

# Analysis of Tatiana-2 satellite data on transient events outside of thunderstorms; a search for their correlation with “ionosphere heating” stations

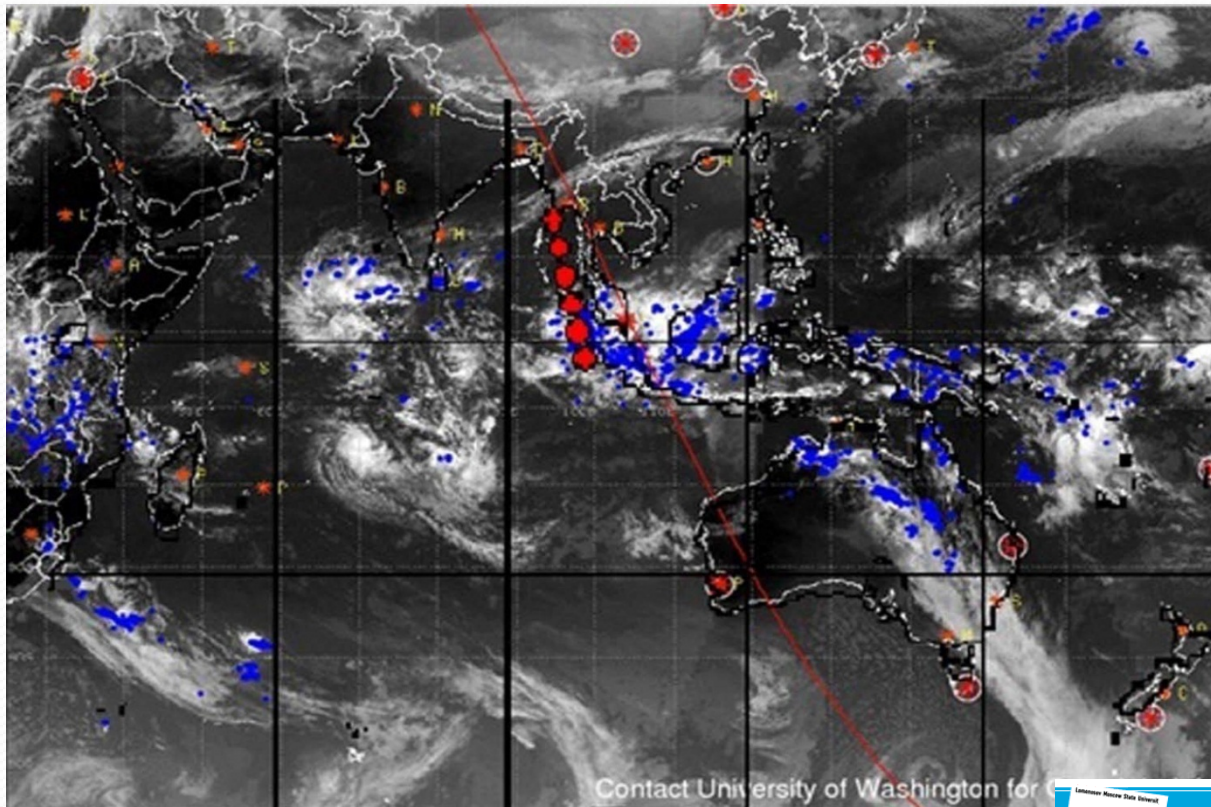
V.S. Morozenko

G.K. Garipov, B.A. Khrenov, P.A. Klimov,  
M.I. Panasyuk, S.A. Sharakin,  
I.V. Yashin

# *What is the reason of such analyses?*

An interesting evidence of flashes outside of thunderstorm area was found in “series” of flashes.

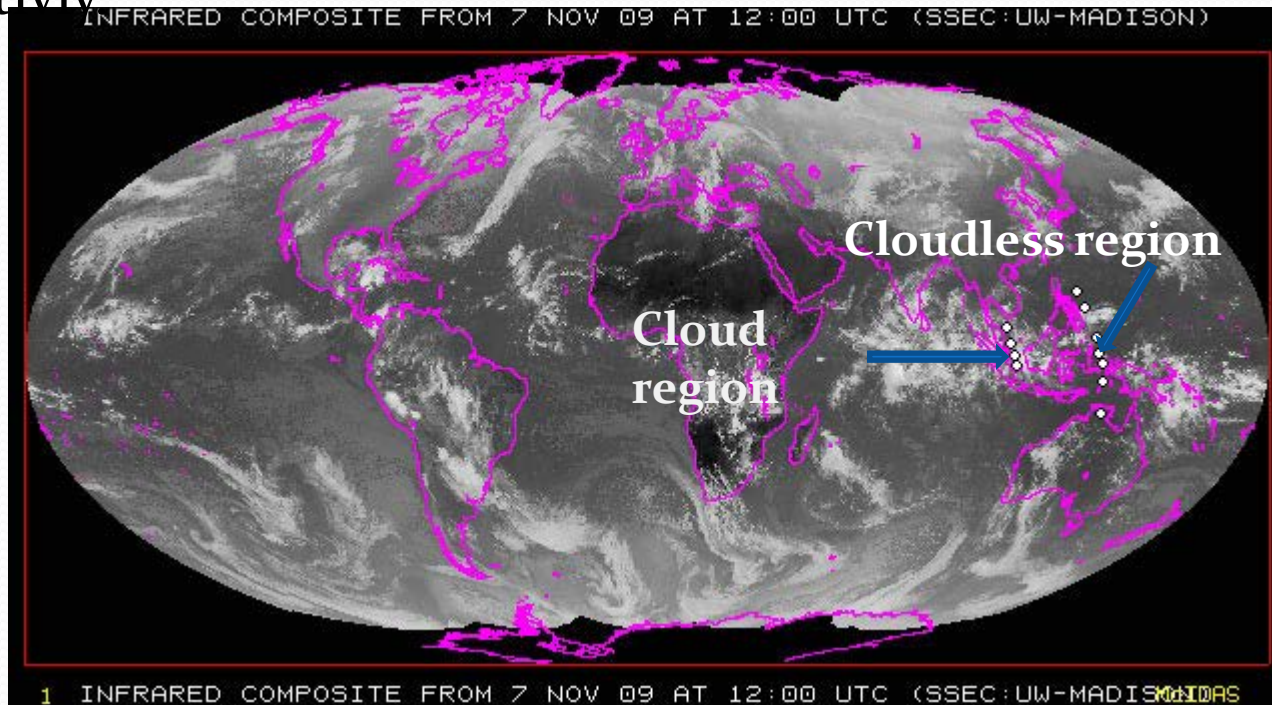
Frequently flashes were registered every minute of detectors operation and such “series” were not interrupted above cloudless areas.



# Methodology of analyses

Assuming position of large cloud region not changing in 3 hours, the “cloud” and “cloudless” transient events were determined by color code.

Observational distribution of detector operation time over cloudless and cloud regions for Tatiana-2 ~25% and 75% respectively



