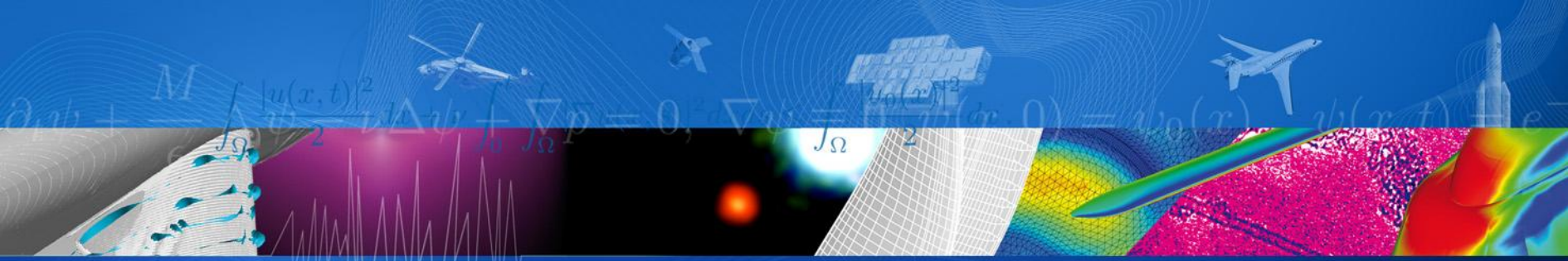

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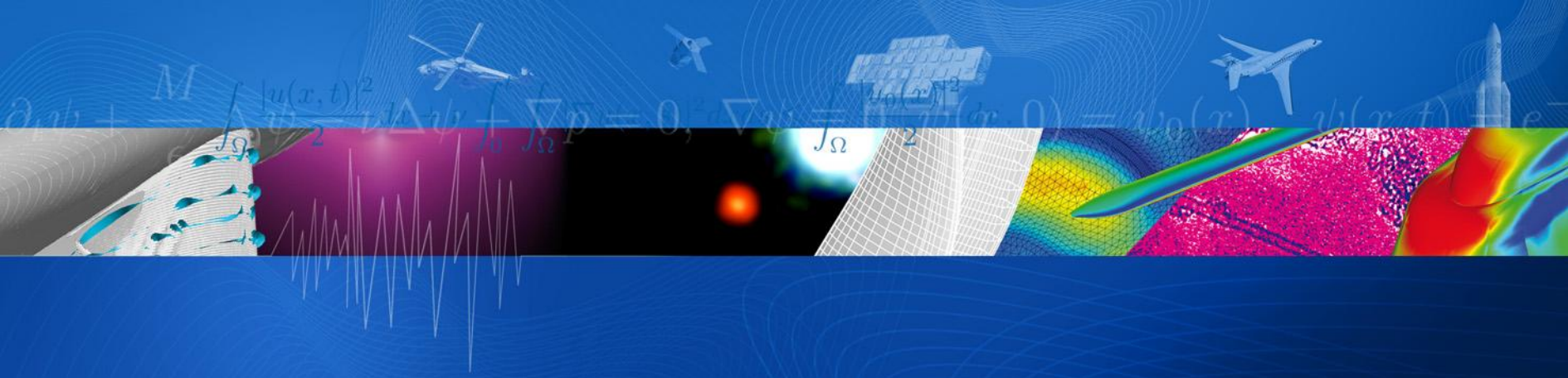

Le Rôle de l'Atmosphère Terrestre dans l'Evaluation de la Menace Astéroïde

Partie II : Trace au Sol et Energie à l'Impact

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AeroThermoDynamic Overview (6):
- *Fragmentation Mechanisms: Earth's Craters Size Estimate Uncertainty*

- **Since we developed the idea that there is a high probability that impact conditions could be significantly different from those of entrance, the following figure has to be re-read according to the proposed hypothesis:**

1) Higher impactors size at impact and so higher NEA for atmospheric entry?

