Occurrence and altitude of the non-specular long-lived meteor trails during meteor showers at high latitudes

EGU2020-1543
https://doi.org/10.5194/egusphere-egu2020-1543

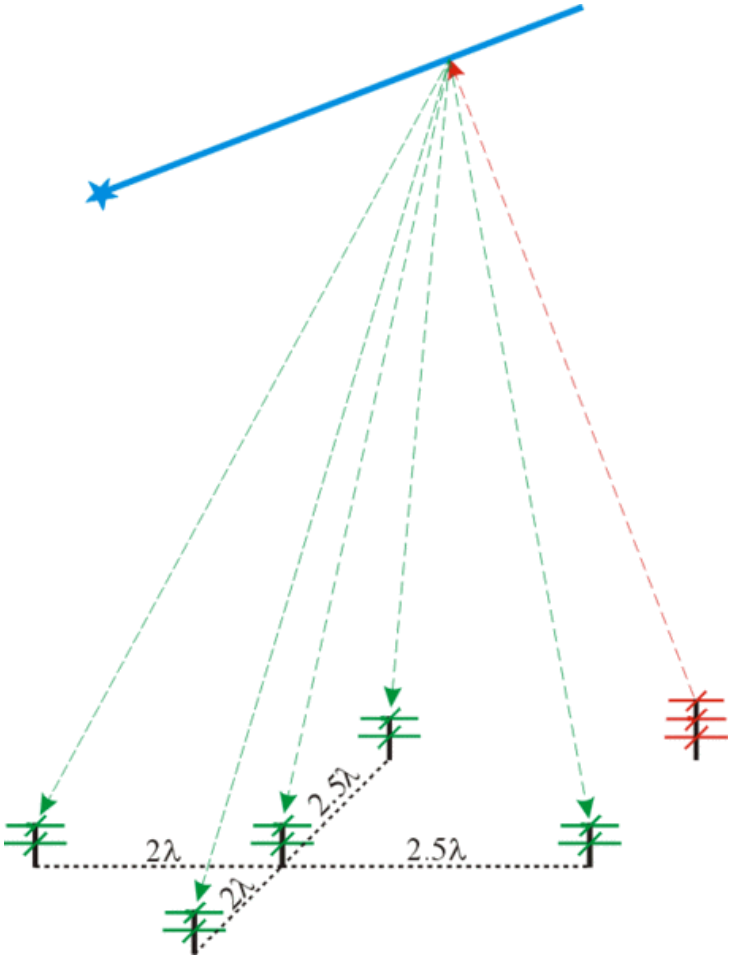
Alexander Kozlovsky[1], Renata Lukianova[2], and Mark Lester[3]

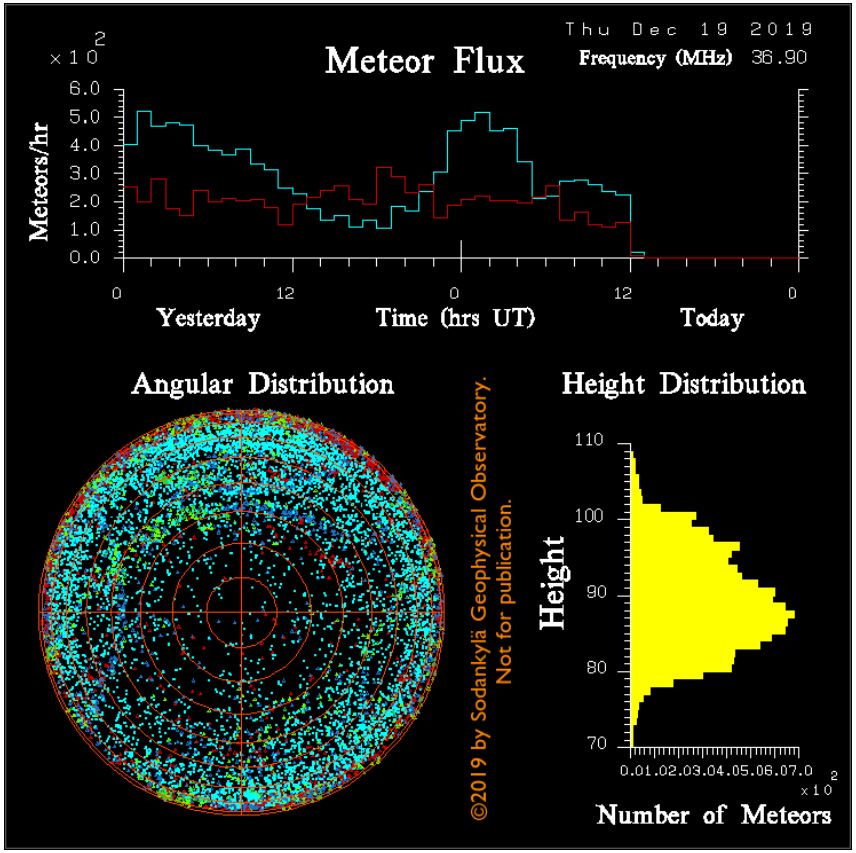
(1) Sodankylä Geophysical Observatory, Finland
(2) Space Research Institute, Moscow, Russia
(3) University of Leicester, UK

