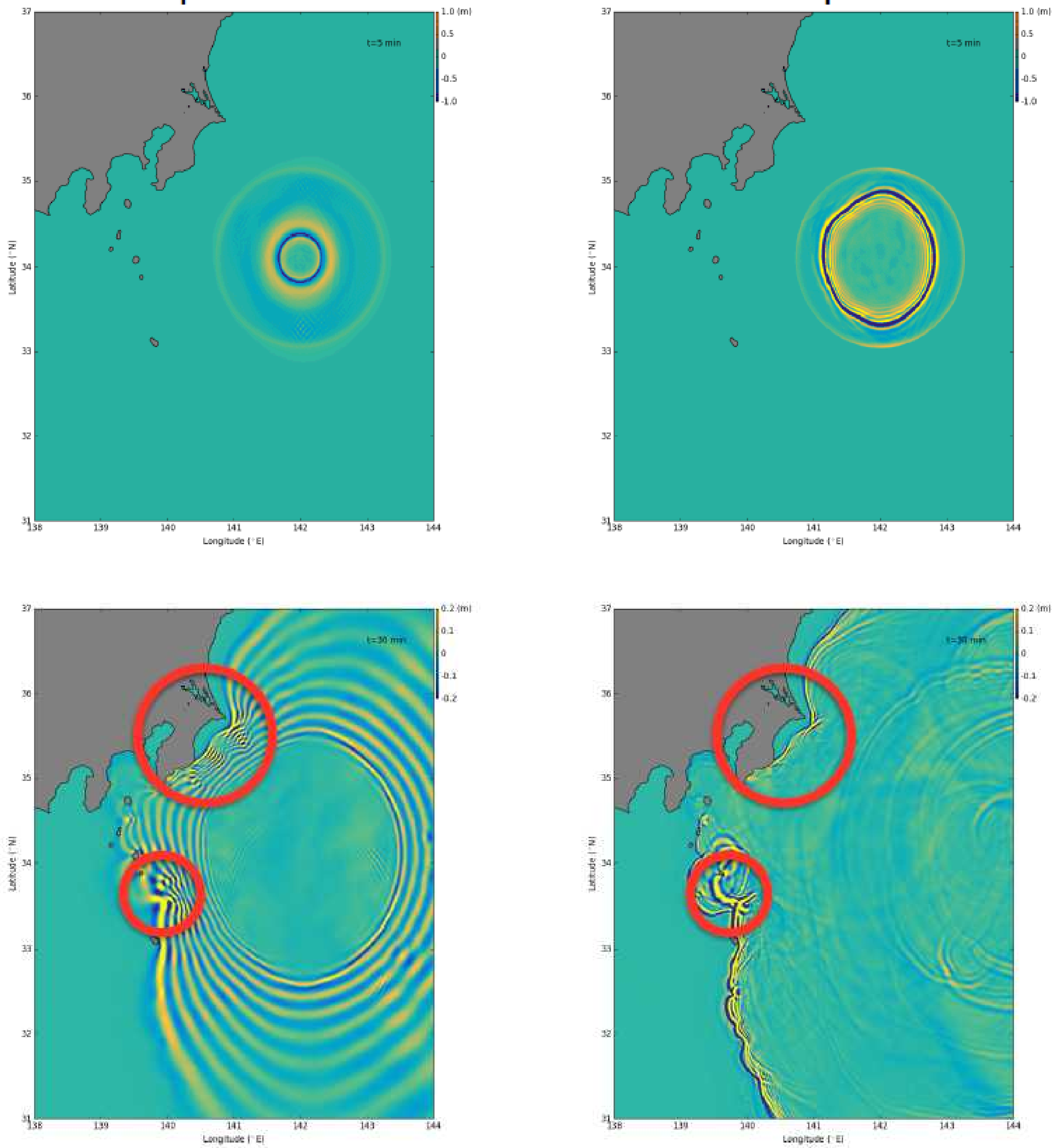


Max depth at shore = 25 m, Flooded area = 46.5 km^2

Maximum wave heights and inundation



	Dispersive	Non-dispersive
5 min		
30 min		



Dispersive:

- Long wave train
- Smaller amplitudes near the source
- Longer waves

Non-dispersive:

- Short wave train
- Larger amplitudes near the source
- Shorter waves

Both:

Similar wave amplitudes and periods near coastline

Therefore, similar coastal impact predictions

Conclusions

- Large airbursts can produce significant water gravity waves leading to regional coastal threat.
- Rarefaction “suction phase” appears to be to be much more strongly coupled to water wave than compressional air blast.
- Coastal inundation does not depend strongly on source distance over studied range.
- Water depth increases amplitude but decreases wavelength.
- Smaller airburst coupling mechanisms have not been eliminated: plume ejection, steam explosion, & toroidal vortices
- Air-driven impact and airburst tsunamis may be significant contributors to overall risk and need to be quantified.