Retrieving meteoroids trajectories using BRAMS data : preliminary simulations

Hervé Lamy & Cédric Tétard

Royal Belgian Institute for Space Aeronomy

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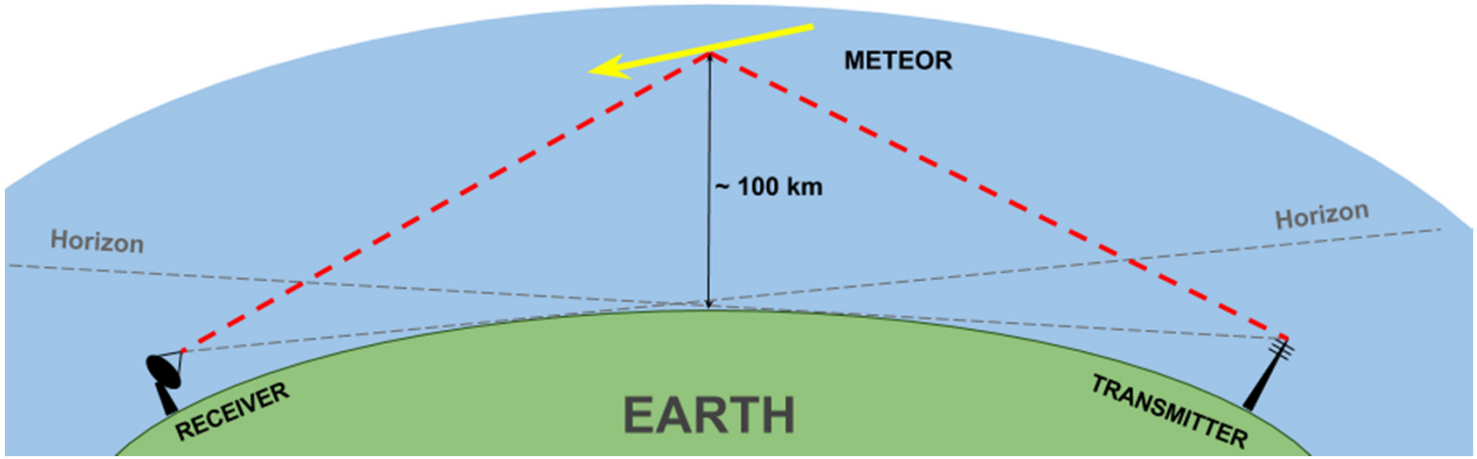
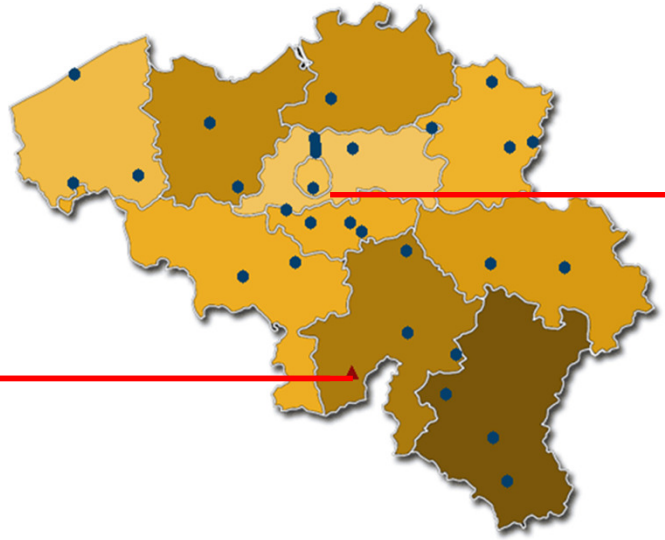
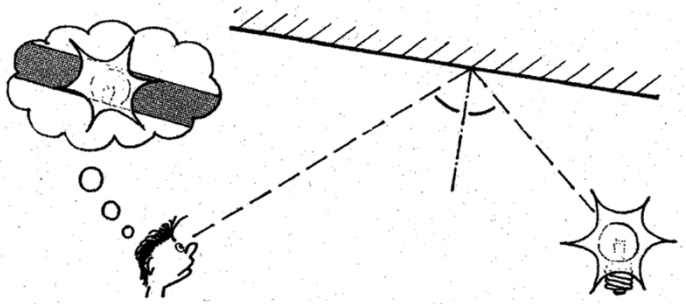
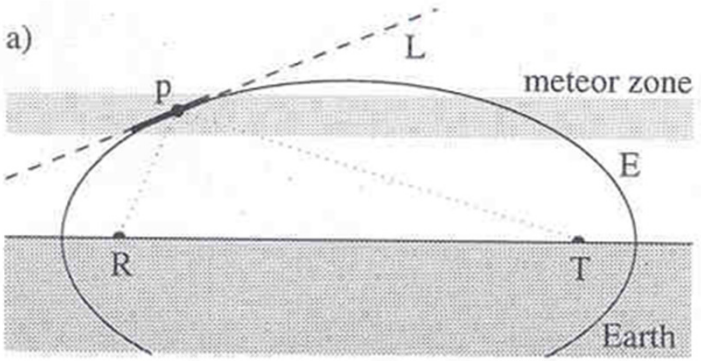
Forward scattering of radio waves





Specular reflection





$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{b^2} = 1$$

$$\frac{x - x_2}{x_1 - x_2} = \frac{y - y_2}{y_1 - y_2} = \frac{z - z_2}{z_1 - z_2}.$$

$$Ax^2 + Bx + C = 0$$

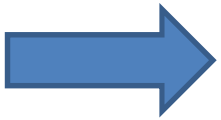
$$x_{1,2} = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$$