Abstract

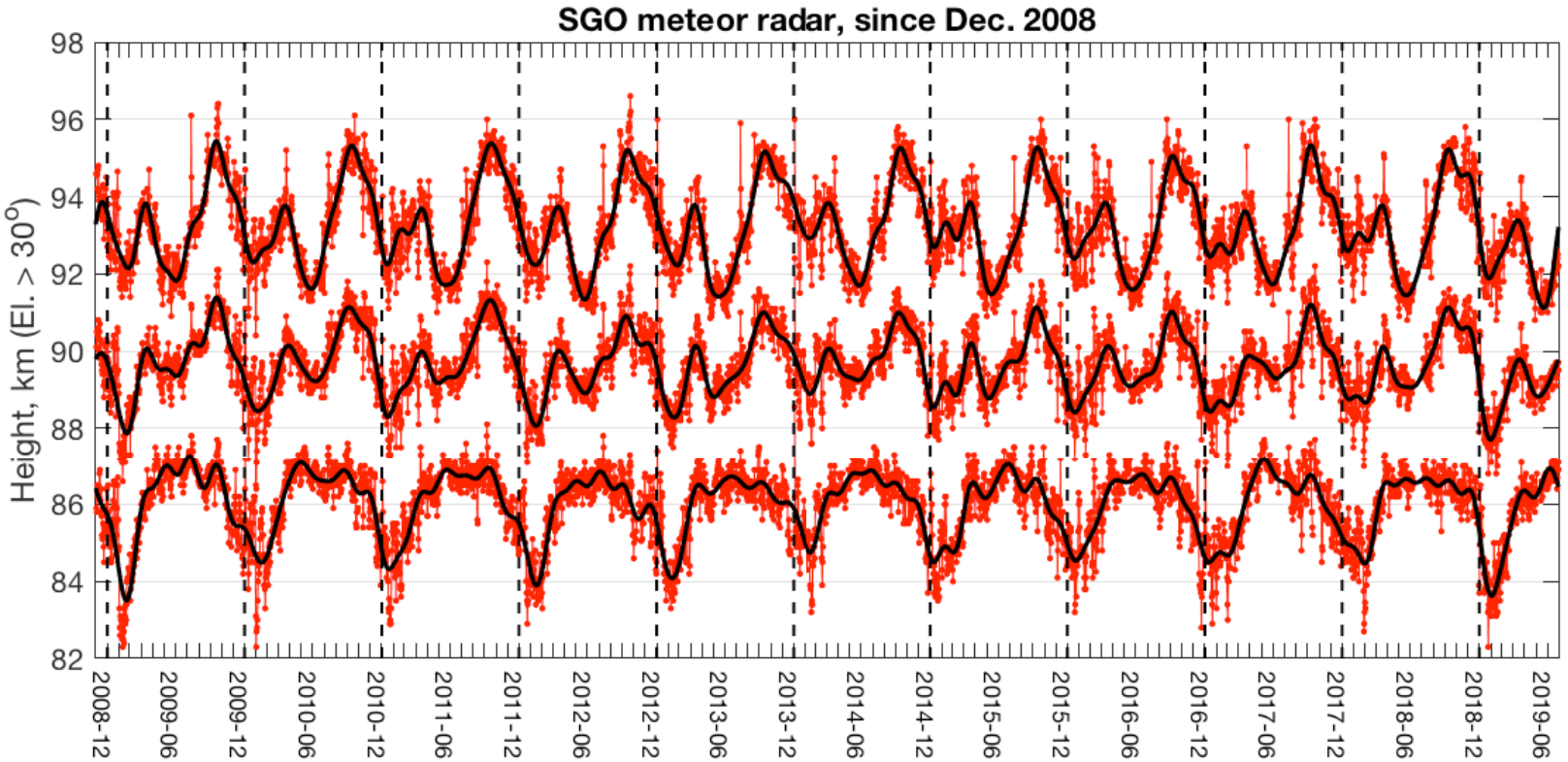
Meteoroids entering the Earth's atmosphere produce ionized trails, which are detectable by radio sounding. Majority of such radar detections are the echoes from cylindrical ionized trails, which occur if the radar beam is perpendicular to the trail, i.e., the reflection is specular. Typically such echoes detected by VHF radars last less than one second. However, sometimes meteor radars (MR) observe unusually long-lived meteor echoes and these echoes are non-specular (LLNS echoes). The LLNS echoes last up to several tens of seconds and show highly variable amplitude of the radar return. The LLNS echoes at high latitudes are received from the non-field-aligned irregularities of ionization generated along trails of bright meteors and it is believed that key role in their generation belongs to the aerosol particles arising due to fragmentation and burning of large meteoroids. The occurrence and height distributions of LLNS are studied using MR observations at Sodankylä Geophysical Observatory (SGO, 67° 22' N, 26° 38' E, Finland) during 2008-2019. Two parameters are analyzed: the percentage and height distribution of LLNS echoes. These LLNS echoes constitute about 2% of all MR detections. However during certain meteor showers (Geminids, Perseids, Quadrantids, Arietids or/and Daytime ζ-Perseids, and Lyrids) the percentage of LLNS echoes is noticeably higher (about 10, 8, 7, 7, and 4%, respectively). Typically, the LLNSs occur ~1-2 km higher than other echoes (in June-July the height difference is reduced to ~0.5-1 km). Due to this elevation, a larger percentage of LLNSs is manifested as an upward shift of the height distribution of meteor trails during meteor showers. Moreover, during Lyrids, η-Aquariids, Perseids, Orionids, and Leonids the LLNS echoes occur noticeably, up to 3-5 km, higher than the echoes from other types of trails.

All-sky interferometric meteor radar (**SKiYMET**) at SGO: location of ionized meteor trails





