Radio Meteor Observation Research Program in Japan

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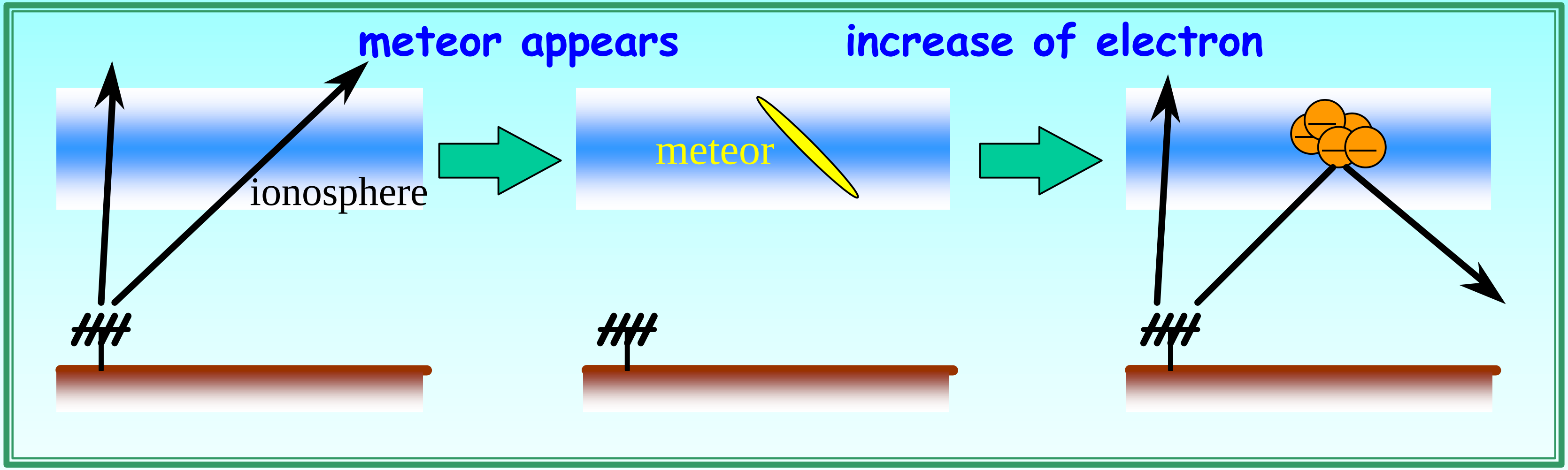
Radio Meteor Observation in Japan

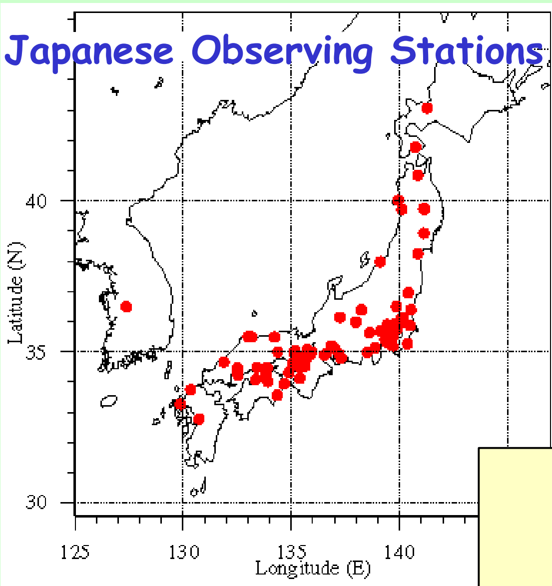
When a meteor appears, it ionizes atmosphere. Then the electron density around there increases and it makes ionized trail. This trail scatters Very High Frequency (VHF) radio wave. Therefore, when a meteor appears, we can receive the scattered radio wave which came from transmitting station.

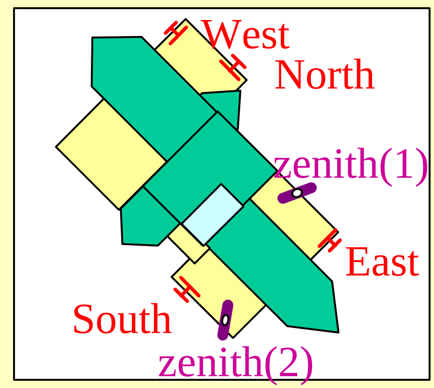


Most of the Japanese Radio meteor observers adopt "**Forward Scattering**" method. The characteristics of this method is that the receiving station is different from the transmitting station.

- Examples of Observing Stations -

Standard observing stations





By using six observing systems, four antennas are turned to East, West, North and South.Other two antennas are turned to zenith (two type). Then we are trying to obtain the change of appearance pattern of each antenna.