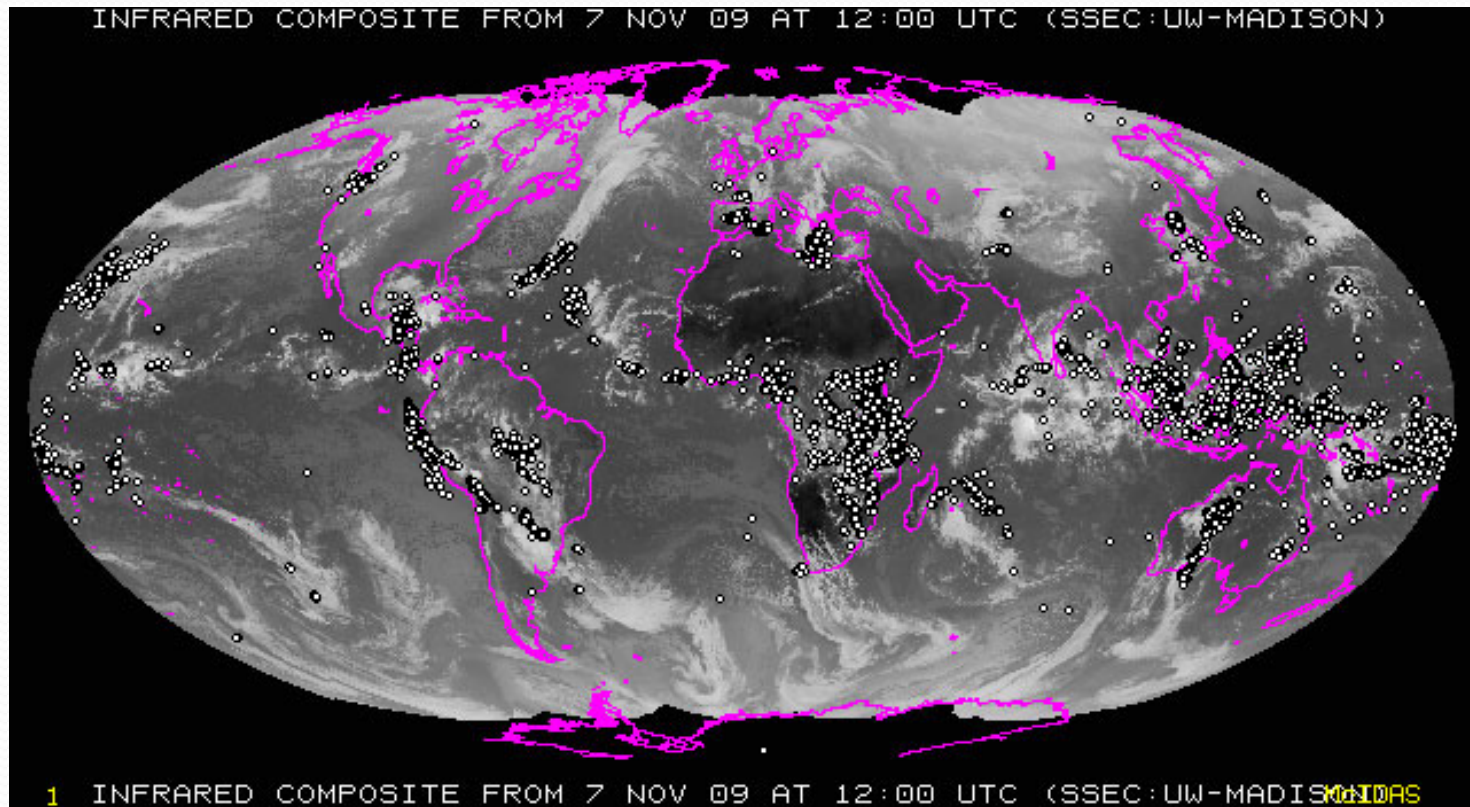
Data on cloud cover was taken from NASA overview  
<http://www.ssec.wisc.edu/data/comp/ir>



# Application cloud/no cloud analyses to lightning

The same analyses for WWLN date (November 2009) were done

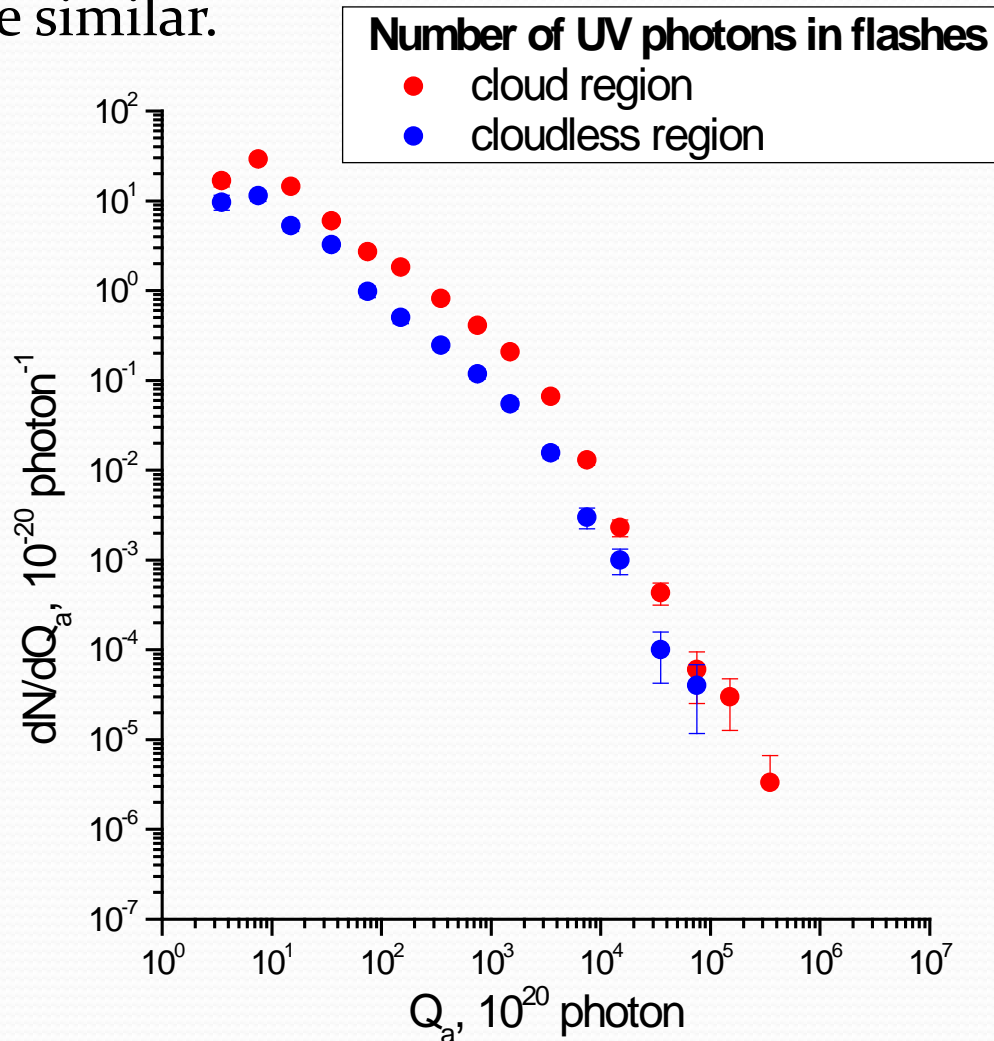
$86 \pm 6\%$  lightning in cloud region



# Distribution of photons number in UV band

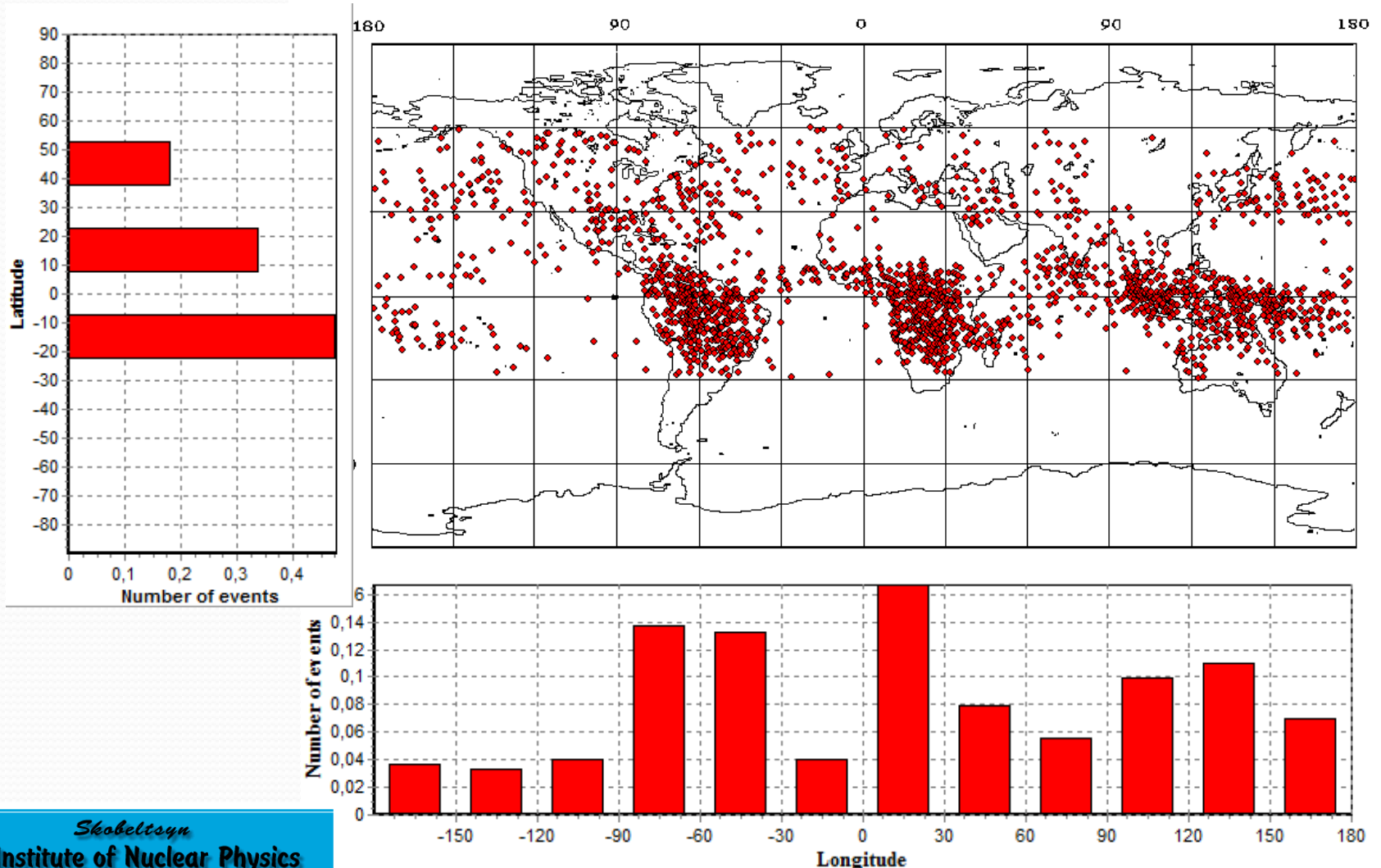
Among all analyzed 2405 events, 600 (~25%) was found to be in cloudless regions and 75%- in cloud regions .