Median and quartiles of the height distribution of meteor trails



Averaged height distributions of meteor trails for each day of year

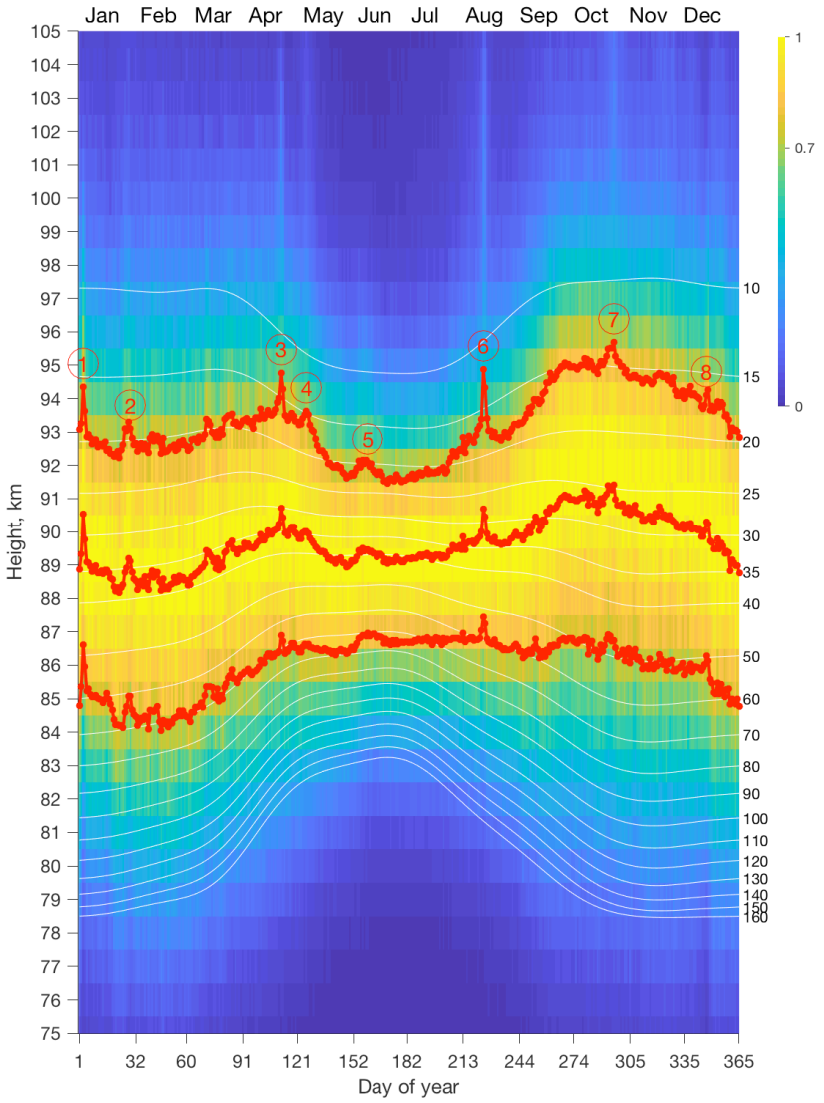
(The white curves show the levels of constant atmospheric density (in 10-10 g/cm-3) calculated for the Sodankylä Geophysical Observatory site using the NRLMSISE-00 model.)

An enhanced percentage of trails is detected above 95 km during certain meteor showers.

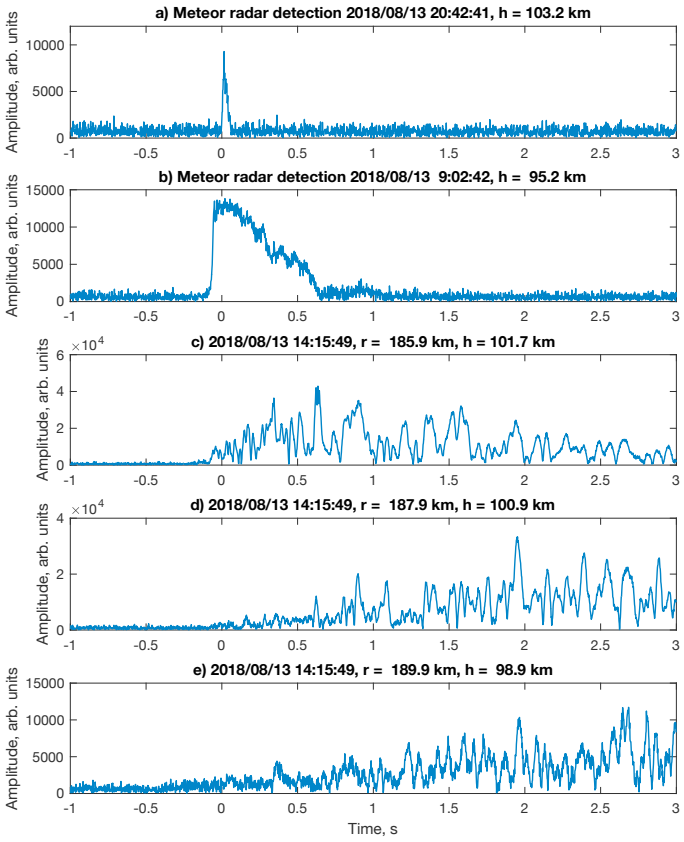
The most prominent such feature is seen for the Perseids in August (6).