= 0

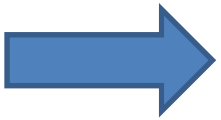
Specular reflection

$$a^2(x_1-x_2)^2\cdot\Big[(x_1-x_2)^2\cdot b^4$$
$$+\Big(\big((y_1-y_2)^2+(z_1-z_2)^2\big)a^2-x_2^2(y_1^2+z_1^2)+2x_1x_2(y_1y_2+z_1z_2)-x_1^2(y_2^2+z_2^2)\Big)\cdot b^2$$
$$-a^2(y_2z_1-y_1z_2)^2\Big]=0.$$

$$f^2=a^2-b^2$$

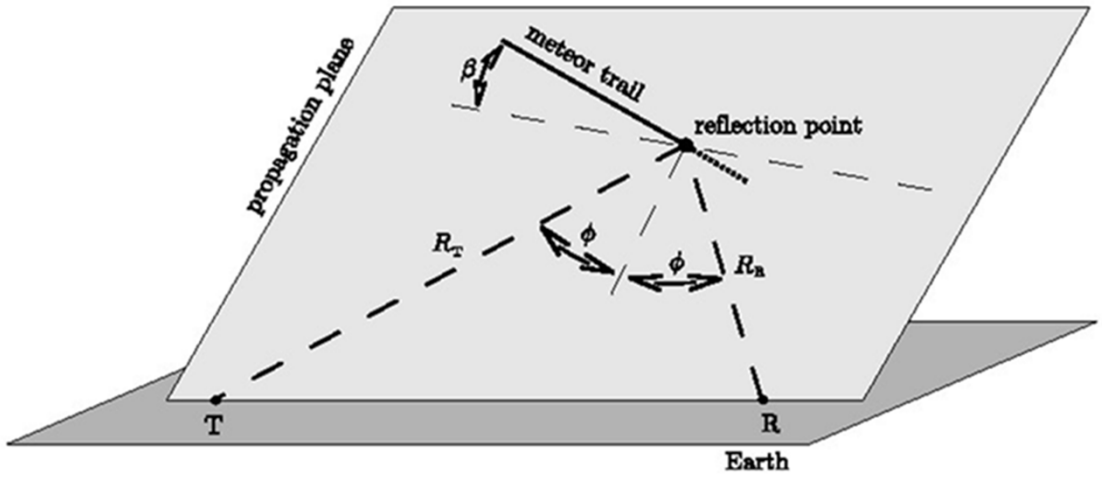


2 equations
for a & b



x (and y,z) of
tangential point

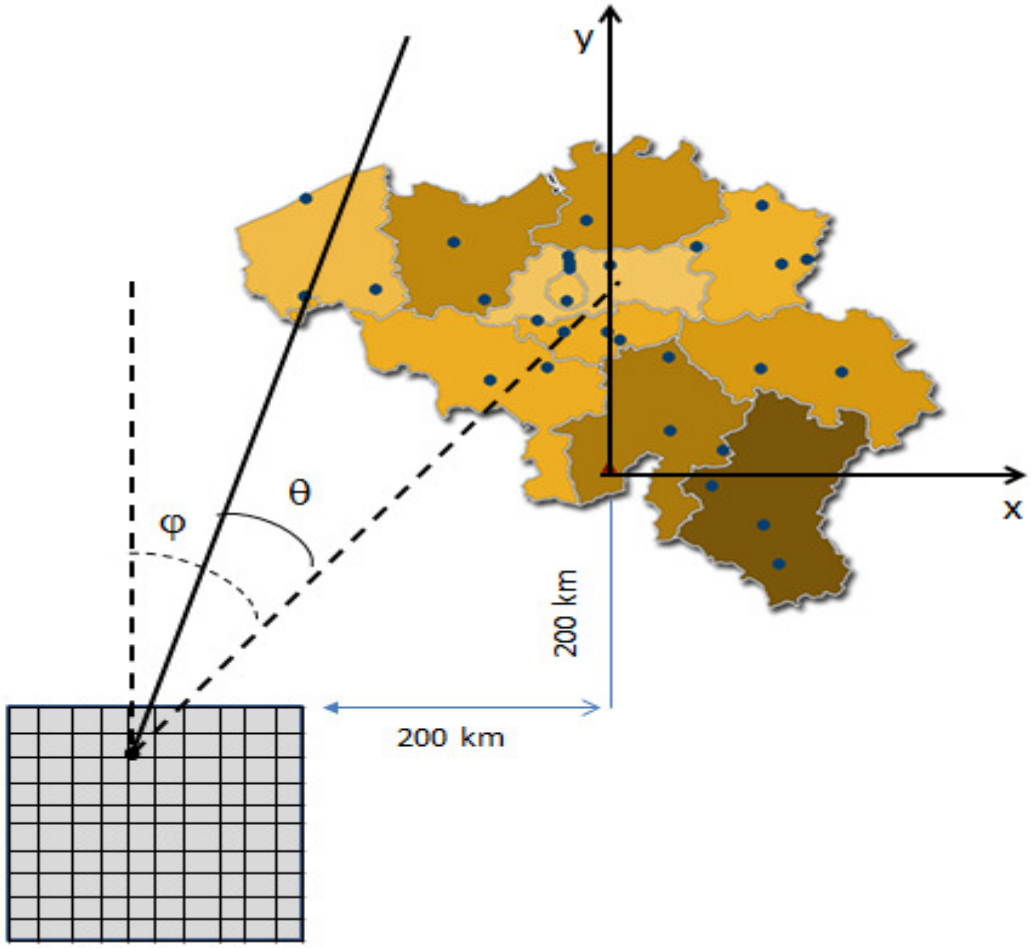
Idea of Nedeljkovic (2005)



If *n* receiving stations detect the same meteor, then the meteoroid trajectory must be tangential to a set of ellipsoids with a common focus T and various focii R1, R2, R3