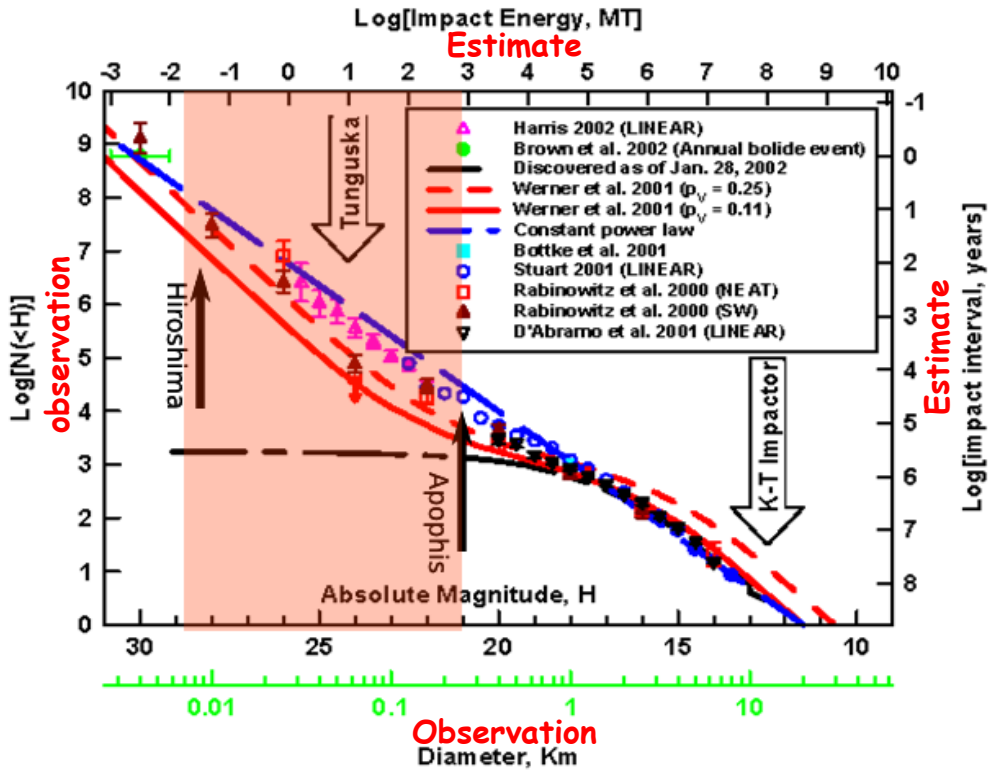
2) Shorter Impact Interval?

3) Impact Energy should be relevant to the impactor diameter

Or

Entry Energy should be only relevant to the observed NEA

Cumulative population of NEAs vs. Absolute magnitude



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Application to *APOPHIS* case: Trends
– *Computational Characteristics*

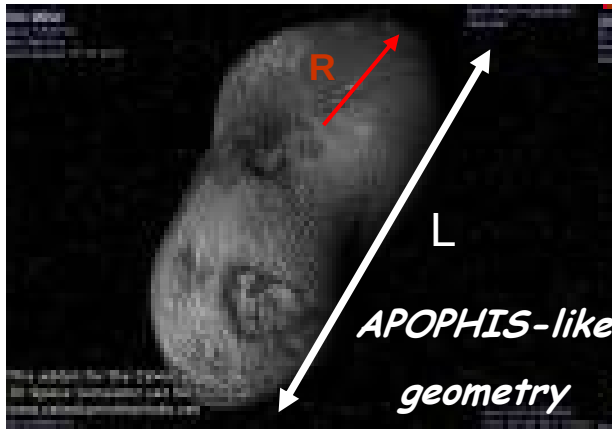
❑ *Apophis* Asteroid Computational Characteristics