Photons number  $Q_a$  distributions of flashes in cloud and cloudless region are similar.



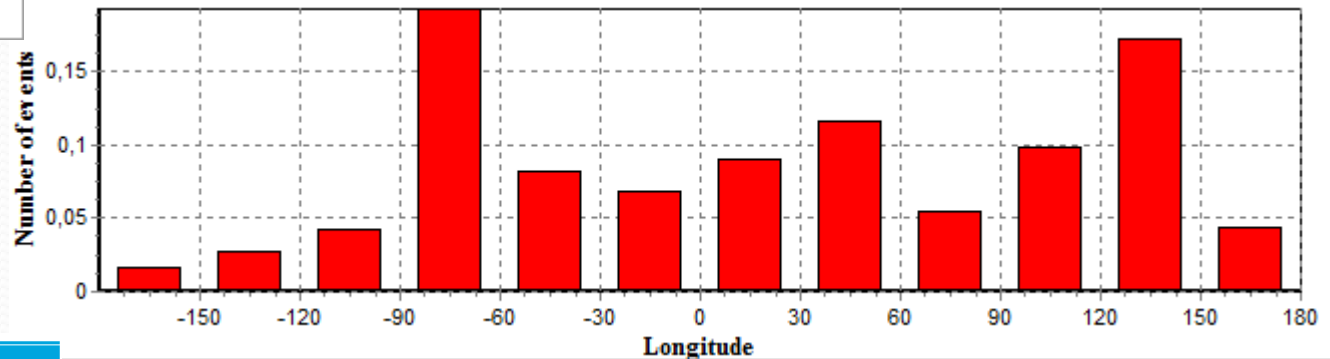
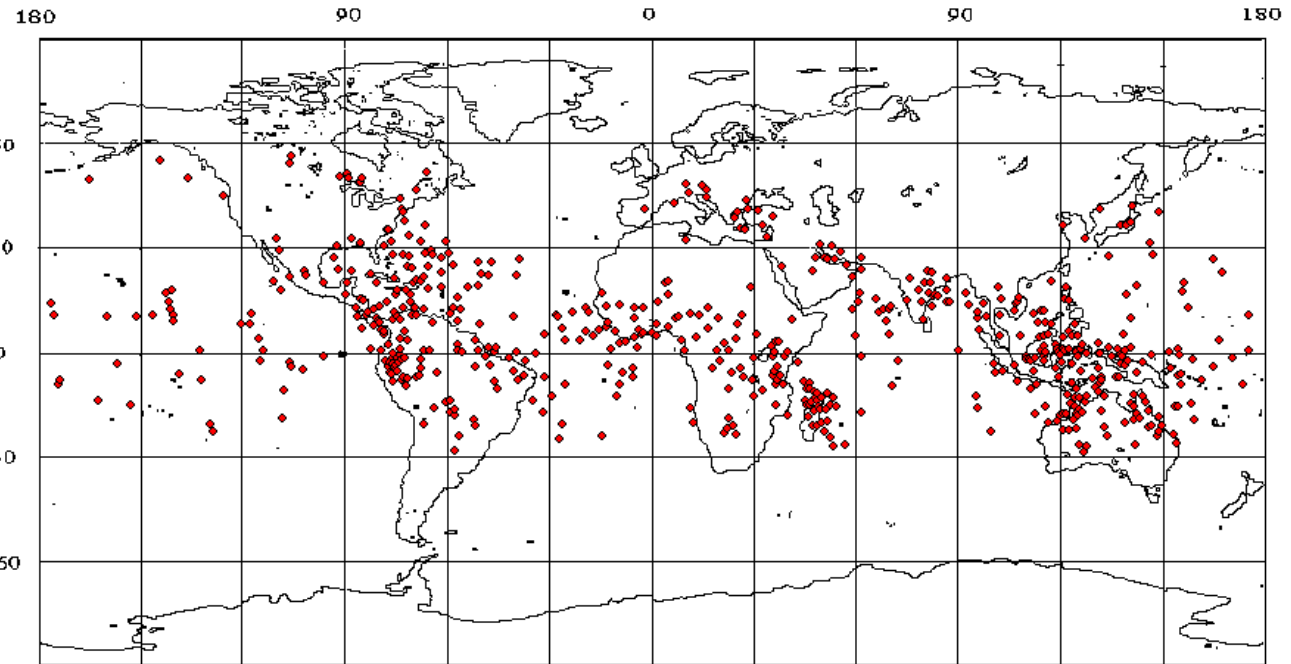
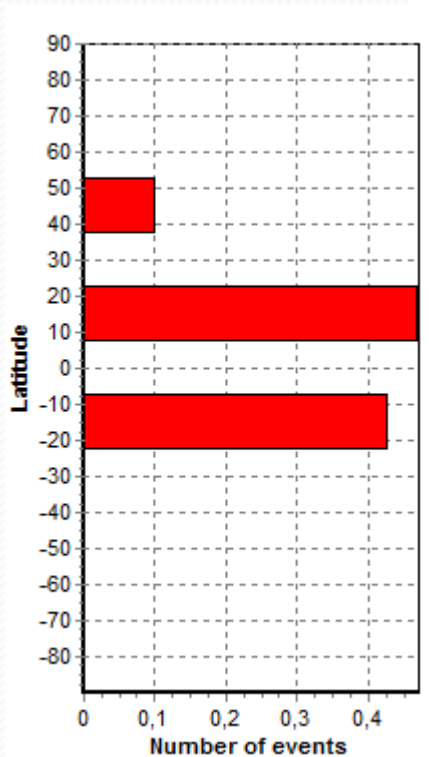
# Global distribution of flashes above clouds

Global distribution of flashes in cloud and cloudless regions demonstrates correlation with thunderstorm areas. They are concentrated in equatorial region above continents as lightning do.