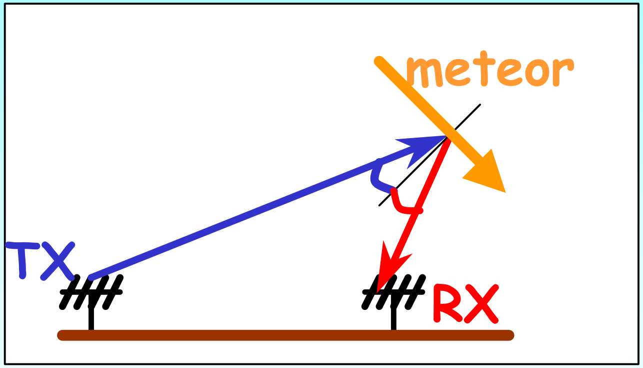
Special observing stations

Big Problem of Forward Scattering

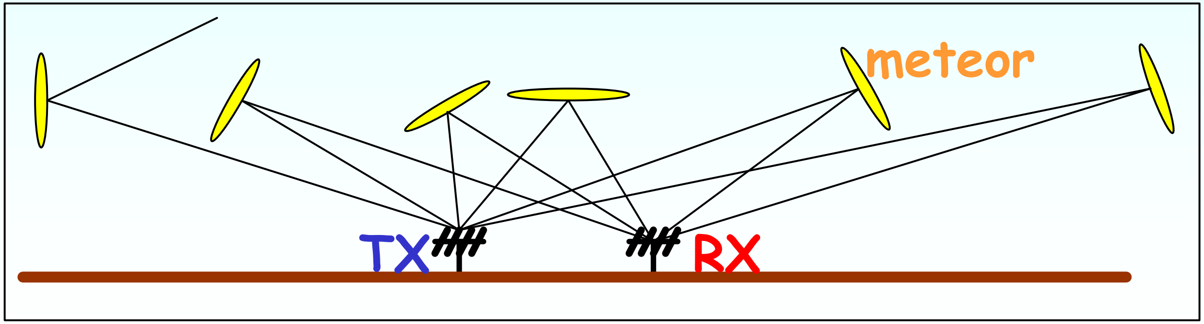
Forward Scattering observation has a big and serious problems. It is…

Where are appearance points of meteor echoes which we observe ?

The forward scattering observation is basically "**incidence angle** = **reflection angle**".

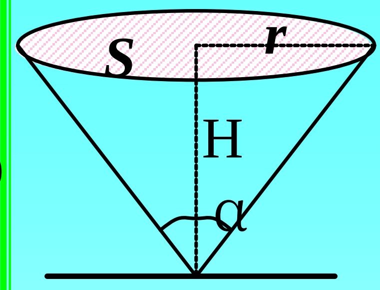


therefore → Reflection Points are changed by meteor incidence angle



In the case of Visual Observation, the observing points is very clear like the right figure. Therefore, we can make the meteor flux clearly.

(α : points of view (angle), H : height of meteor appearance)



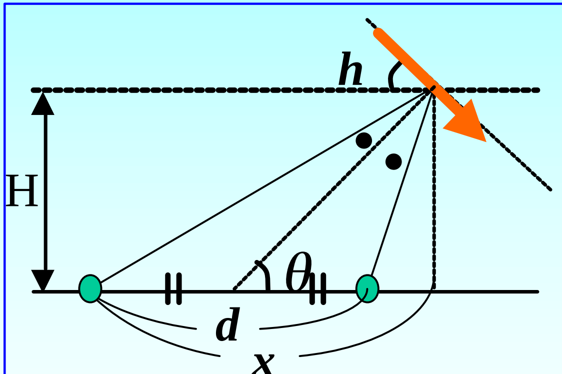
$$S = p\,r^2$$

$$r = H \tan\left(\frac{a}{2}\right)$$

$$S = H^2 p \tan\left(\frac{p}{2}\right)$$

on the other hand…

Like the above figures, appearance points detected by Radio Meteor Observation depend on the incidence angle (radiant elevation). Therefore, we cannot discuss the meteor flux.



h : radiant elevation

H : height of meteor appearance

d : distance between TX and RX

$$q + h = 90^\circ$$

$$x = \frac{d}{2} + \frac{1}{\tan(q)} H$$

$$x = \frac{d}{2} + H \frac{1}{\tan(90 - h)}$$

$$\lim_{h \to 90} x = \infty$$

The distance between TX and the appearance point, x is calculated as left figure. Since $\lim_{h \to 90} x = \infty$, when the radiant rises around zenith we cannot detect meteor echoes because the distance is very long.

We have to simulate the reflection points of Radio Observation

- Purpose -

Calculating the reflection points of Radio Meteor Observation

By supposing that “incidence angle = reflection angle” and “underdence echoes”, we calculated the reflection points of Radio Meteor Observation.

Confirmation of reflection points by using Optical Observation

By researching of correspondence between Radio and Optical, we confirm the existence of reflection points. Then we research where are appearance points.

Goal of research

By the correction of the reflection points, we’ll estimate meteor shower flux distribution from Radio Meteor Observation !!

- Methods -

1. calculation of the reflection points
of Radio Meteor Observation

(using the theoretical model by Y. Utsumi)

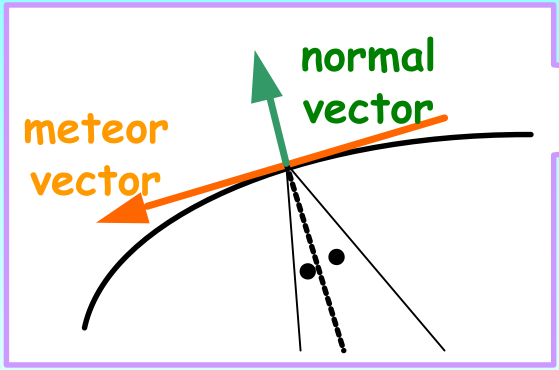
The calculation of reflection points in some meteor streams by using the theoretical model suggested by Y. Utsumi.