Length L ~ 270 m, mass ~ 27 Millions Tons

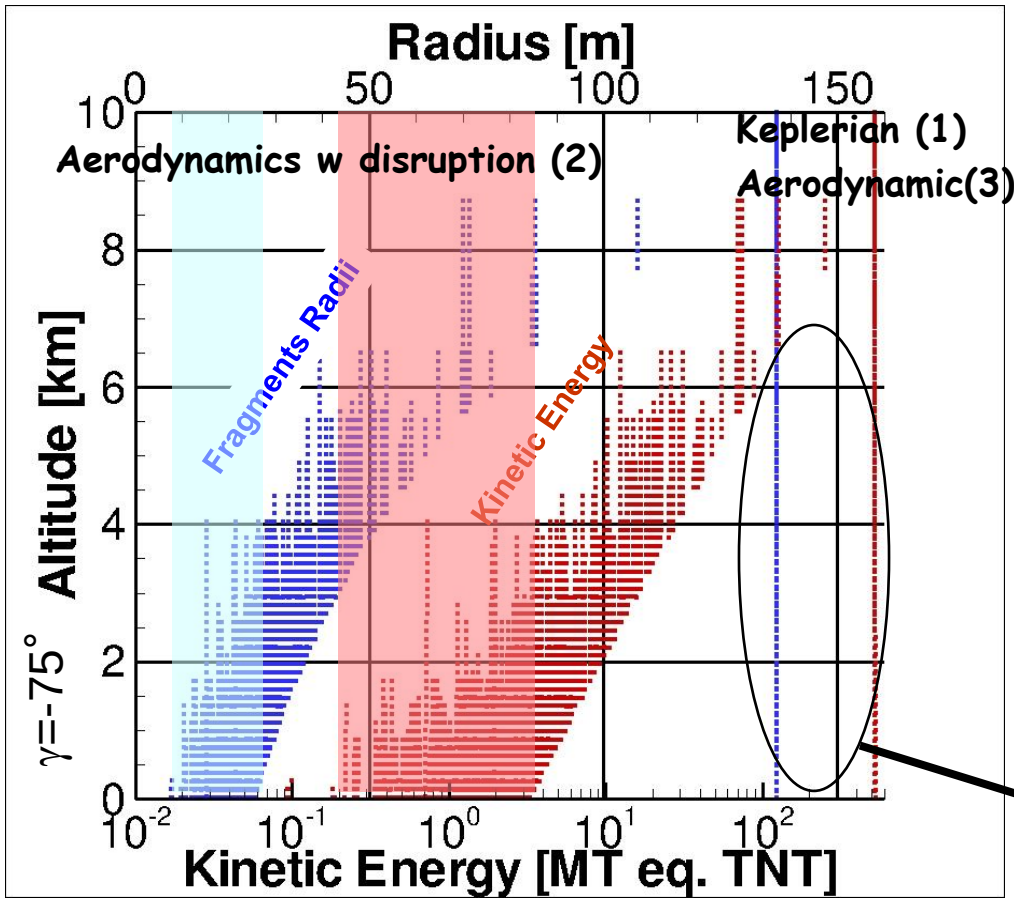
- **Entry Kinetic Energy**: 520 MT eq. TNT

❑ Computational Conditions:

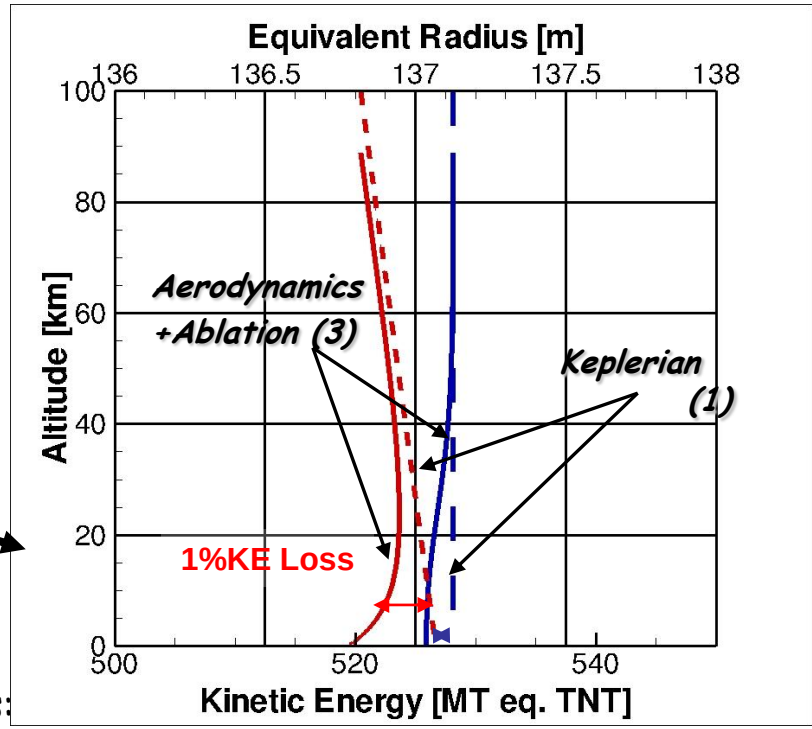
- **Entry Velocity**: 12.7 km/s
- **Entry slope**: -15° and -75°
- **Material**: Ordinary Chondrite (ρ=2.5g/cm^3) and monolithic
- **Strength Parameters** $\sigma_{0=}$50 MPa – wo porosity influence: f=1
- **Entry Stagnation Radius:** ~137m
- **Entry Attitude**: AoA=45° sideslip=45° equivalence
- **ATD models** coupled with **flight dynamics**