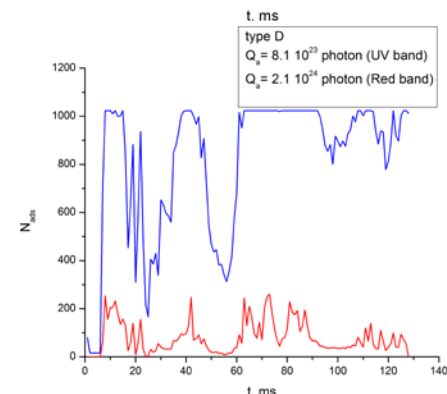
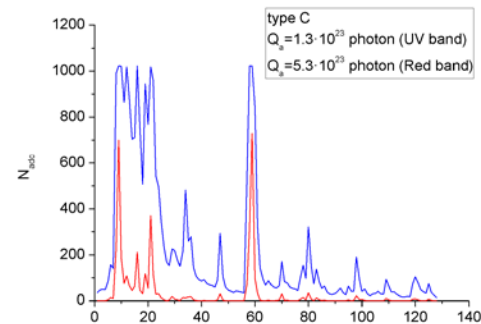
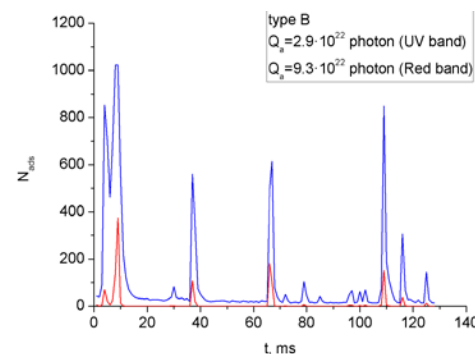
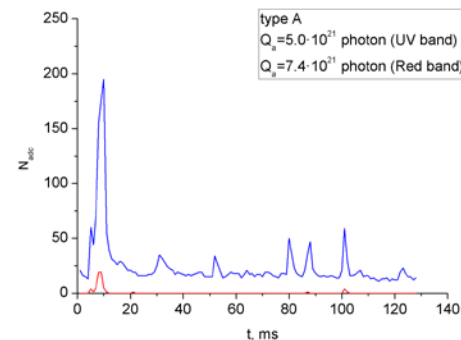
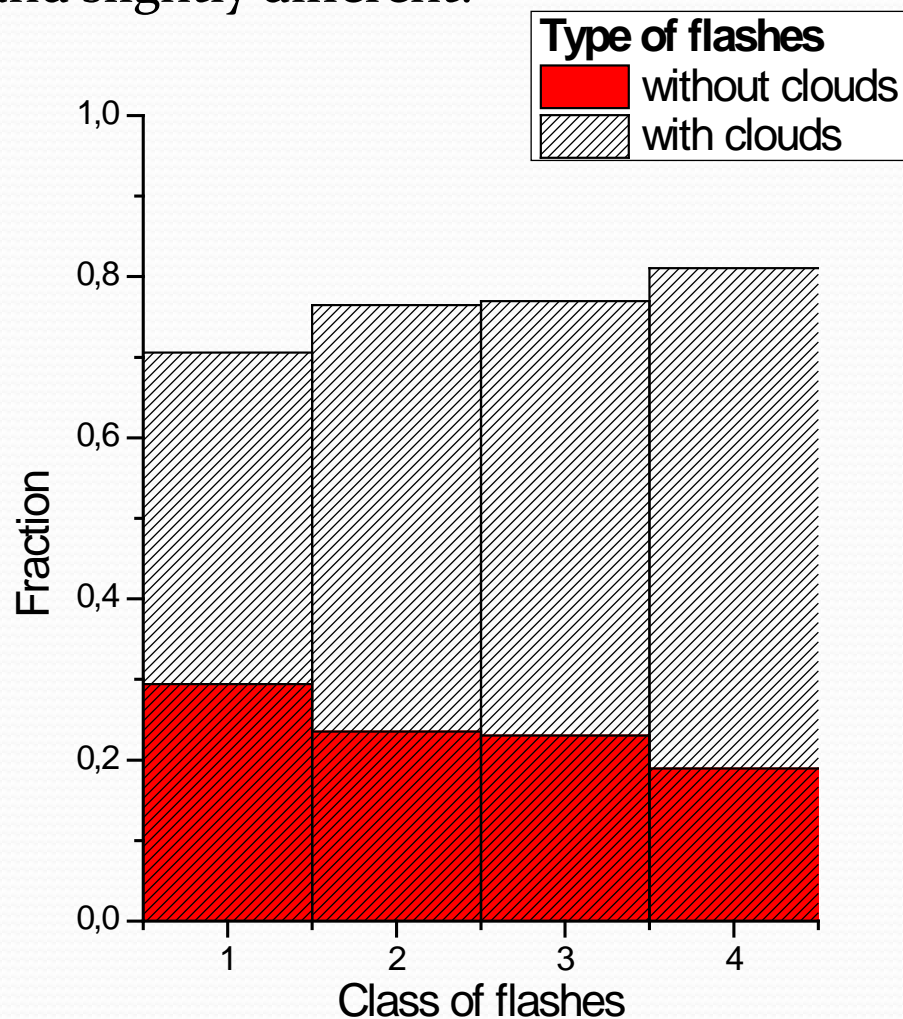


# Global distribution of flashes without clouds

Concentrated in equatorial region! *Distance effect of thunderstorms?*



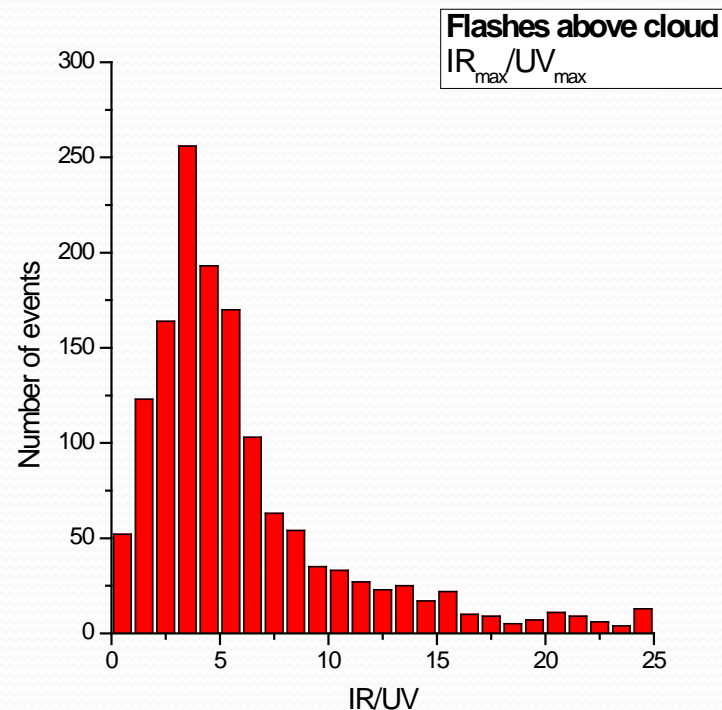
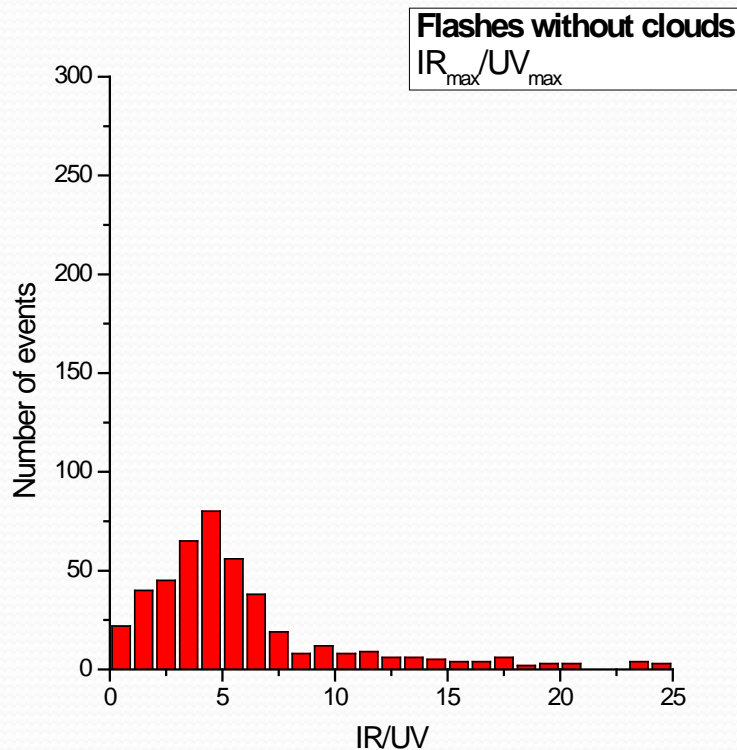
**Distribution of flash events on temporal structure in cloud and cloudless areas** was found slightly different.





# The ratio $P$ of photon number in Red range to photon number in UV range

Spectral characteristic of flash events (ratio of Red- IR photon number to UV photon number) is similar for cloud and cloudless events and indicates large height in the atmosphere ( $H \sim 50\text{-}80\text{ km}$ ) of electric discharge responsible for flashes (Vedenkin et al, 2011).



Evidences on presence of transient events in cloudless regions (outside of thunderstorms) indicate a process of electric discharge in upper atmosphere ( $H \sim 50-80$  km) occurring far away of lightning.