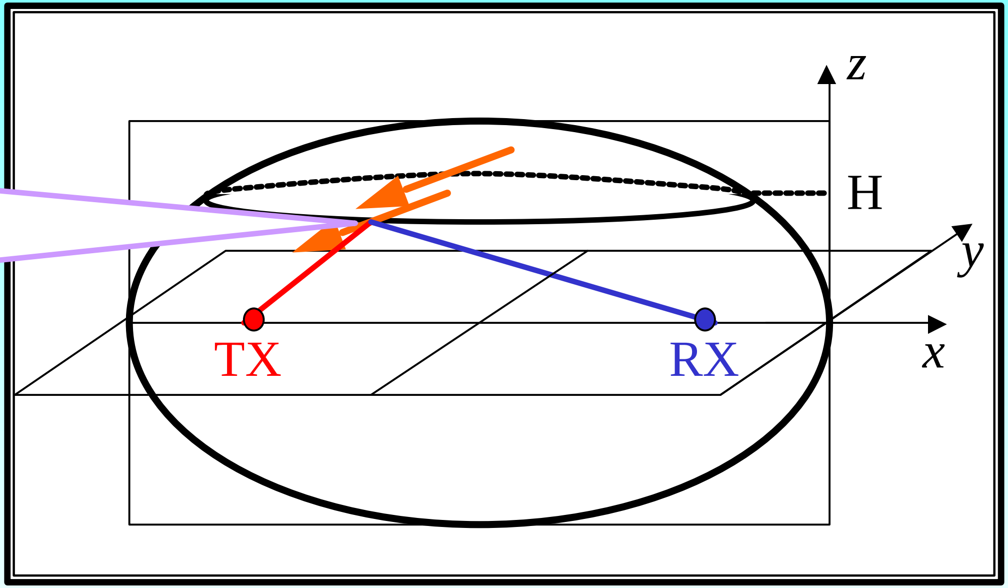
2. Observing the reflection points of radio by optical methods

The observing campaign by all meteor observers was held in the night (2nd/3rd August). Optical observations are Visual and Video Observations.

- Calculation of Reflection Points -

The basic assumption is “incidence angle = reflection angle”. In this time, therefore, we adopted the spheroid whose focal points are Transmitting and Receiving Stations. (as following figure)





The inner product between normal and meteor vector is equal to zero.

(meteor vector means tangent vector of spheroid)

The spheroid equation is shown as following.

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

a : semimajor axis
d : a half distance between TX and RX

Next, we can obtain normal and tangent vector as following.

$$\frac{x^2}{a^2}+\frac{y^2}{a^2-d^2}+\frac{z^2}{a^2-d^2}=1 \qquad (1)$$

This is spheroid equation

differentiation by parameter "s"

$$\frac{d}{ds}\left(\frac{x^2}{a^2}+\frac{y^2}{a^2-d^2}+\frac{z^2}{a^2-d^2}\right)=\frac{d}{ds}\cdot 1 \qquad (2)$$

$$\frac{dx}{ds}\frac{2x}{a^2}+\frac{dy}{ds}\frac{2y}{a^2-d^2}+\frac{dz}{ds}\frac{2z}{a^2-d^2}=0 \qquad (3)$$

Then, $\left(\frac{dx}{ds},\frac{dy}{ds},\frac{dz}{ds}\right)$ means tangent vector. Now, the inner product between normal vector "$\vec{n}$" and tangent vector "$\vec{t}$" is equal to zero. So, we can obtain $\vec{n}\cdot\vec{t}=0$. Since the meteor vector is equal to tangent vector, we can obtain following equation which means that the inner product between normal and meteor vector is zero.

$$\vec{n}\cdot\vec{t}=0$$

tangent vector = meteor vector (p,q,r)

$$\vec{t}=\left(\frac{dx}{ds},\frac{dy}{ds},\frac{dz}{ds}\right)=(p,q,r)$$

insert to eq.(3)

$$\frac{2x}{a^2}\cdot p+\frac{2y}{a^2-d^2}\cdot q+\frac{2z}{a^2-d^2}\cdot r=0 \qquad (4)$$

The final answer is calculated by simultaneous equations, (1) and (4).