Application to *APOPHIS* case: Trends
– *ATD Effects vs. Keplerian Approach* – γ_{entry}=-75°



Zoomed impact conditions for
Keplerian and **Aerodynamics wo disruption**



Atmospheric history for entry slope γ=-75° for 3 scenarios:

1) Keplerian

2) Aerodynamics w & 3) wo disruption

$$\frac{\sum_{j\ fragment} KE_j}{KE_{Tot}} = 0.98$$

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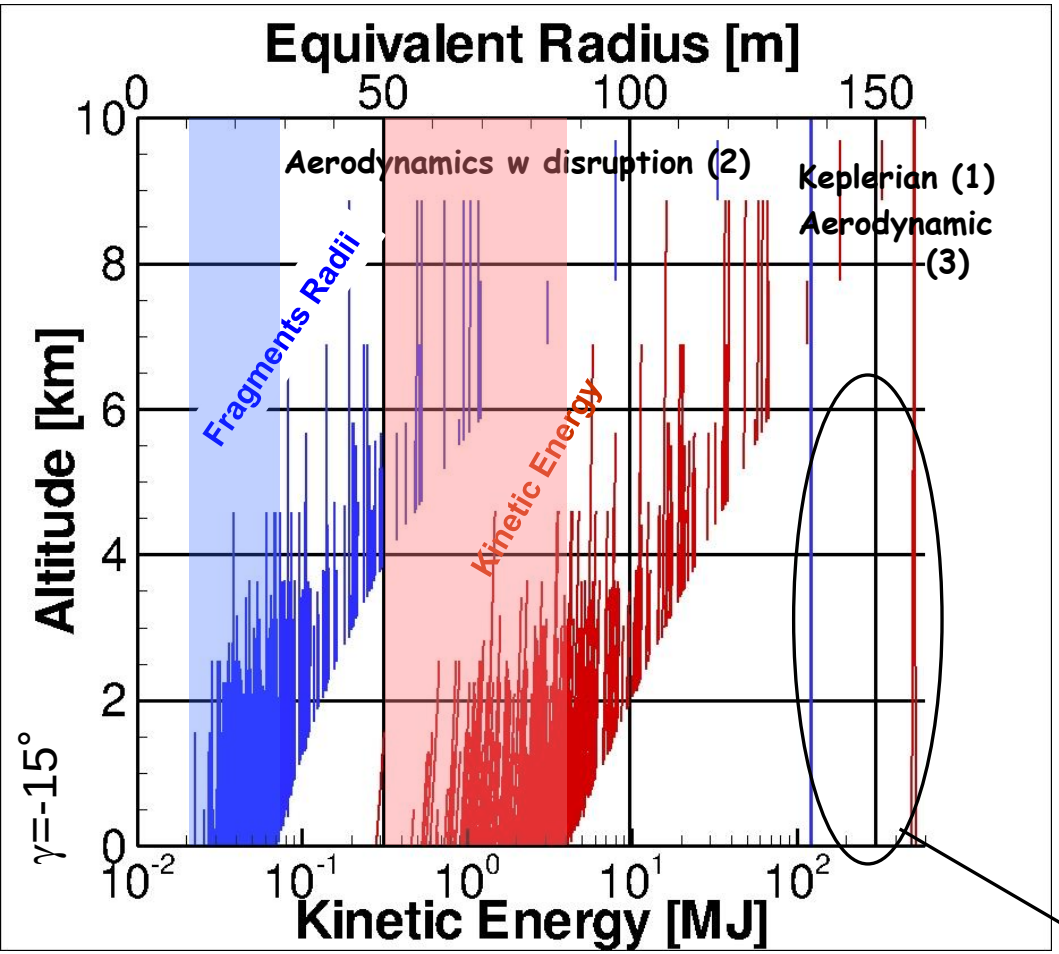
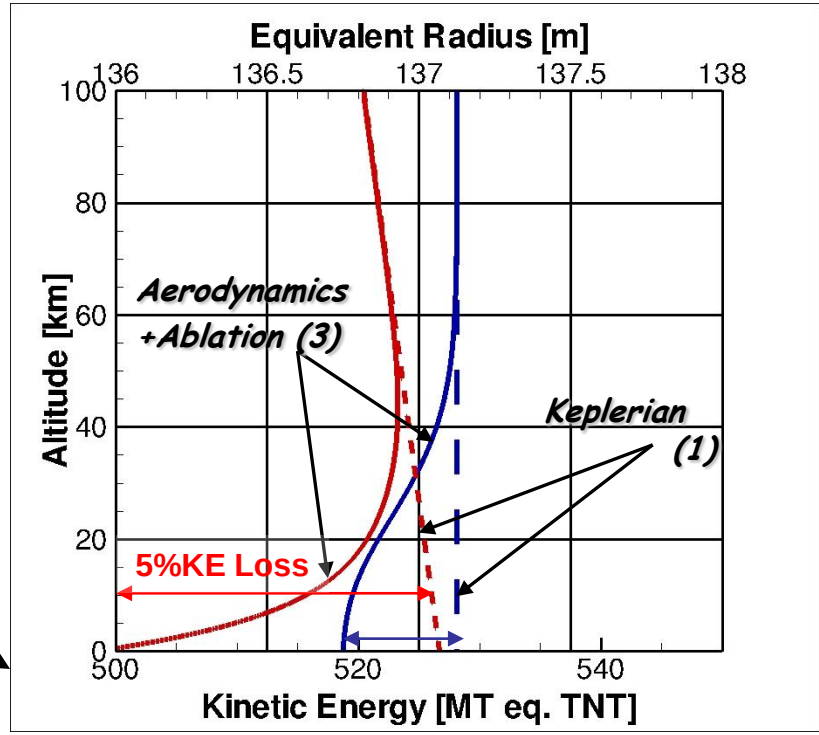
Application to *APOPHIS* case: Trends
– *ATD Effects vs. Keplerian Approach* – γ_{entry}=-15°