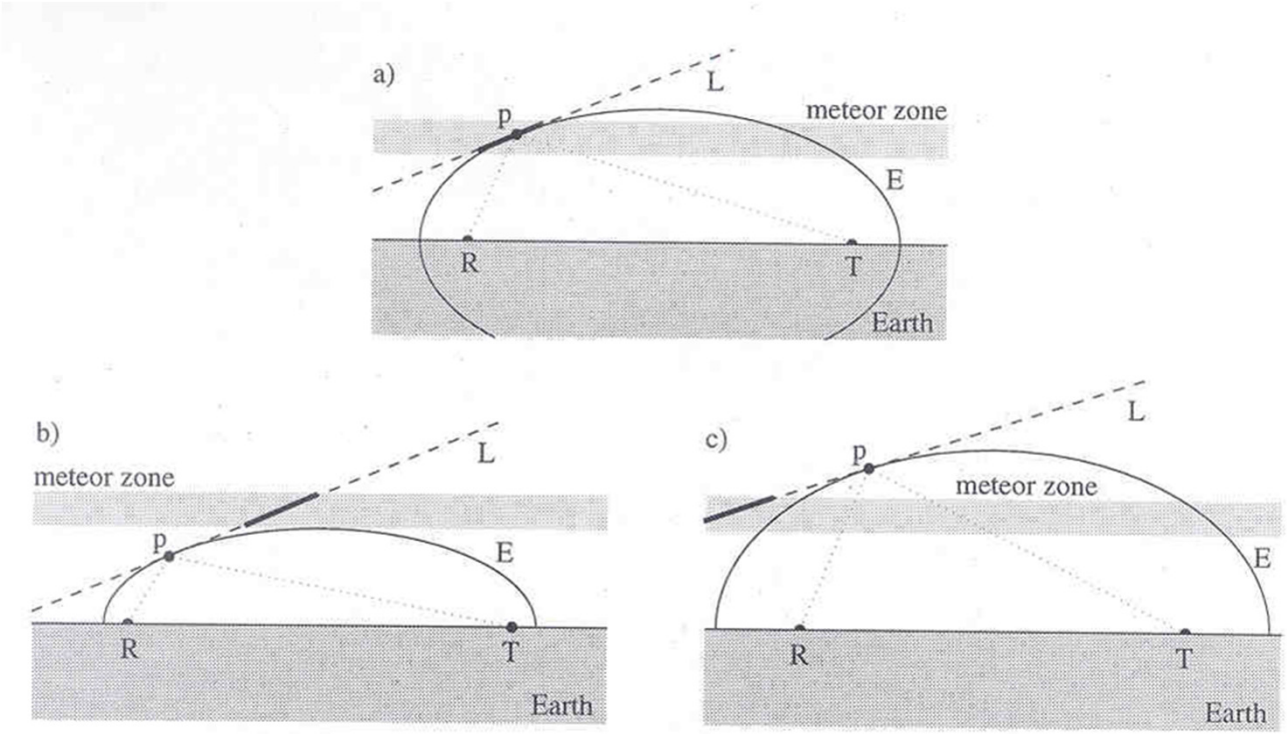
Model for simulations

10^6 trajectories are simulated using a point (intersection of the trajectory and the ground) and a direction (two angles for elevation θ and azimuth φ). We calculate the positions of each tangential point for several combinations T-R1, T-R2, …



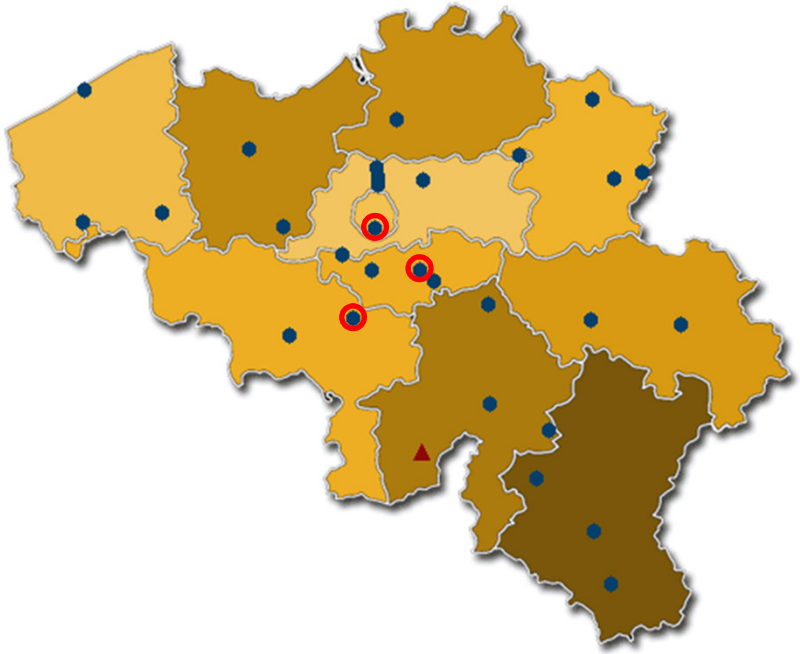
First criterion

Altitude of the reflection point must lie between 95 and 110 km



Number of trajectories remaining

With 3 stations, Uccle, Ottignies and Seneffe



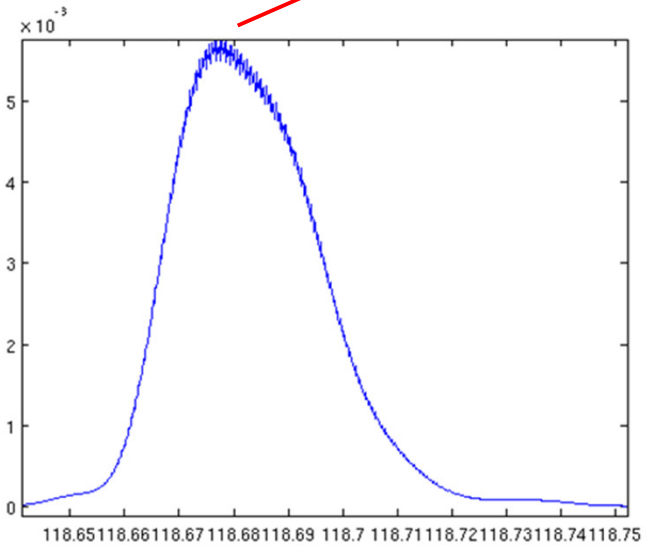
	$95 < z_p < 110$ km
U	65631
O	65344
S	67870
U & O	61186
O & S	57003
U & O & S	54734