- Example of Calculated Result -

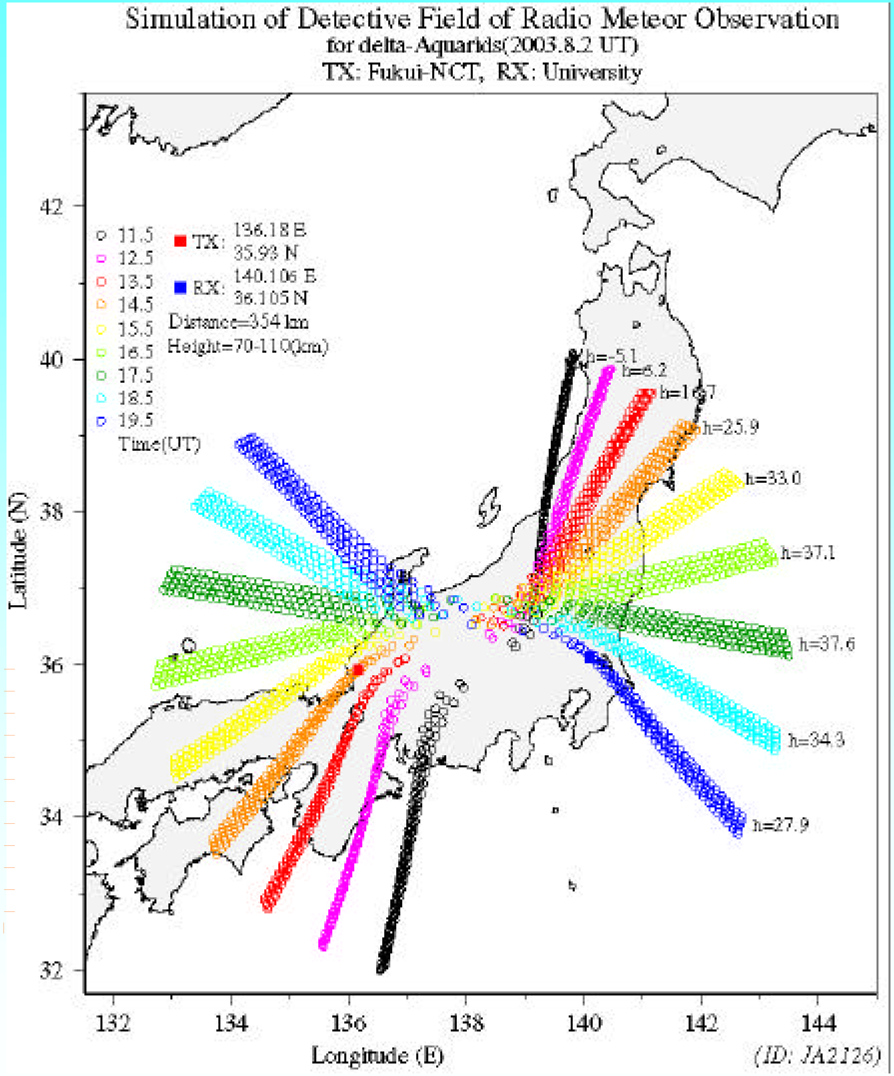
== δ Aquarids ==

▼ **parameters**

Observing station : University of Tsukuba
Date : 2nd August, 2003 (UT)
Time : 11.5 – 19.5 UT (every 1hour)
Height : 70km – 110km (every 10km)

▼ **tools**

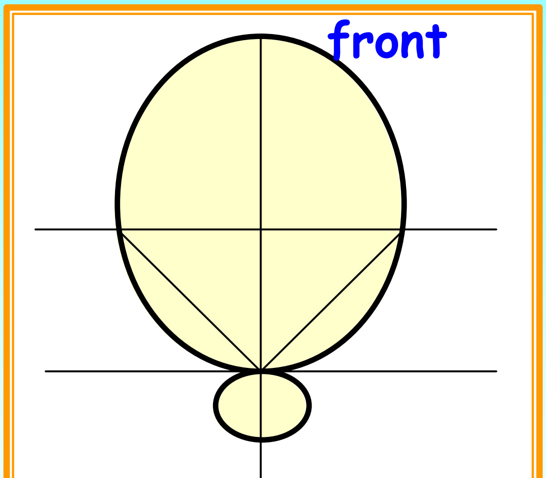
Unix tools
--- Fortran, GMT, Shell Script



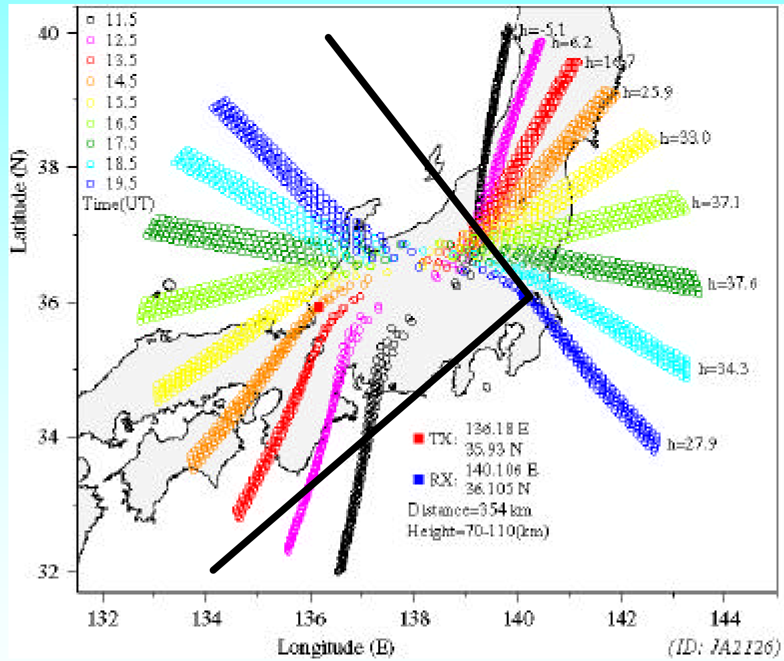
Circle points show reflection points which are the answer of eq.(1) and (4). Therefore, these points are inner product between normal and meteor vector = 0.

- more important problem -

Most of Japanese radio observers use 2el. Yagi antenna. And a half of observers set to the zenith, and other observers set to the horizon. Therefore, we have to consider the directionality of antenna. The directionality of 2el. Yagi antenna is shown as following (left). And right figure shows the observing points under considering directionality when antenna is turned to transmitting station (Western horizon).