Types of radar echoes from the Perseids meteor trails above 95 km - ?

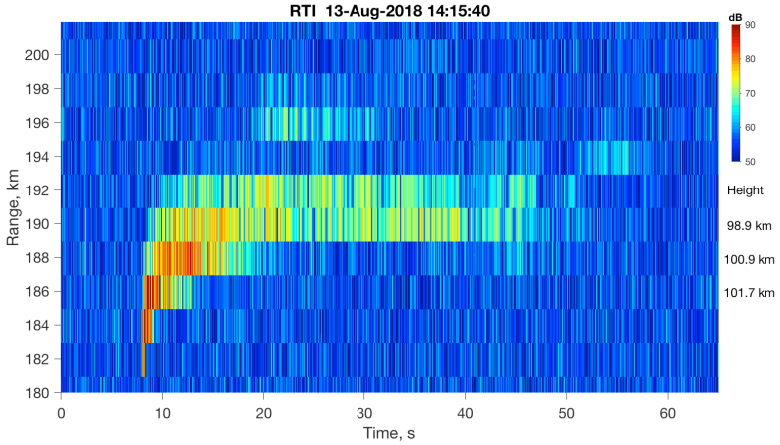
Comparison with detections at 89-91 km, (max of the distribution) - ?



SGO MR examples: under-, over-dense, and long-lived non-specular (LLNS)



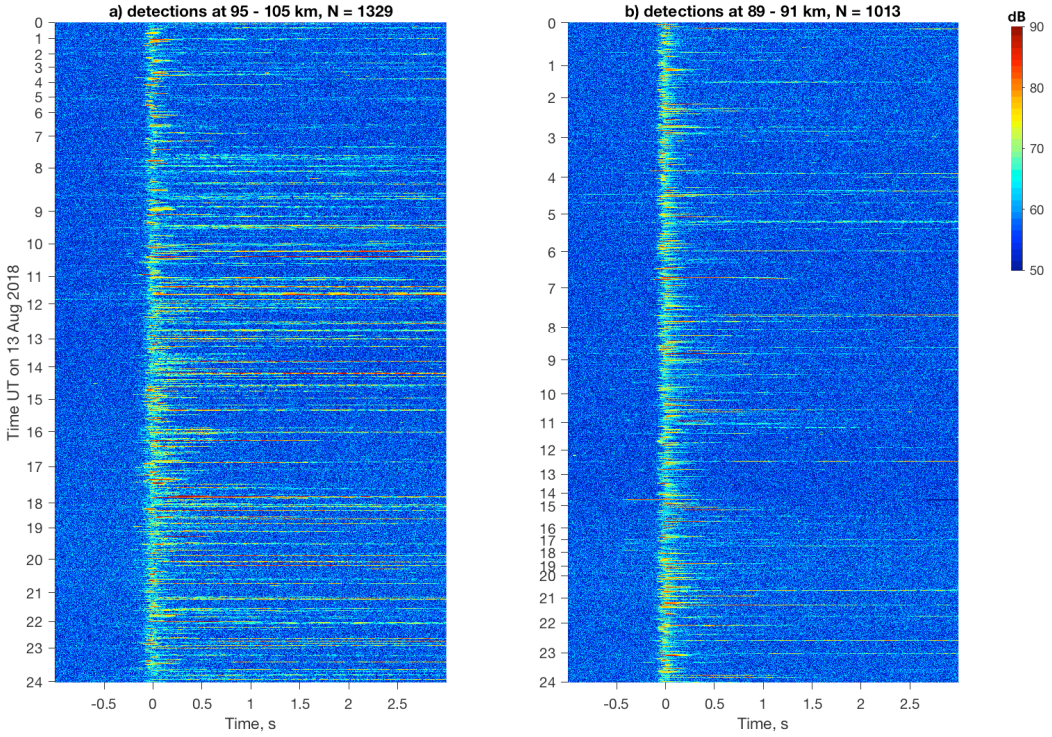
The range-time-intensity (RTI) color plot showing meteor radar raw data for the event of LLNS echoes.