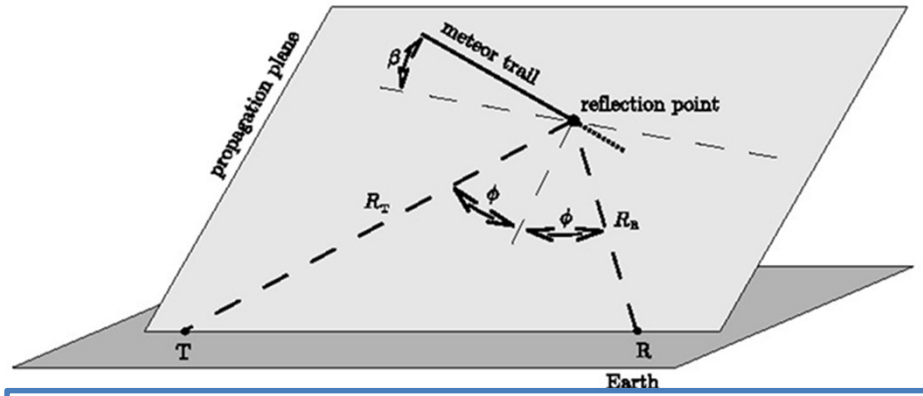
The number of remaining trajectories does not decrease drastically when O and S are added to U, probably because of the rather similar T-R geometry for the 3 stations.

Second criterion

Power received at a given station must be > 10^{-17} W

$$P = \frac{P_t G_t G_r \lambda^3 r_e^2 \alpha^2 \sin^2\gamma}{16\pi^2 R_t R_r (R_r + R_t)(1 - \sin^2\phi . \cos^2\beta)}$$





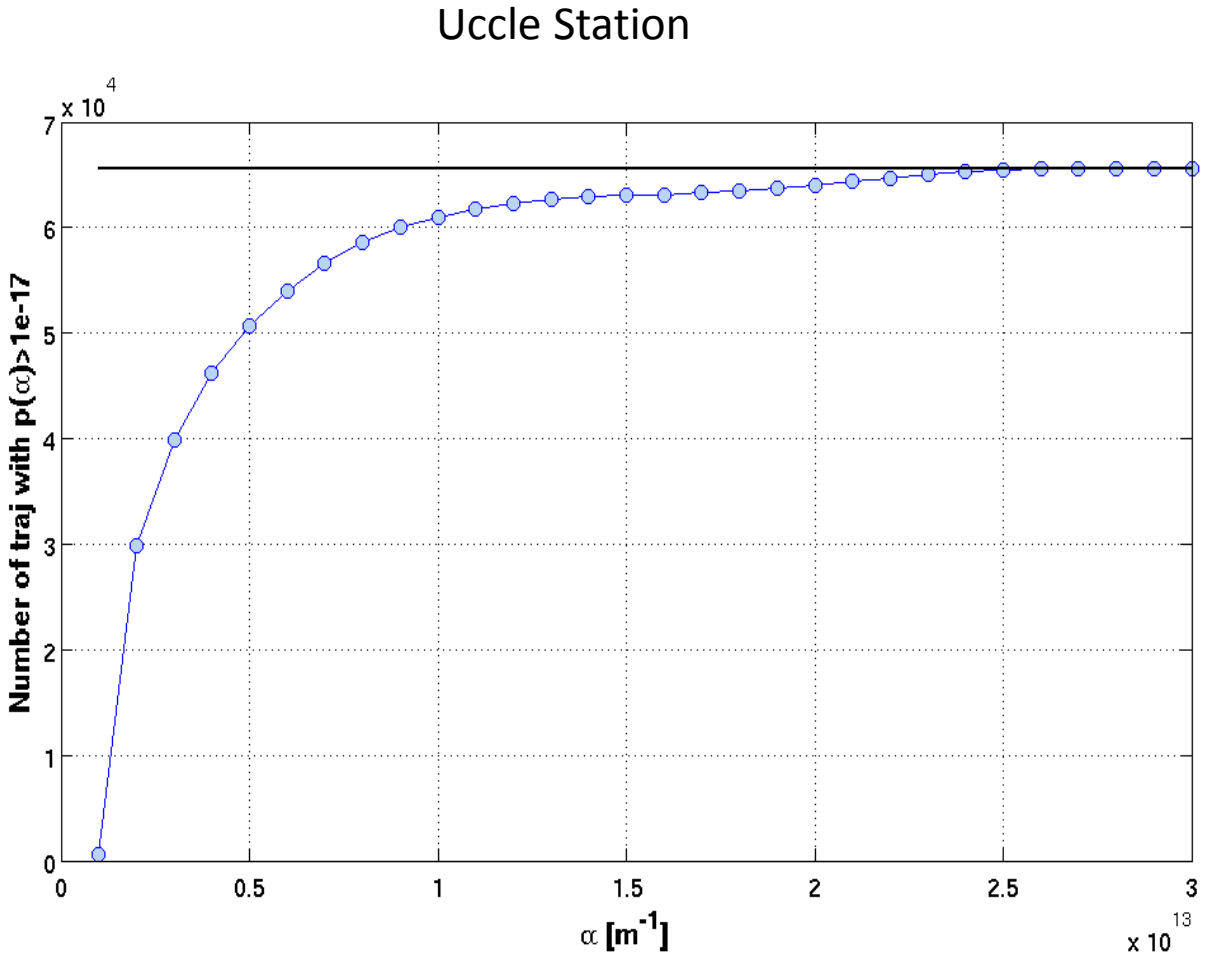
Numerator :