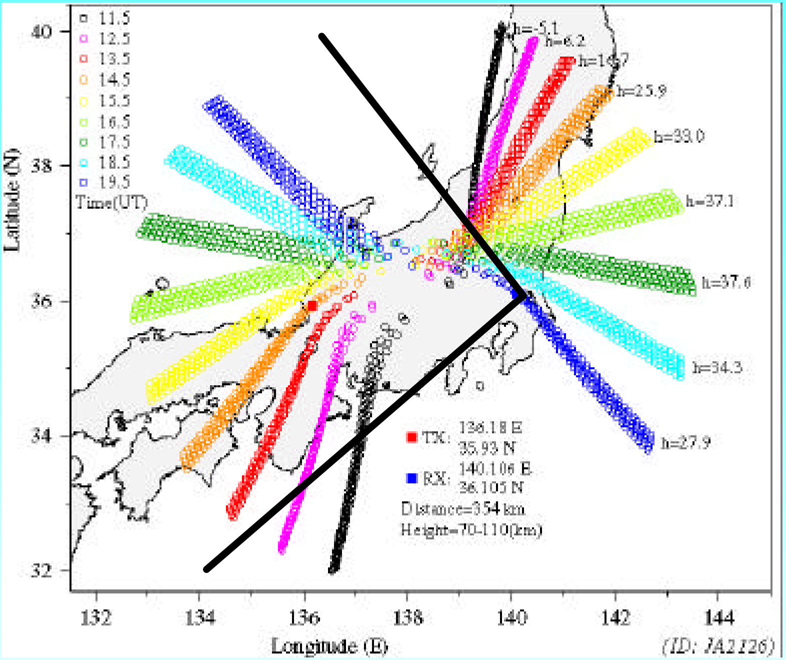
directionality of 2el. antenna



In δ Aquarids, there are many reflection points inside antenna directionality all the time. As for Perseids, however, we have to consider the antenna direction in the case by case. In this research, we considered this antenna direction factor.

- Observing Campaign -

In this time, we planed the observing campaign and examined the reflection points of radio by using optical (visual and TV) observations



Reported data

Visual	:	5 data
Video	:	10 data
Radio	:	49 data

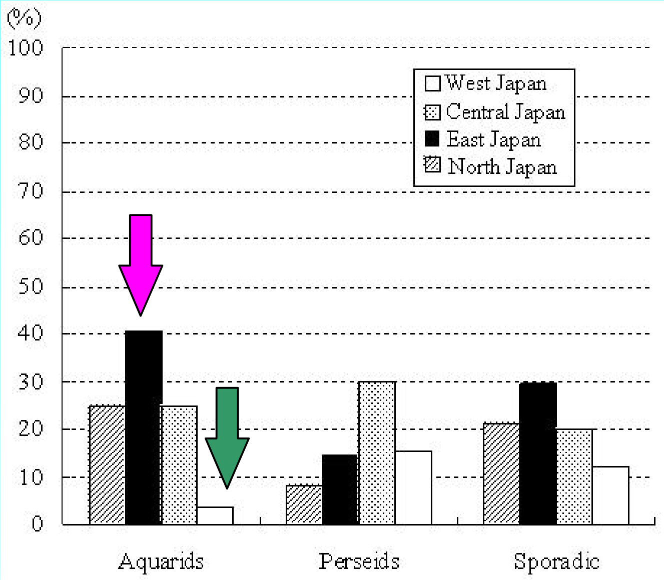
It was bad weather in the campaign night. Therefore, there are only a few optical reports.

We used Visual and Radio data from 15:00UT 2nd August.

*1 this is because δ Aquarids radiant is low elevation until 14:00UT

*2 Video data have not been analyzed yet.

- Results (1) -



We calculated the coincidental rate of meteors which were observed by Visual Observation. This rate is defined as following.

$$rate = \frac{N_{obs}}{N_{all}} \times 100$$

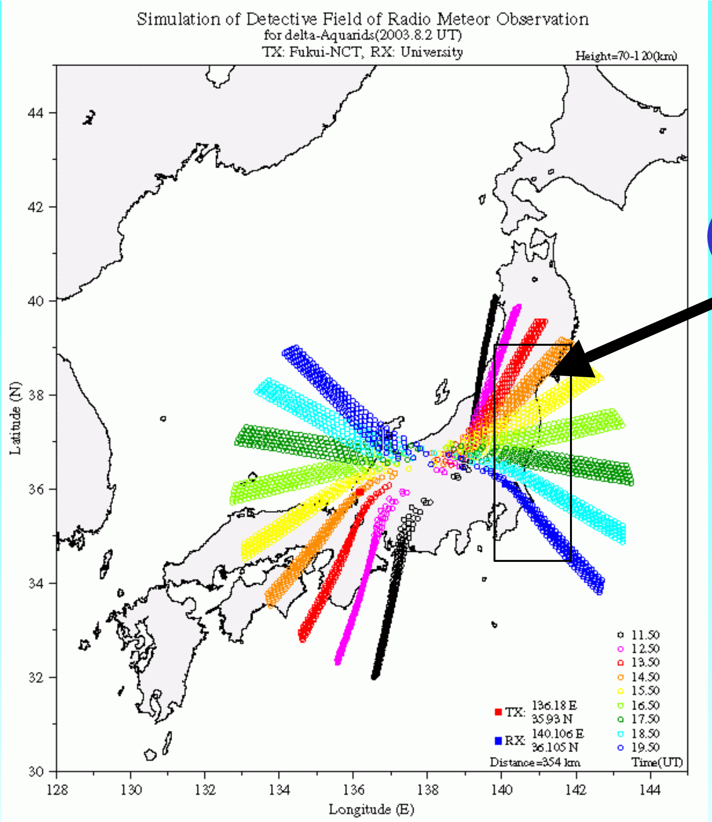
N_{obs} : the number of radio station that observed echo which obtained by Visual meteor