Zoomed impact conditions for
Keplerian and **Aerodynamics wo disruption**



Atmospheric history for entry slope γ=-15° for 3 scenarios:

1) Keplerian

2) Aerodynamics w & 3) wo disruption

$$\frac{\sum_{j\ fragment} KE_j}{KE_{Tot}} = 0.87$$

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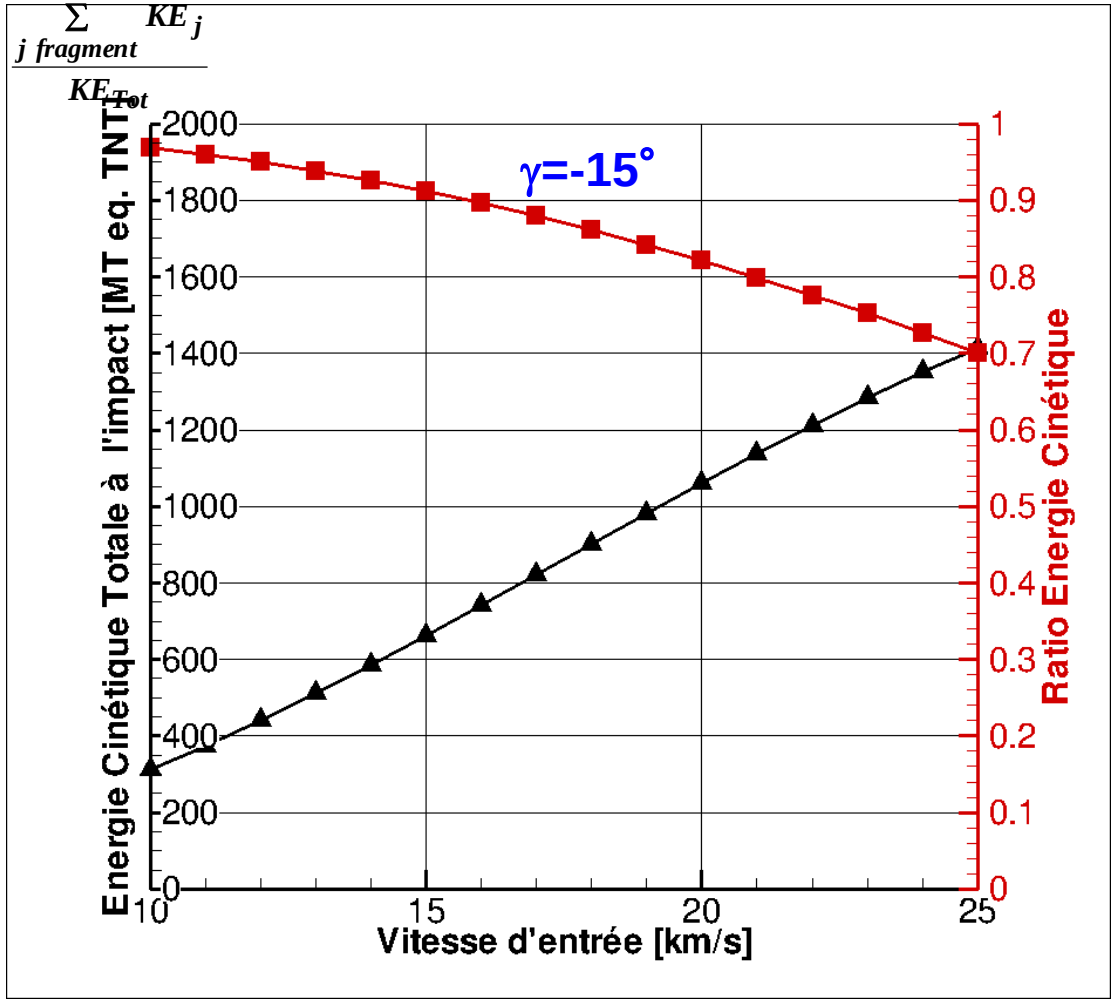
Application to *APOPHIS* case: Trends
– *Entry Velocity Effect on Impact Energy* – γ_{entry}= -15°