- $\lambda \sim 6$m, $P_T = 150$ W, r_e = Bohr radius
- γ = polarisation
- $G_T(\theta,\phi)$ and $G_R(\theta,\phi)$ are antenna gains
- α : electron line density at the specular point

Polarisation

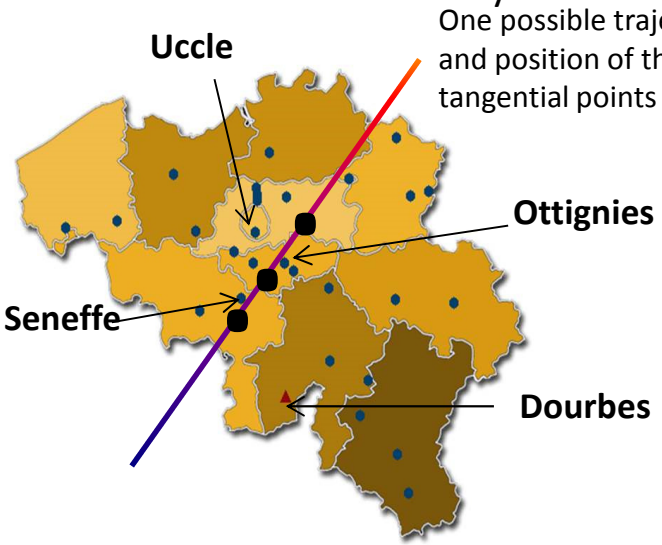
- Can only be measured using a crossed Yagi antenna (in BEHUMA or BEUCCL)
- Otherwise, assume we receive 50% of the power (so $\sin^2 \gamma = ½$)
- Assumption to check statistically on a large set of meteor echoes observed at Humain or Uccle

Influence of electron line density

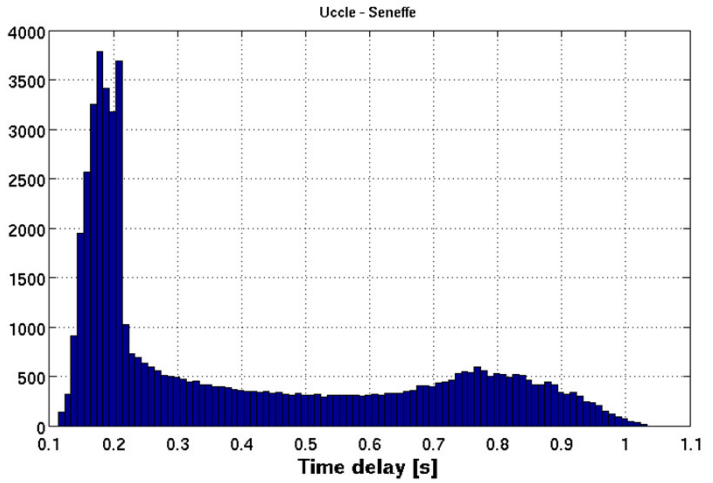


Third criterion : time delays

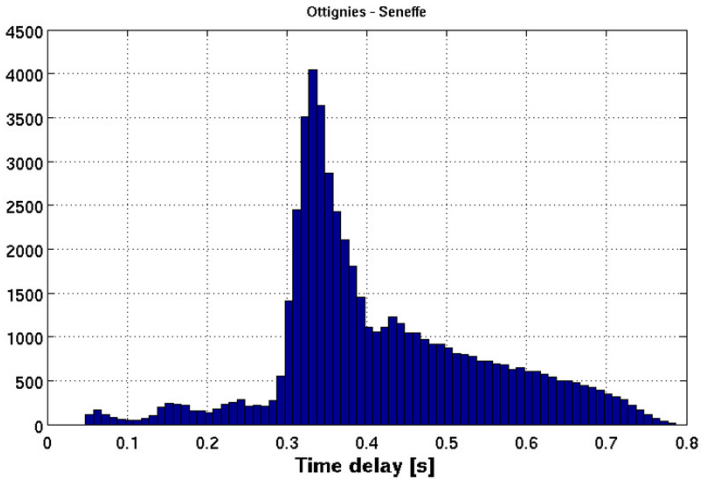
For each remaining trajectory, we compute the distance between tangent points and the corresponding time delays (assuming the velocity of the meteor) and we choose the trajectory that matches the observed time delays.