N_{all} : the number of all radio stations

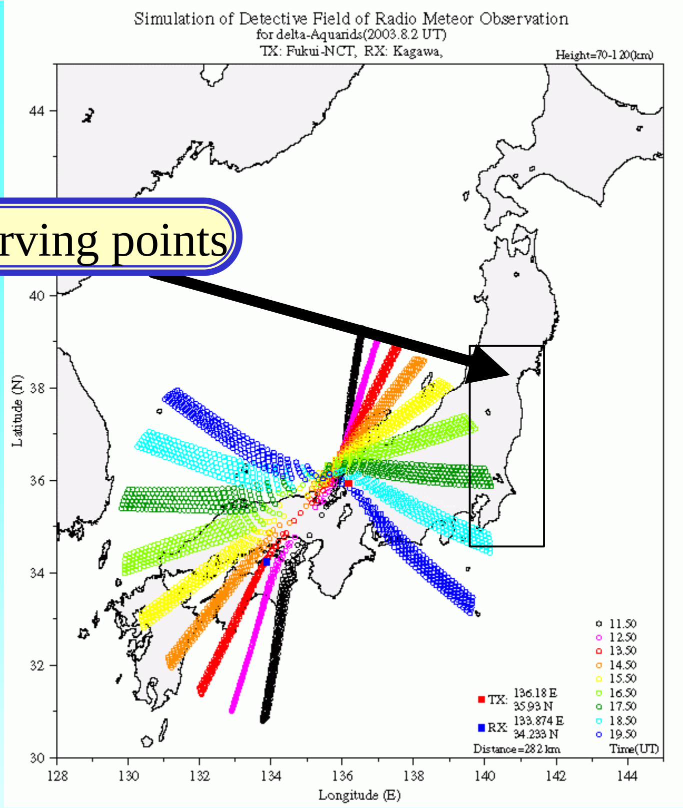
▼ **In the case of δ Aquarids …**

High coincidental rate in East Japan
Low coincidental rate in West Japan

this reason is ……



visual observing points



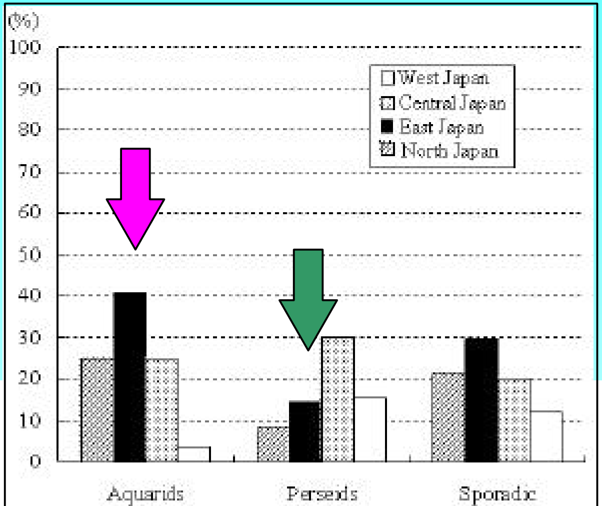
reflection points at Eastern stations
(ex. University of Tsukuba)

reflection points at Western stations
(ex. University of Tsukuba)

Radio (East Japan) : reflection points is upper sky around East Japan
Radio (West Japan) : reflection points is upper sky around Central Japan
Visual Observation : Observing points is upper sky around East Japan

It seems that coincidental rate in East Japan is high because observing fields of radio stations in East Japan and visual observers are the same.