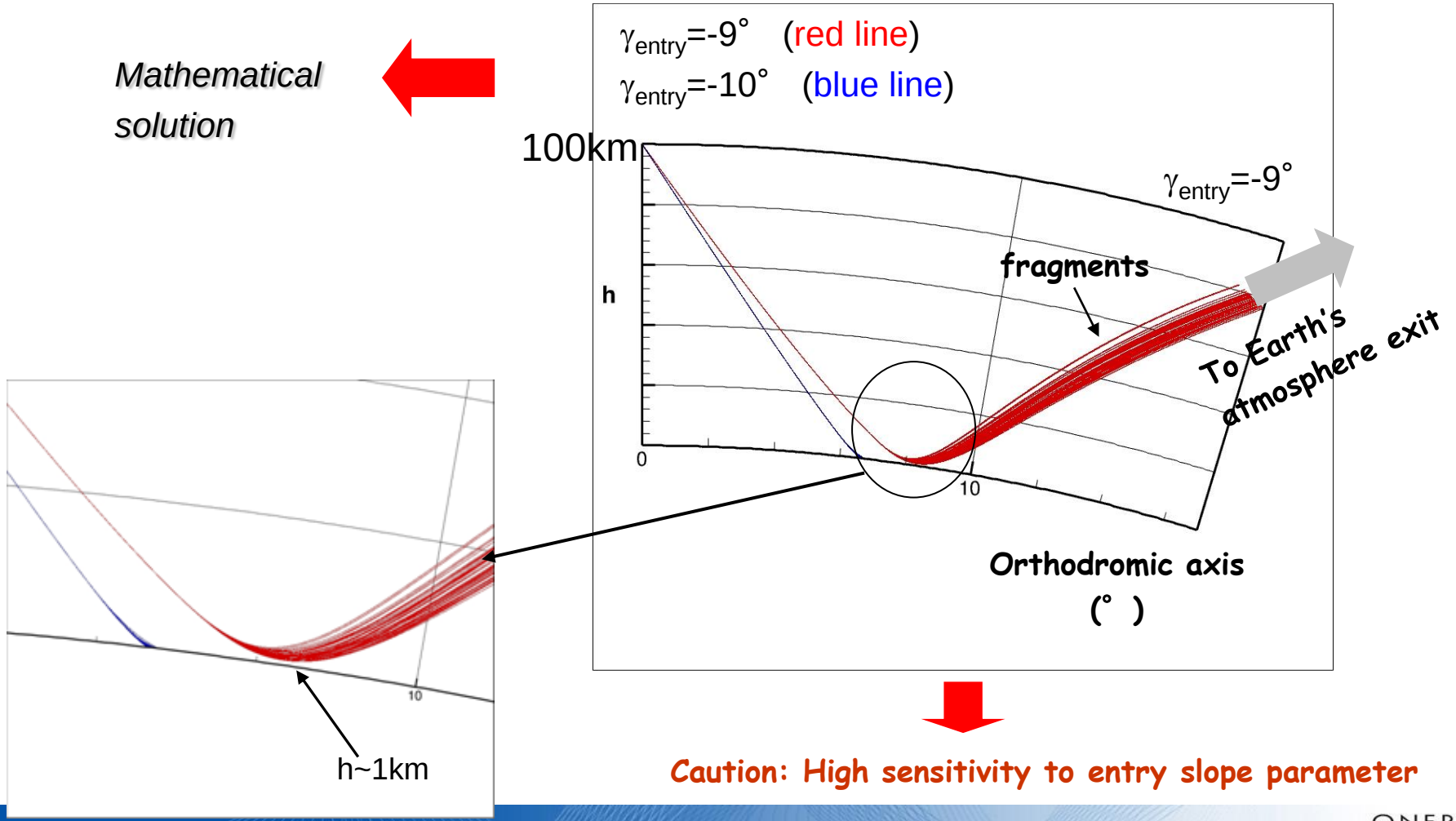
- **Evolution de l'énergie d'impact en fonction de la vitesse d'entrée**