## «ELVE» model

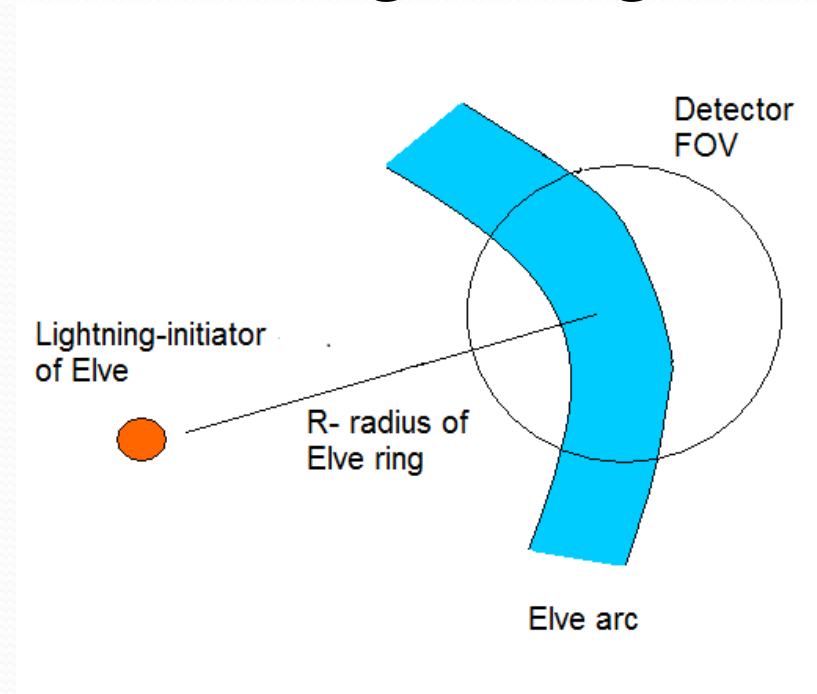
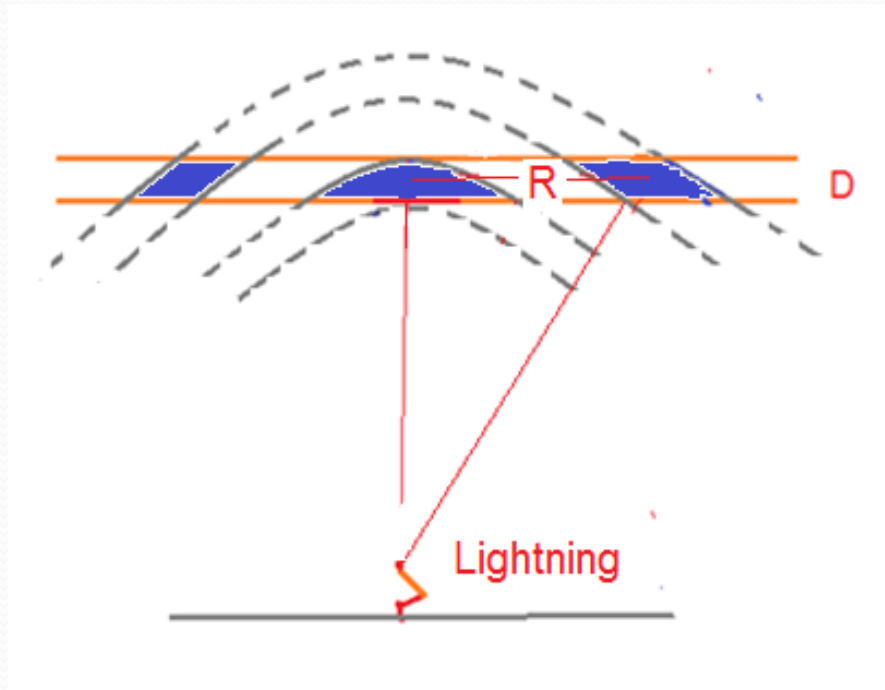
- In previous experiments and their interpretations electric discharge models were suggested for thunderstorm area where lightning is close (less than 100 km) to detector.

«ELVE» MODEL of heating the lower ionosphere by lightning electric pulse :

- *easily explains transient radiation at distances of hundreds km from lightning*
- *could help to understand flashes in series*
- *predicts short ( $\sim 1$  ms) flashes at  $H \sim 50$ -80 km (in lower ionosphere) in agreement with Tatiana-2 experiment (flashes of the first two classes)*

# «ELVE» model

## Schematic of distant effect of lightning



$R$  is EMP radius at the lower border of chosen layer of the ionosphere.  
 $D$  is ionosphere layer thickness

Output of photons  $q(Q) \sim 1/R$  (expected if the radiation intensity is proportional to the electric field)

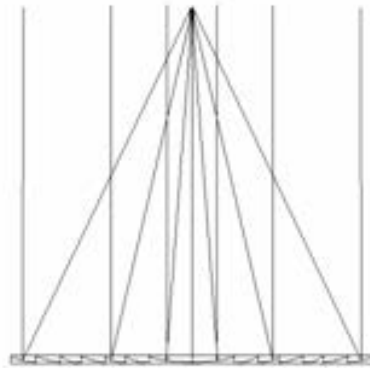
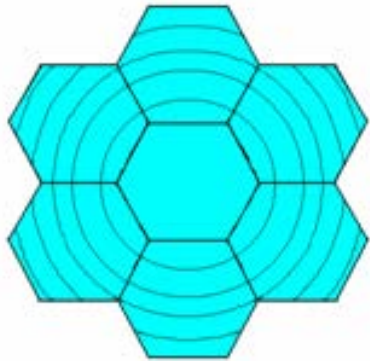


Skobeltsyn  
Institute of Nuclear Physics

Lomonosov Moscow State University



# Detector TUS



Fresnel type mirror-concentrator

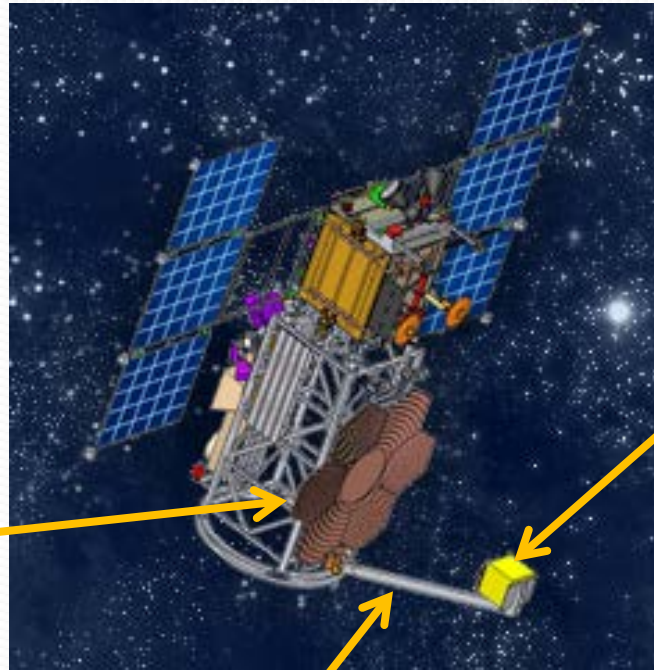
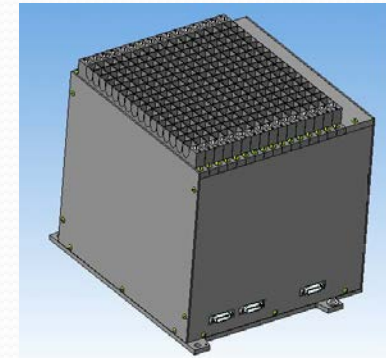
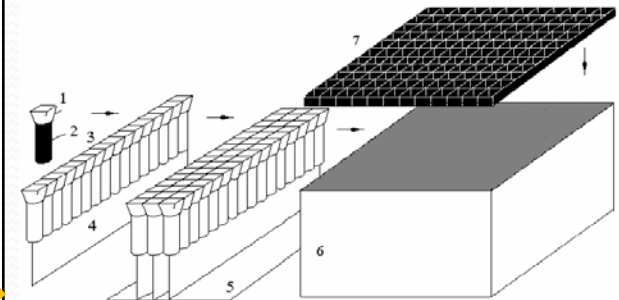


Photo receiver  
moving system

Photo receiver

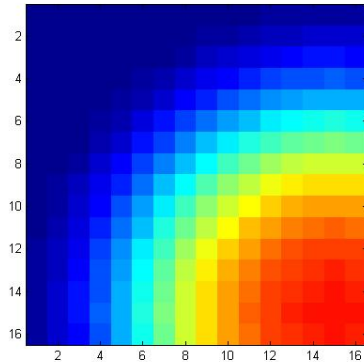


TUS detector will be able to measure time –space distribution of transients photons with temporal resolution of  $1\mu\text{s}$  and 5 km in space

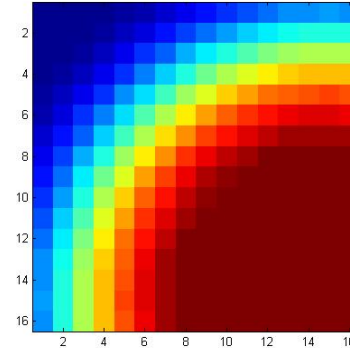
# Example of an event “measured” by TUS detector

It is ELVE type event generated in the atmosphere at the right bottom corner of TUS. Number of TUS pixels is 256 pixels, time resolution 1  $\mu\text{s}$ .