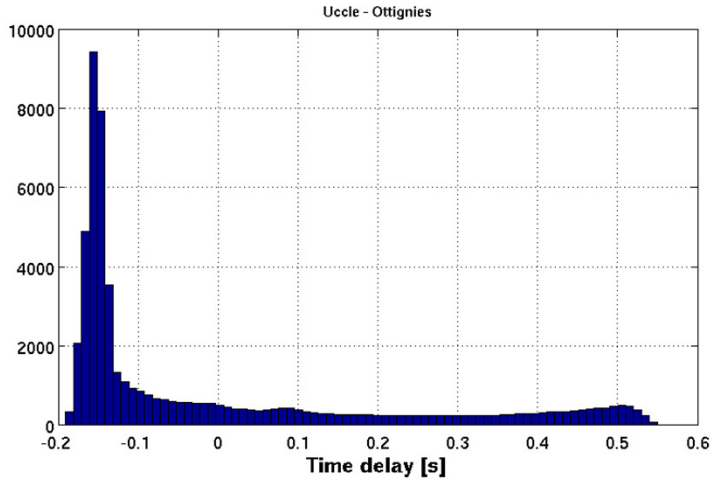


One possible trajectory and position of the 3 tangential points

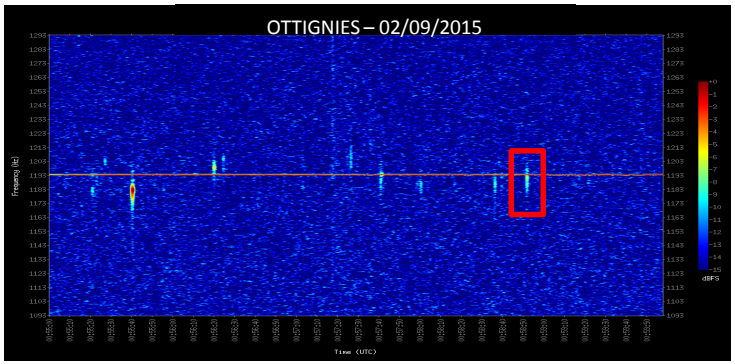


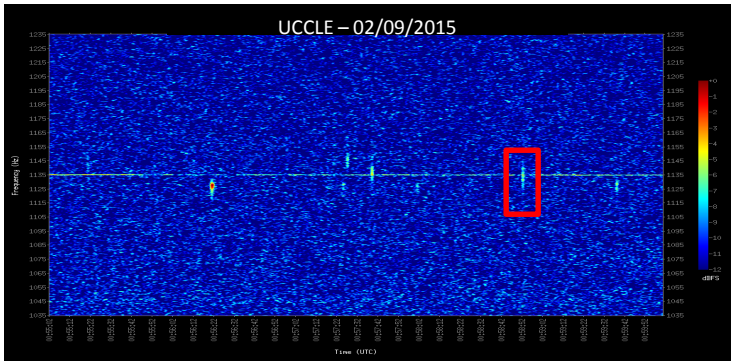
V=20 km/s

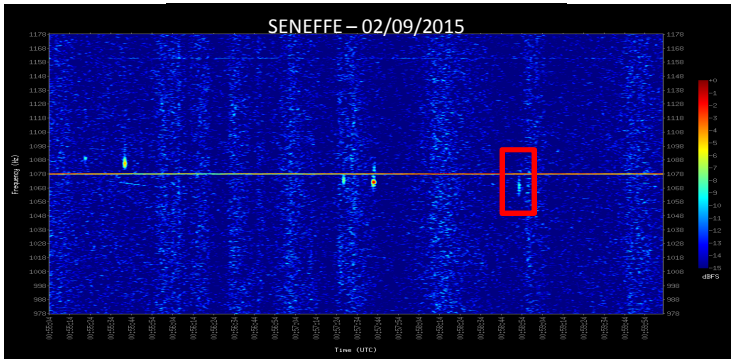


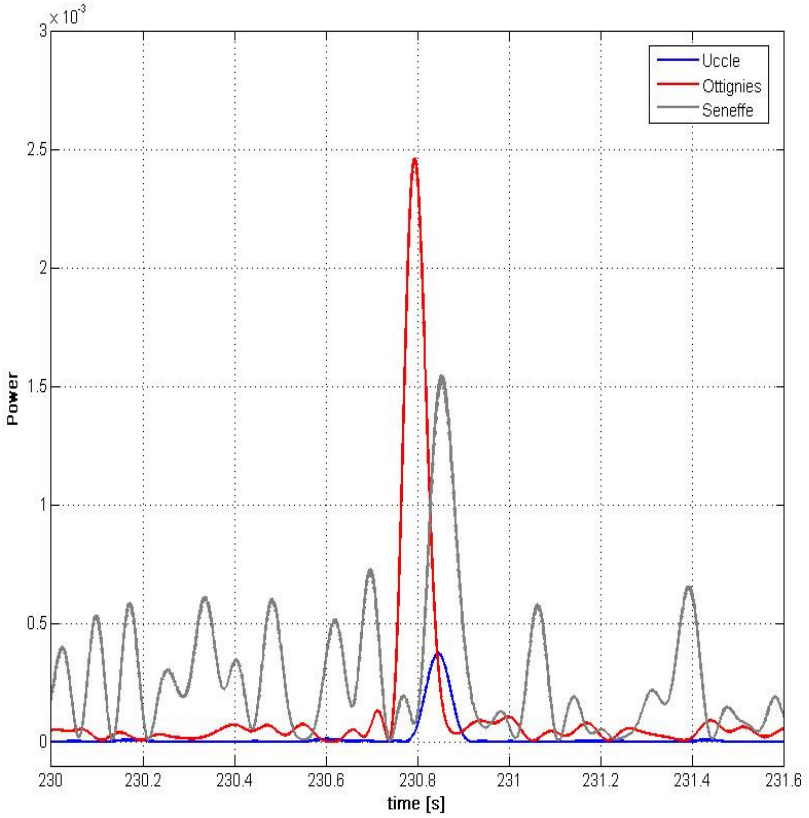