Application to *APOPHIS* case: Trends
– *Entry Slope Treshold*

❑ **Entry Slope Treshold for Aerodynamic Bouncing Conditions**

Mathematical solution



Caution: High sensitivity to entry slope parameter

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❑ Synthèse des données

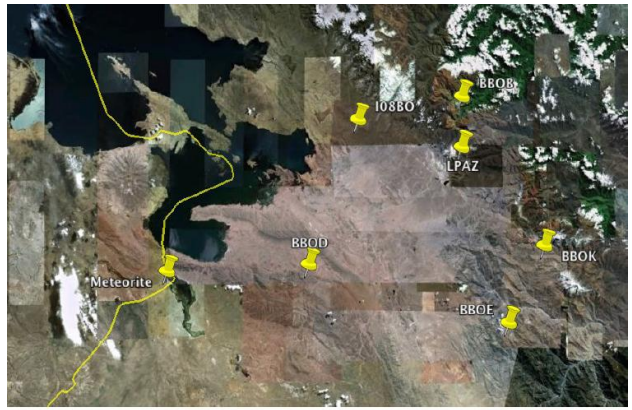
- **Détermination des données d'entrée atmosphérique**

  - Contraintes de trajectoire : signaux infrasonores aux stations LPAZ et IS08

    → azimut∈[50°,100°]
    → angle entrée∈[45°,63°]

  - Contraintes orbitales

    → vitesse d'entrée∈[12km/s,18km/s]
    → diamètre d'entrée∈[0.9m,2m]



Position géographique des stations, GoogleEarth

- **Détermination des données d'impact : taille du cratère**

  → énergie cinétique d'impact∈[2tTNT,3tTNT]
  → hypothèse : entrée sans fragmentation
  → diamètre impact ∈[0.6m,1.3m]