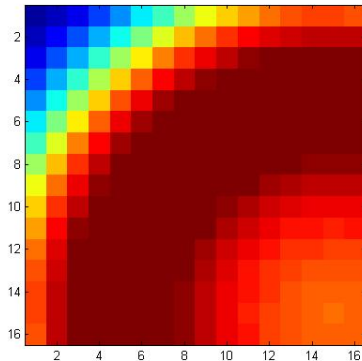
T=75  $\mu\text{s}$



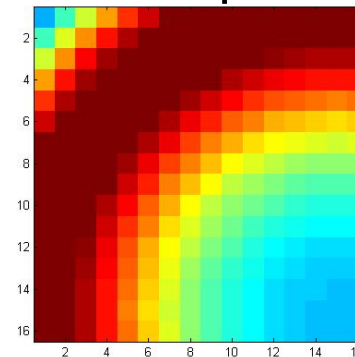
T=100  $\mu\text{s}$



T=125  $\mu\text{s}$



T=150  $\mu\text{s}$



T- is time started from the moment of original electric pulse crossing the above atmosphere (ionosphere).

Considered above model is attractive for explanation of flashes at distances of hundreds km from original lightning i.e. by lightning belonging to large region with several thunderstorms covering a whole continent like Africa or South America in tropical area.

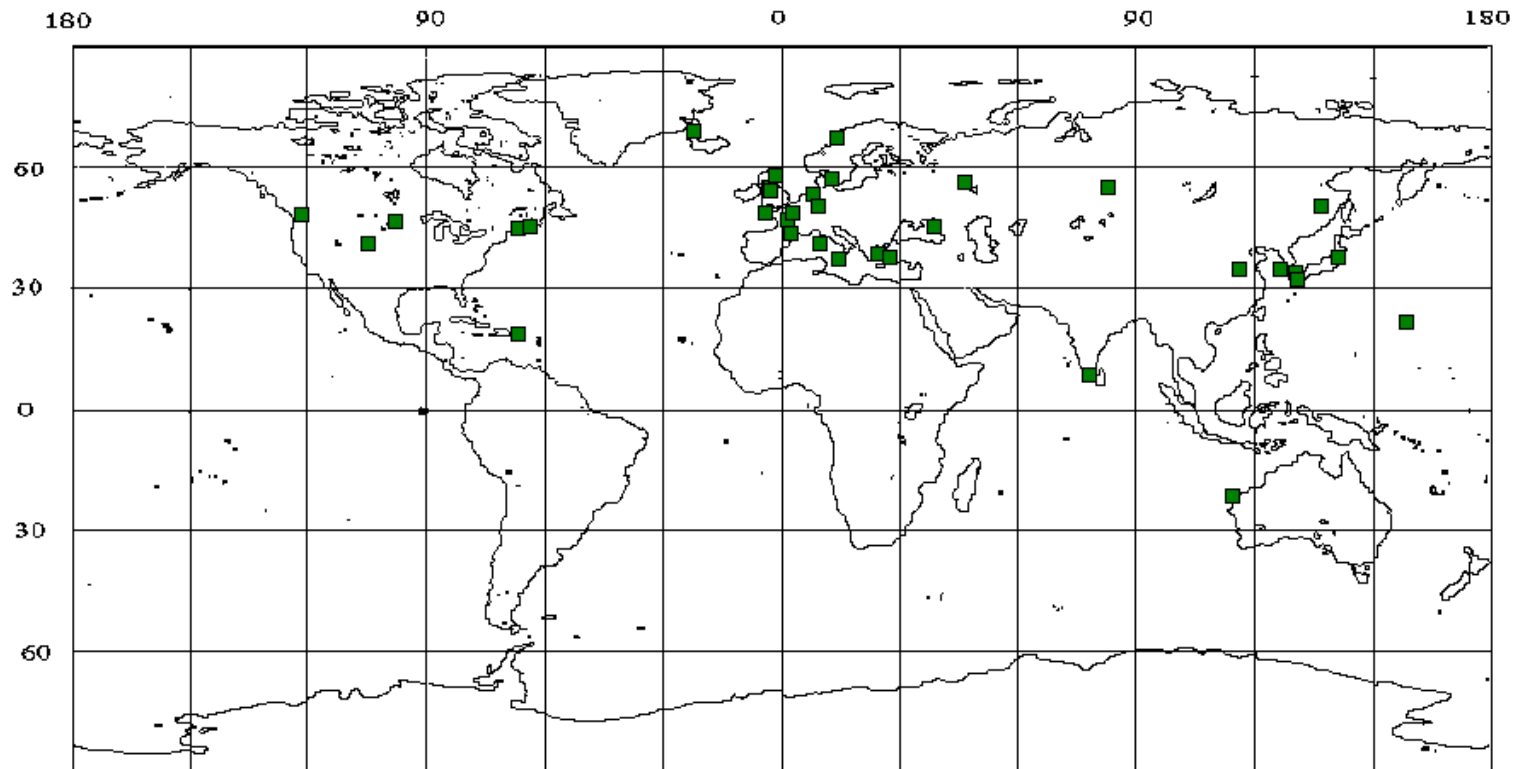
Many lightning in such large area may produce enough “distant” flashes for understanding Tatiana’s experimental data on serial flashes and flashes in cloudless regions.

# Correlation with VLF station

As an alternative interpretation one may suggest that those events were generated by radio VLF stations.

<http://sidstation.loudet.org/stations-list-en.xhtml> VLF station list

## Coordinates of VLF stations

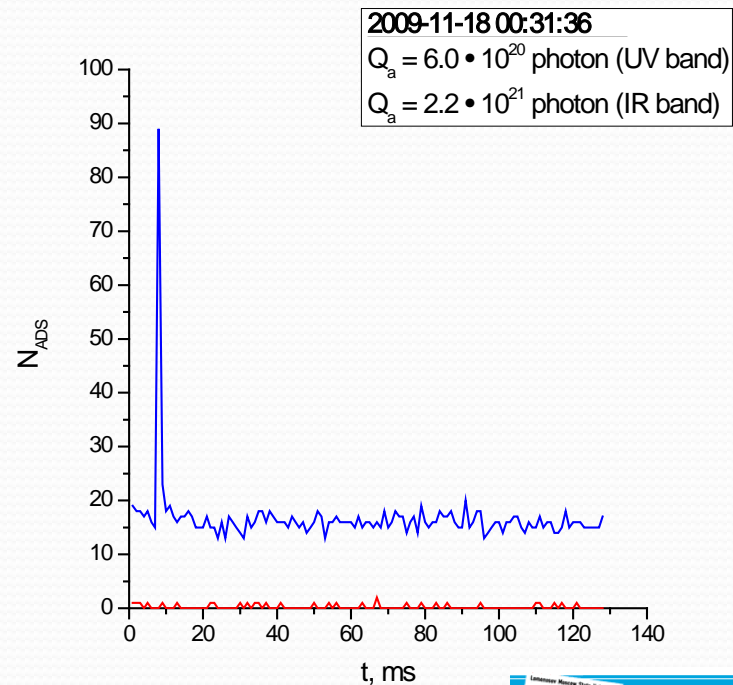
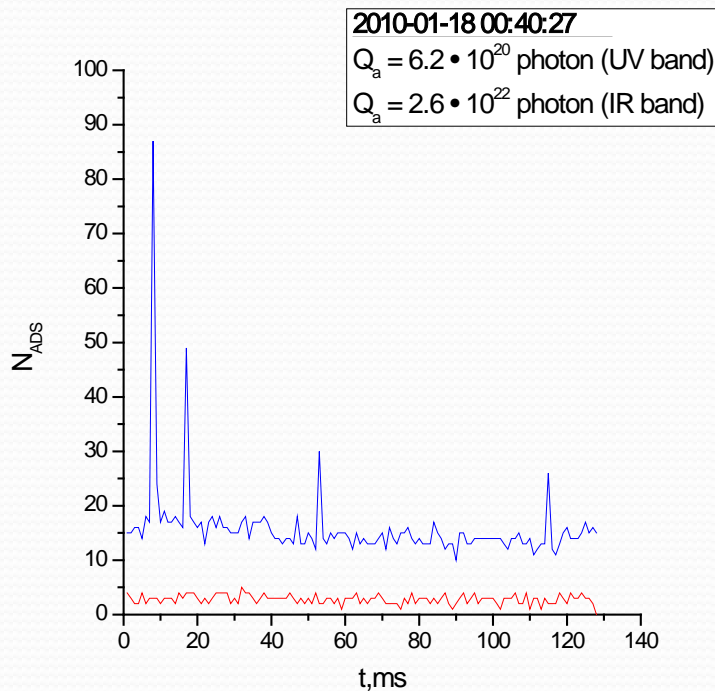