Example of detection of the same meteors in Uccle, Seneffe and Ottignies



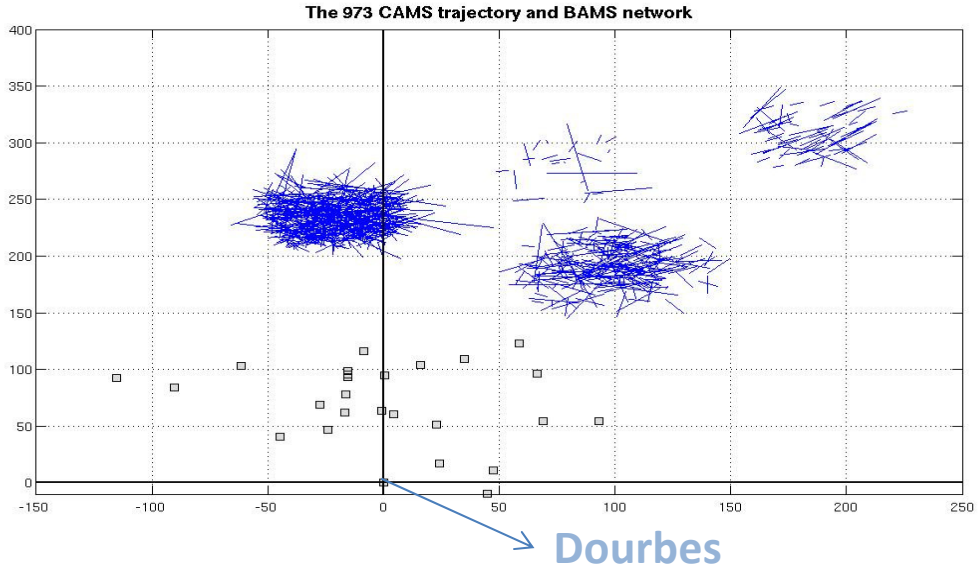






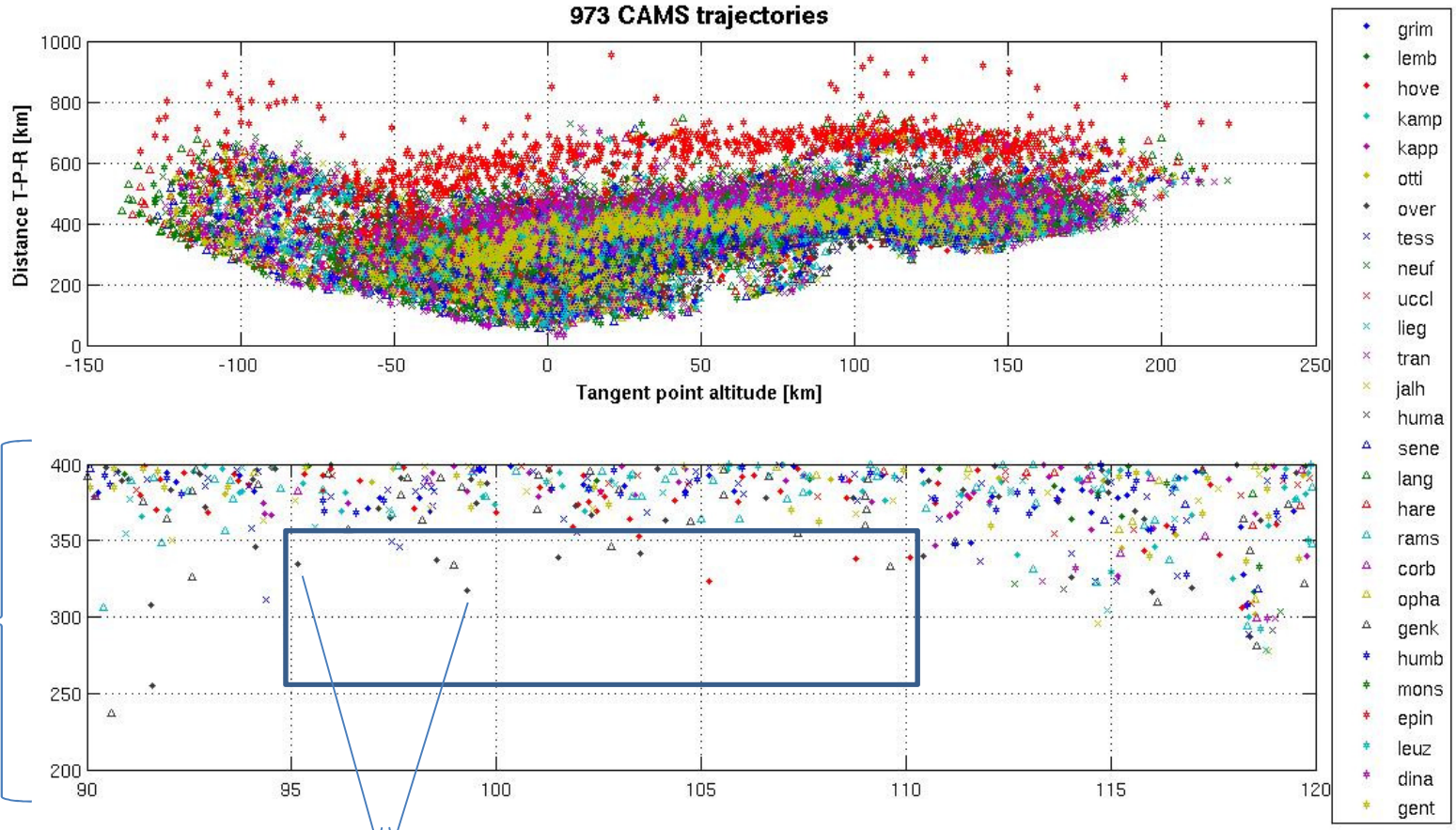
CAMS and BRAMS

Among the 973 trajectories of meteoroids calculated using the CAMS BENELUX network, which are detectable by BRAMS?