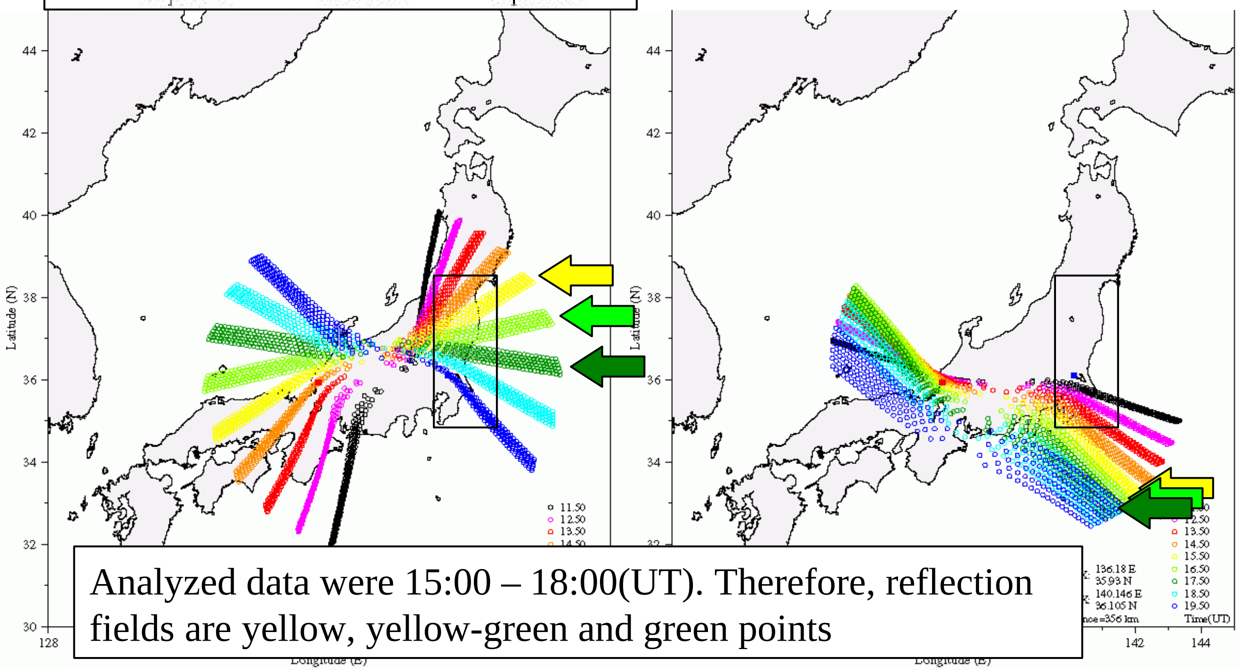
- Results (2) -



at same observing points…

High coincidental rate in Aquarids

Low coincidental rate in Perseids



Analyzed data were 15:00 – 18:00(UT). Therefore, reflection fields are yellow, yellow-green and green points

Aquarids

visual observing points includes radio reflection points

Perseids

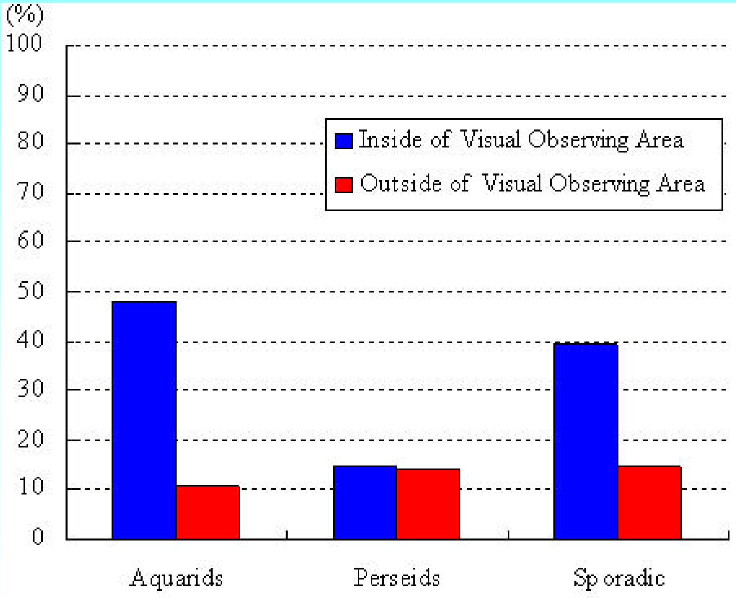
visual observing points includes little radio reflection points

- Results (3) -

Next, we distinguished whether the radio reflection points is included in the visual observing points or not.

The coincidental rate : radio reflection area is inside of the visual area

The coincidental rate : radio reflection area is outside of the visual area

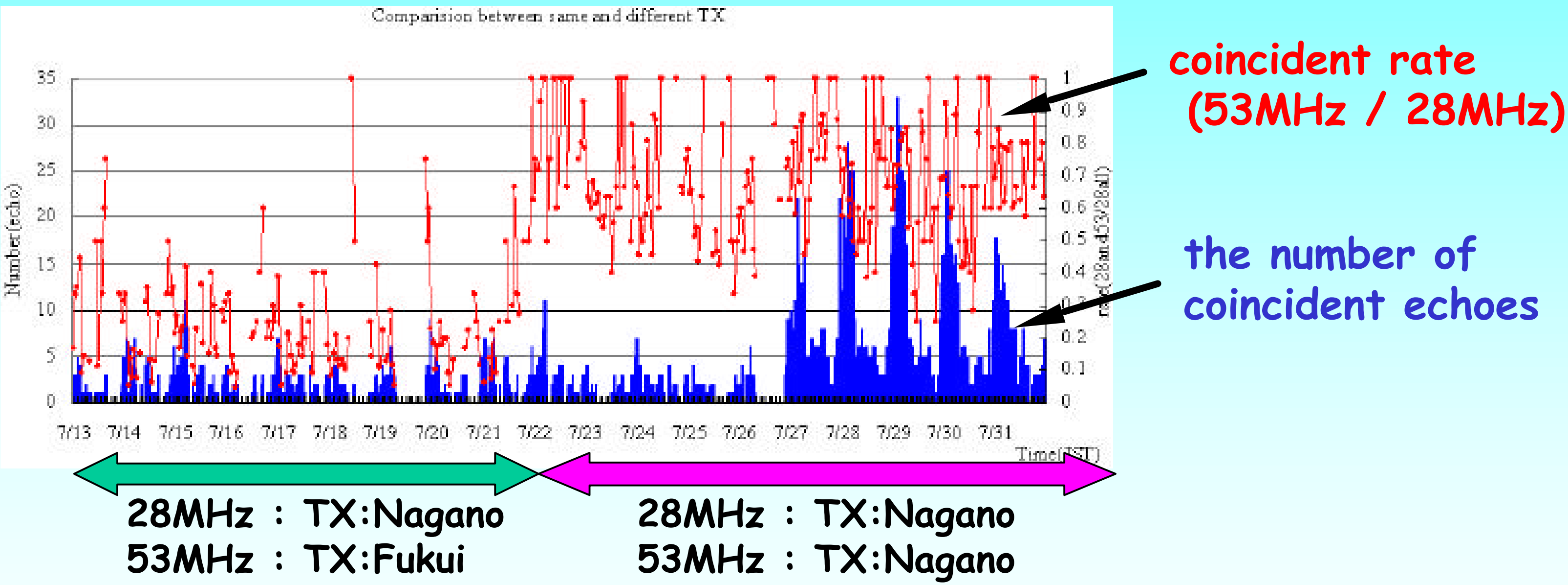


According to the left graph, the coincidental rate that the radio reflection areas are inside of the visual area is higher than the rate that they are outside.