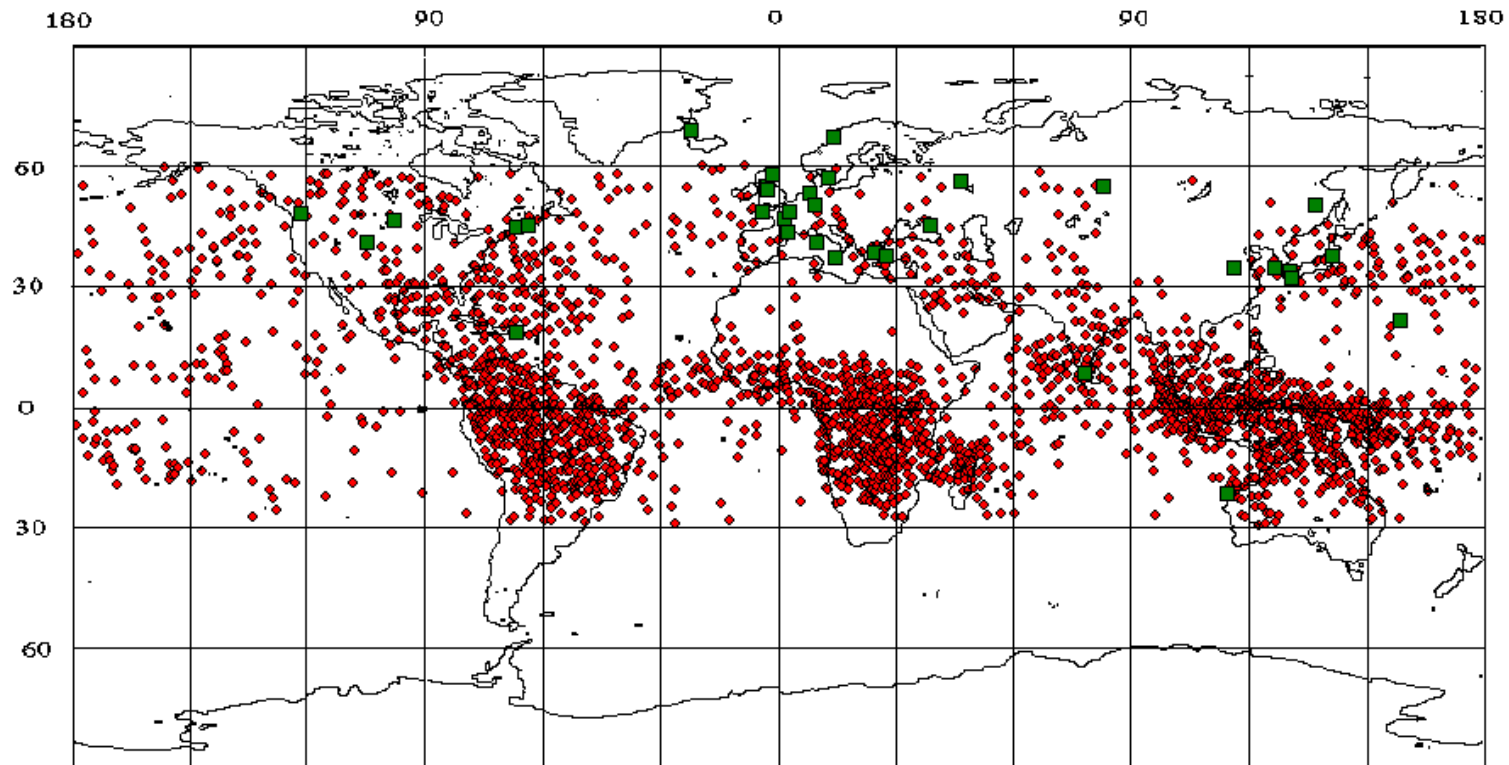
# Event above VLF station

There are two coincidence with the same VLF station

Call sign	Location	Latitude	Longitude
CFH	Halifax, Canada Locator: FN84ax	N 44° 58' 2.19" (+44.967276°)	W 063° 58' 55.78" (-063.982160°)



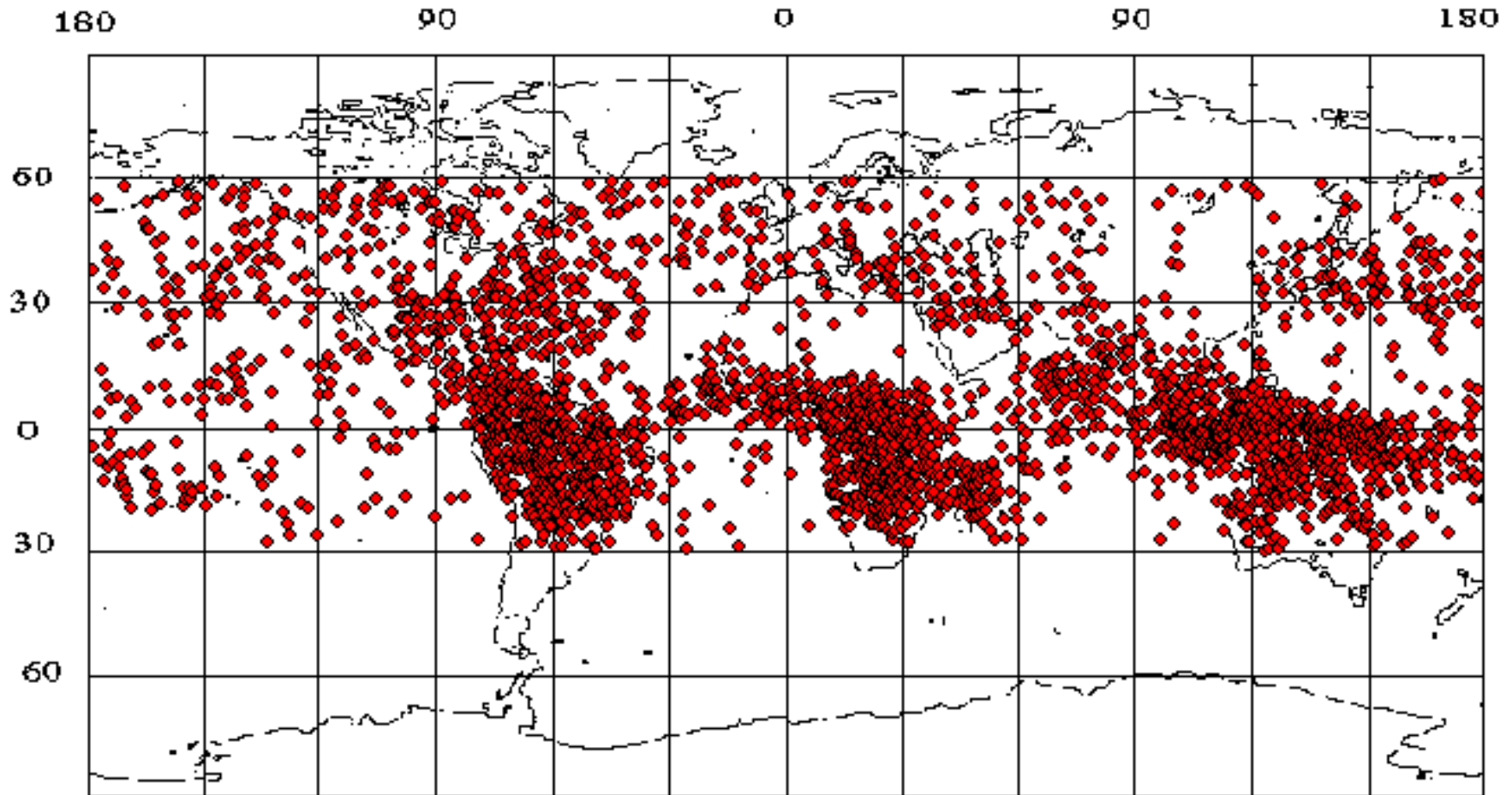
There is no correlation of VLF radio stations and transients.