- For all the 973 trajectories and for all the BRAMS stations, we compute the coordinates of the tangent point and the distance covered by the signal (d_{PTR} = transmitter – tangent point – receiver)
- Criterion that defined if a BRAMS station can detect the same meteor : $95<z_t<110$ and $d_{PTR}<350$ km

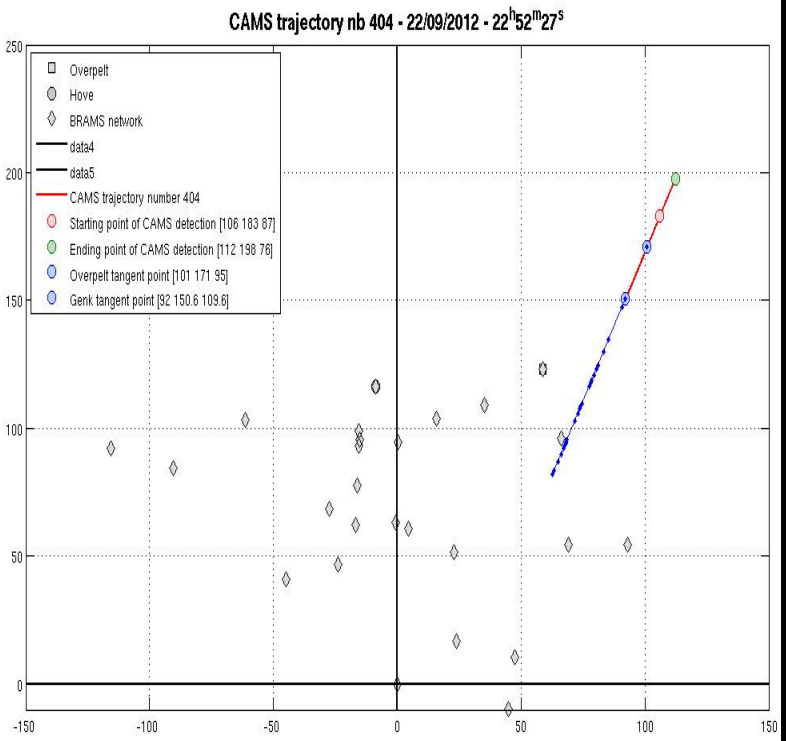
CAMS and BRAMS

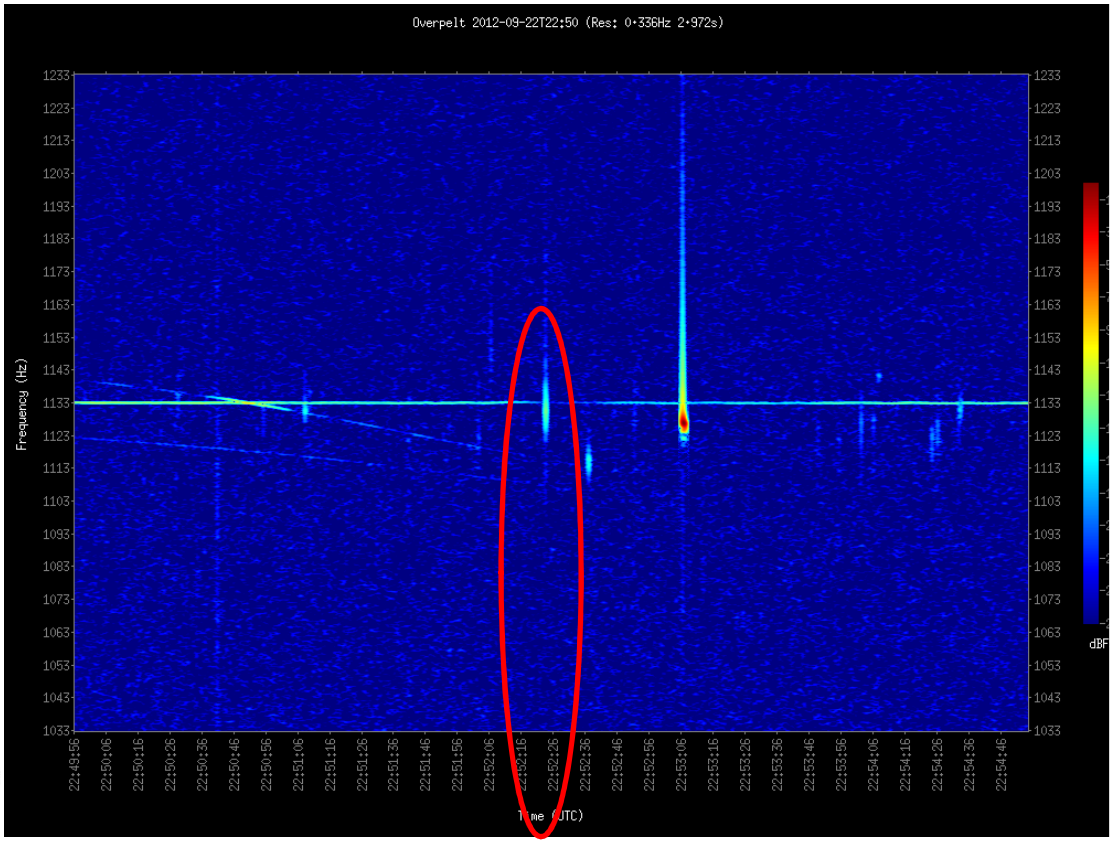


Zoom of above

Trajectoire n° 404, détectable par Overpelt et Genk

CAMS trajectory n°404





Météore éventuellement détectable par Genk (no data at this date) et Overpelt
On observe un météore au ~même instant
Vitesse de ce météore = 16 m/s (froms CAMS data)

Conclusions

- Method proposed by Nedeljkovic (2005) is difficult to use in practice but is a great help to understand the geometry and influences of parameters such as electron line density or meteoroid speed

- The inverse problem of finding the meteoroid trajectory from multi-station observations is still going on and will maybe need the use of at least 6 stations. In practice, it is not so easy to find 6 stations seeing the same meteor in current BRAMS data

- Need to go to coded CW? Radar?

- Any suggestion is welcome