The coincidental rate securely rises when visual observers look at reflection points of radio meteor observation

- Results (4) -

In another view point, the existence of radio reflection points was confirmed by 28MHz and 53MHz observation at the same station. But these transmitting stations are different until 22nd July. After that day, these transmitting stations are same location. The following graph is provided Mr. Hirotoshi HARA.



In the case of using the same transmitting stations, the reflection areas are same even if using frequencies are different.

- Consideration -

About the validity of the simulation of radio reflection points

The incident rate is about 50% in δ Aquarids. This value is the greatest result in previous research. On the other hand, however, another 50% is not incident. The reasons are as following.

(1) Visual observed data were not enough

First, it was bad weather in this time. In addition, we did not specify observing time. Therefore, some observed data were not so good because radiant elevation at the observing time was low.

(2) Antenna directionality problem

In Japan, many observing stations adopt 2el. Yagi antenna. This antenna doesn’t cover all the sky. Therefore, we need to turn to the reflection points every meteor shower. The best antenna is cross-Yagi antenna.

(3) Parameter problem

First, the current range of the appearance height is too wide. The underdense echoes are affected by Height Ceiling effect. Therefore, we have to narrow the range of appearance height. Second, in this time, we assumed the semimajor axis as 500km. But we have to obtain this value from radar equation. And third, this simulation considers underdense echoes only. Therefore, we cannot consider overdense echoes.

- Conclusion -

We have to consider the reflection points of Radio Meteor Observation

At least, since the reflection points exists, we have to consider this factor when we discuss the meteor activity.

Reflection points simulation is correspond with results well

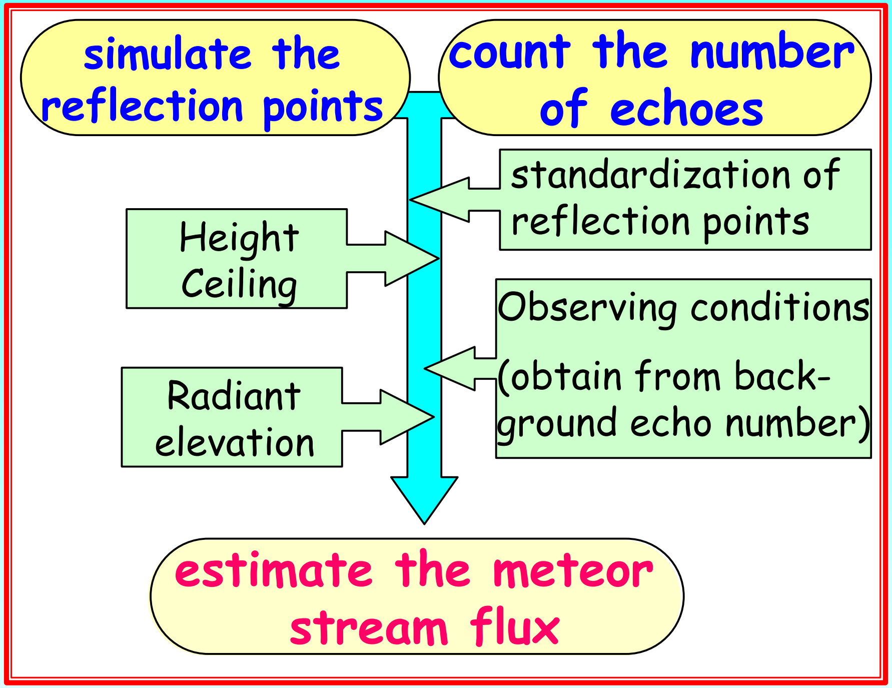
The coincident rate is 50% in this time. We can say this value is good result as compared with previous research. But this is not enough, therefore, we have to think much better model than current model.

The possibility of correction for reflection points

Since we can obtain the high coincident rate, it is possible to consider the reflection points correction. By using this correction, it becomes possible to discuss the meteor stream activity more accurately.

- Goal of this research -

By using the simulation of the reflection field and counting the number of echoes with some corrections, it becomes possible to estimate meteor stream flux. Some examples of corrections are; considerations of Ceiling Height, radiant elevation, observing condition, and so on. The flow chart is as right figure. And this is very useful for grasping the activities of the annual meteor stream and outburst meteor shower.



Then, the goal of this research is to establish an index which is correspond to Zenithal Hourly Rate (ZHR) of visual observation. By this index, Radio Meteor Observation plays more important part in meteor astronomy !!

- Epilogue -

Japanese radio meteor observing stations increased recently. This is because that the forward scattering observation is very easy and inexpensive .

Many problems are pointed out…… but we tried to solve these problems.

For examples…

•Time precision

⇨ Many stations adopt GPS, radio clock, NTP, etc.

•Multi-frequencies

⇨ We tried to use 28MHz, 53MHz, VOR, etc.

Japanese Radio Meteor Observation has a chance of developing now !!
If you have a good research program, please suggest us !!

- Contact -

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