# Conclusion

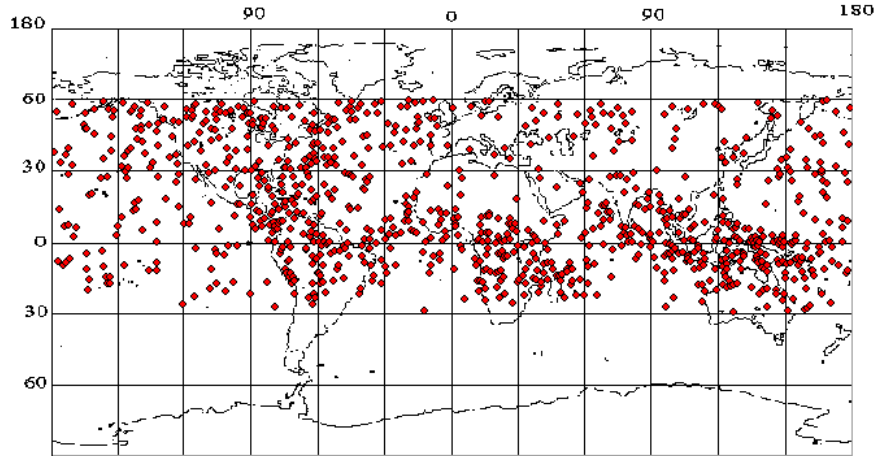
- Data of Tariana-2 satellite detectors (transient events) indicate existence of transients in cloudless regions- hundreds km from thunderstorms with lightning.
- Model of transient “elve”-like event may explain existence of transients at hundreds km from lightning in area contained many thunderstorms (in tropical regions of continents).
- Alternative source of transients could be electric pulses from VLF radio stations. A search for correlation of transient coordinates with position of VLF stations does not show such correlation.

## *Transient events global distribution:*



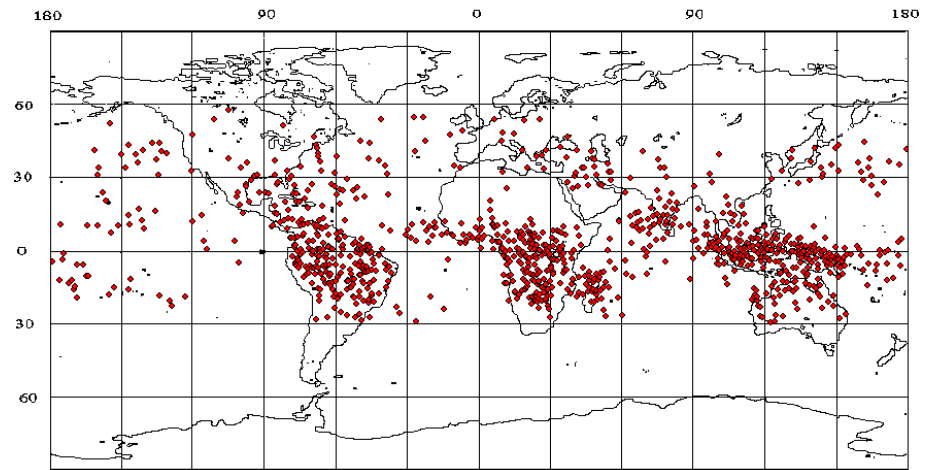
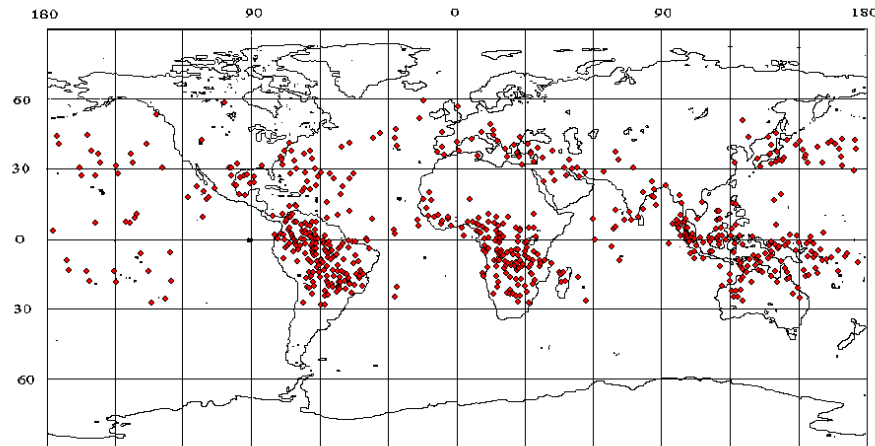


# Transient events global distribution:



Photon number  $< 5 \cdot 10^{21}$

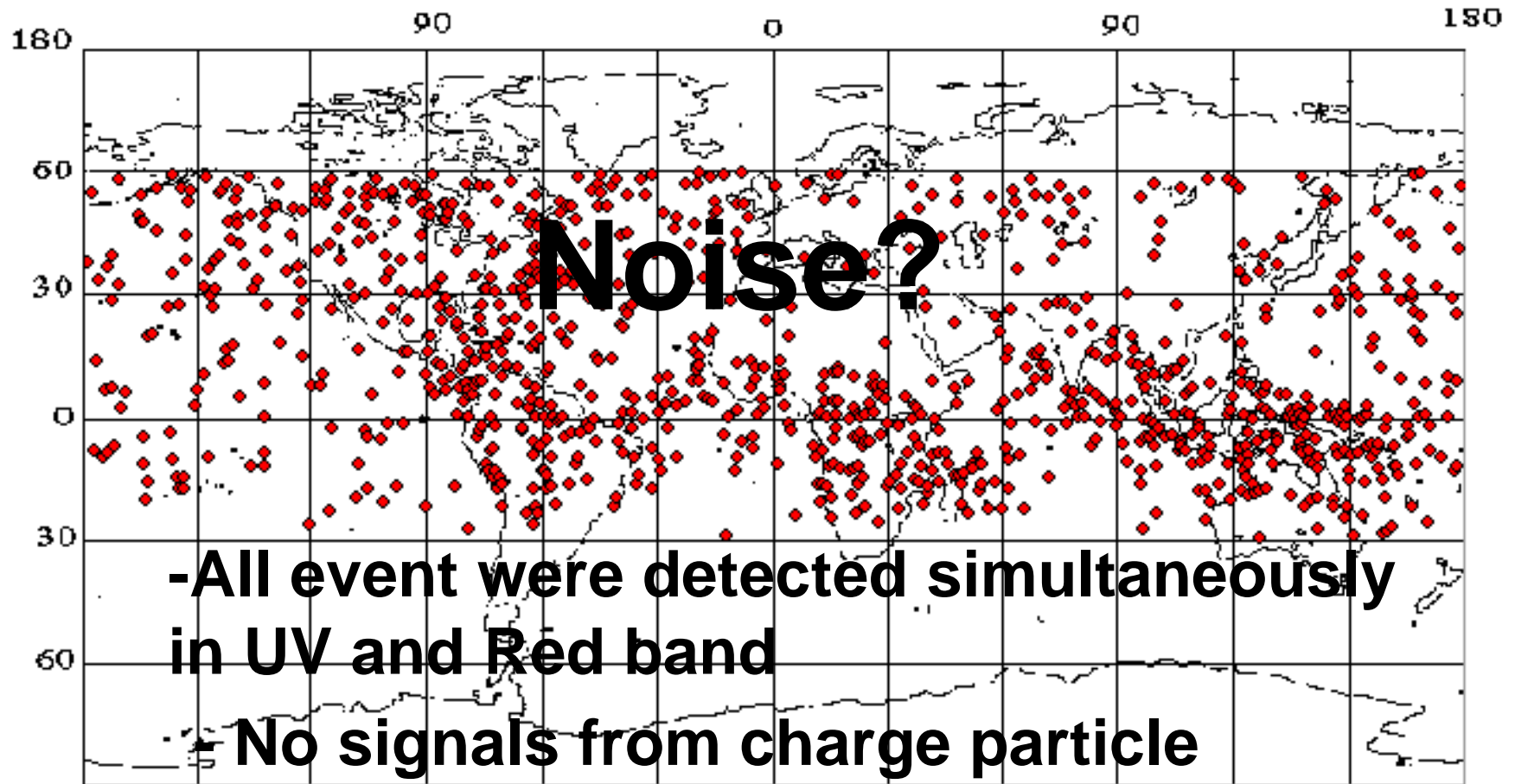
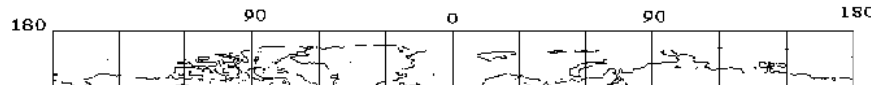
Photon number  $5 \cdot 10^{21} - 10^{23}$



Photon number  $> 10^{23}$

## Transient events global distribution:

Photon number  $< 5 \cdot 10^{21}$



**-All event were detected simultaneously  
in UV and Red band**

**-No signals from charge particle  
simultaneously to UV-Red signal**