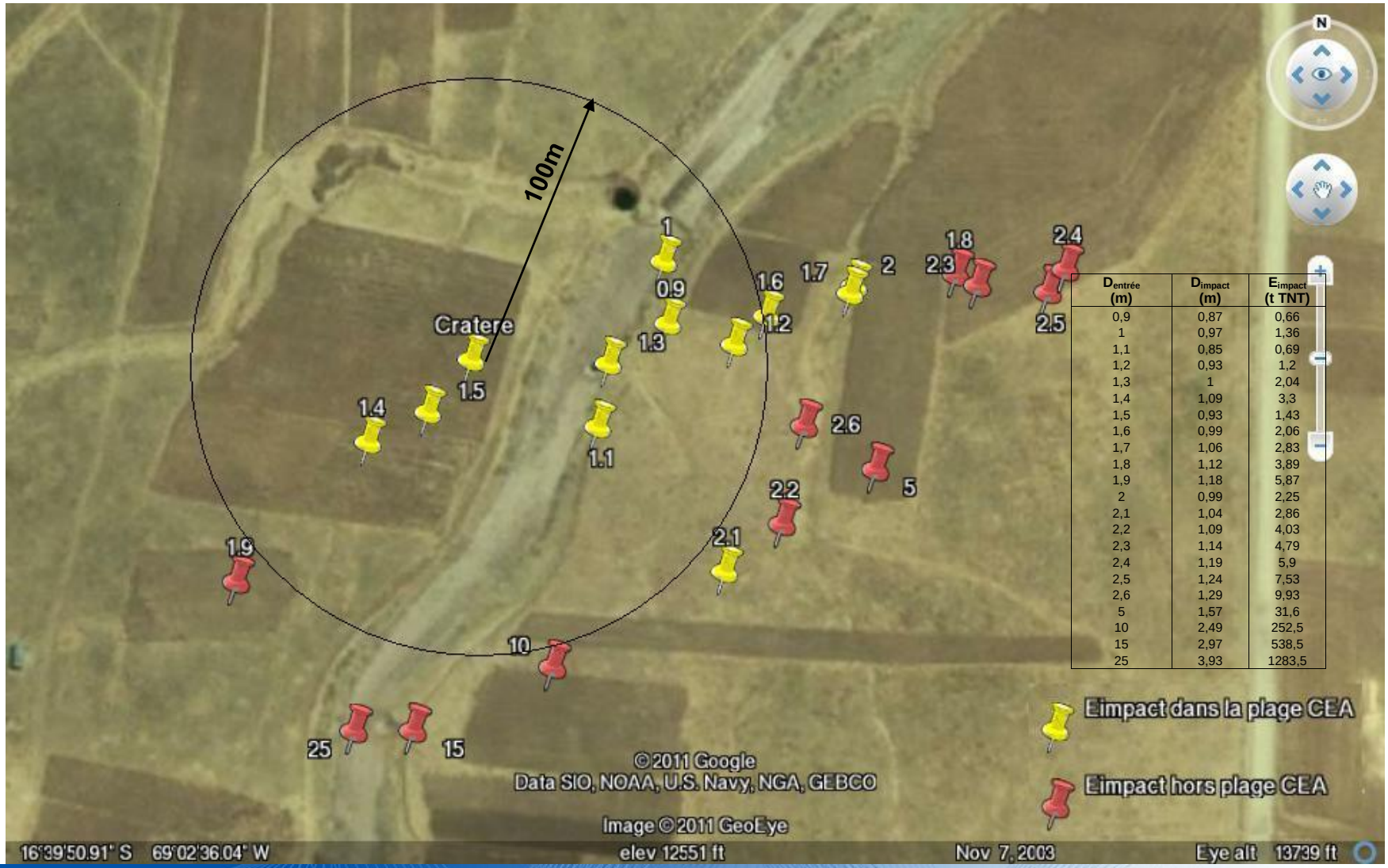
Application au Cas *Carancas*
– Conditions de Simulation

Hypothèses

- Conditions initiales prises au milieu des plages d'estimation du CEA
- Condition d'arrêt du calcul : atteinte de l'altitude d'impact (3826m)
- Choix de facteurs d'ablation et de fragmentation caractéristiques des chondrites H4-H5
- Itération du calcul pour divers diamètres d'entrée

Application au Cas *Carancas*
– Analyse des scénarios

- **Impact au sol**



$D_{entrée}$ (m)	D_{impact} (m)	E_{impact} (t TNT)
0,9	0,87	0,66
1	0,97	1,36
1,1	0,85	0,69
1,2	0,93	1,2
1,3	1	2,04
1,4	1,09	3,3
1,5	0,93	1,43
1,6	0,99	2,06
1,7	1,06	2,83
1,8	1,12	3,89
1,9	1,18	5,87
2	0,99	2,25
2,1	1,04	2,86
2,2	1,09	4,03
2,3	1,14	4,79
2,4	1,19	5,9
2,5	1,24	7,53
2,6	1,29	9,93
5	1,57	31,6
10	2,49	252,5
15	2,97	538,5
25	3,93	1283,5

CONCLUSION

- This presentation exhibited the main features of ATD processes occurring during the atmospheric flight of a NEA type-S at hyper-orbital velocity,

Atmosphere remains an essential parameter to assess the impact risk on Earth by space threat,

…but also to estimate accurately NEA size from Earth's craters impact analysis

Completed ATD investigations are required to describe impact conditions within satisfying accuracy for a potential risk against populated and infrastructured areas