Power of echoes 13-08-2018 as functions of the record duration time and time of detection

The LLNS echoes are manifested as horizontal lines from 0 to 3 s.

The relative number of the LLNS echoes is larger above 95 km (a), compared to heights between 89 and 91 km ((b)



Power of echoes 13-08-2018 as functions of the record duration time

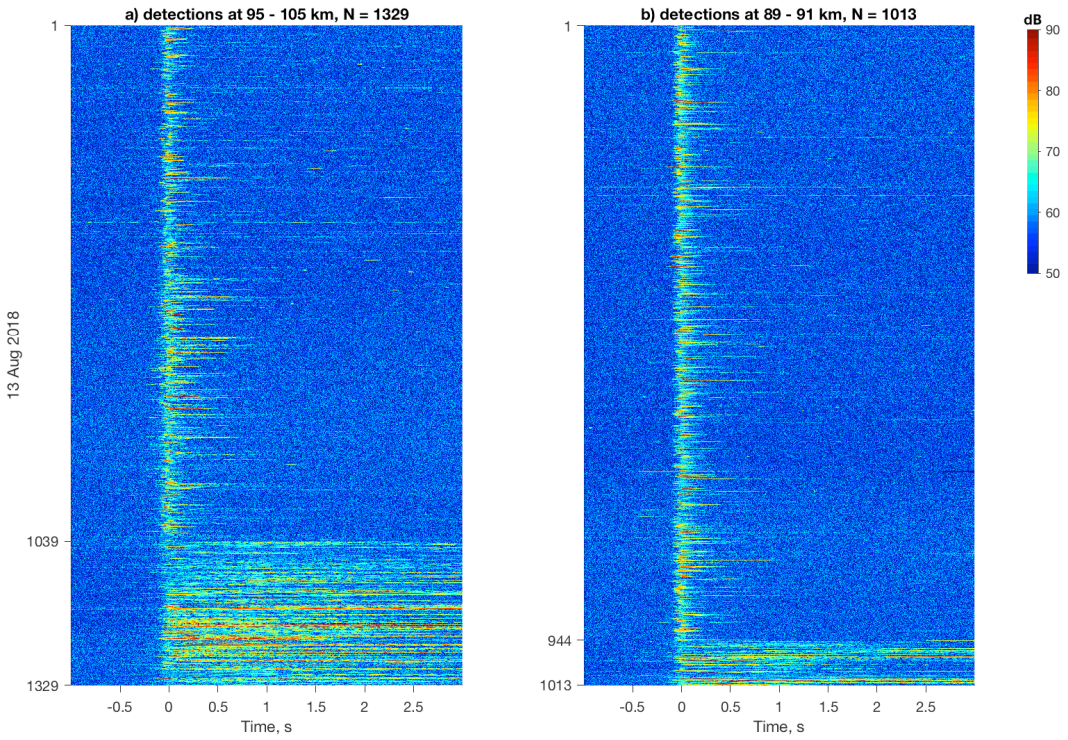
We invented a method to identify LLNS echoes

The data were re-ordered in such a way that the identified LLNS detections are placed in the bottom of each plot and other detections are above.

a) Between 95 and 105 km 291 of 1329 detections (i.e., **22 %**) were LLNS,

b) At 89-91 km LLNS were only **7 %**.

This may indicate a role of LLNS echoes in the height distribution of Perseids.



Statistics of LLNS trails
Dec 2008 – Jul 2019

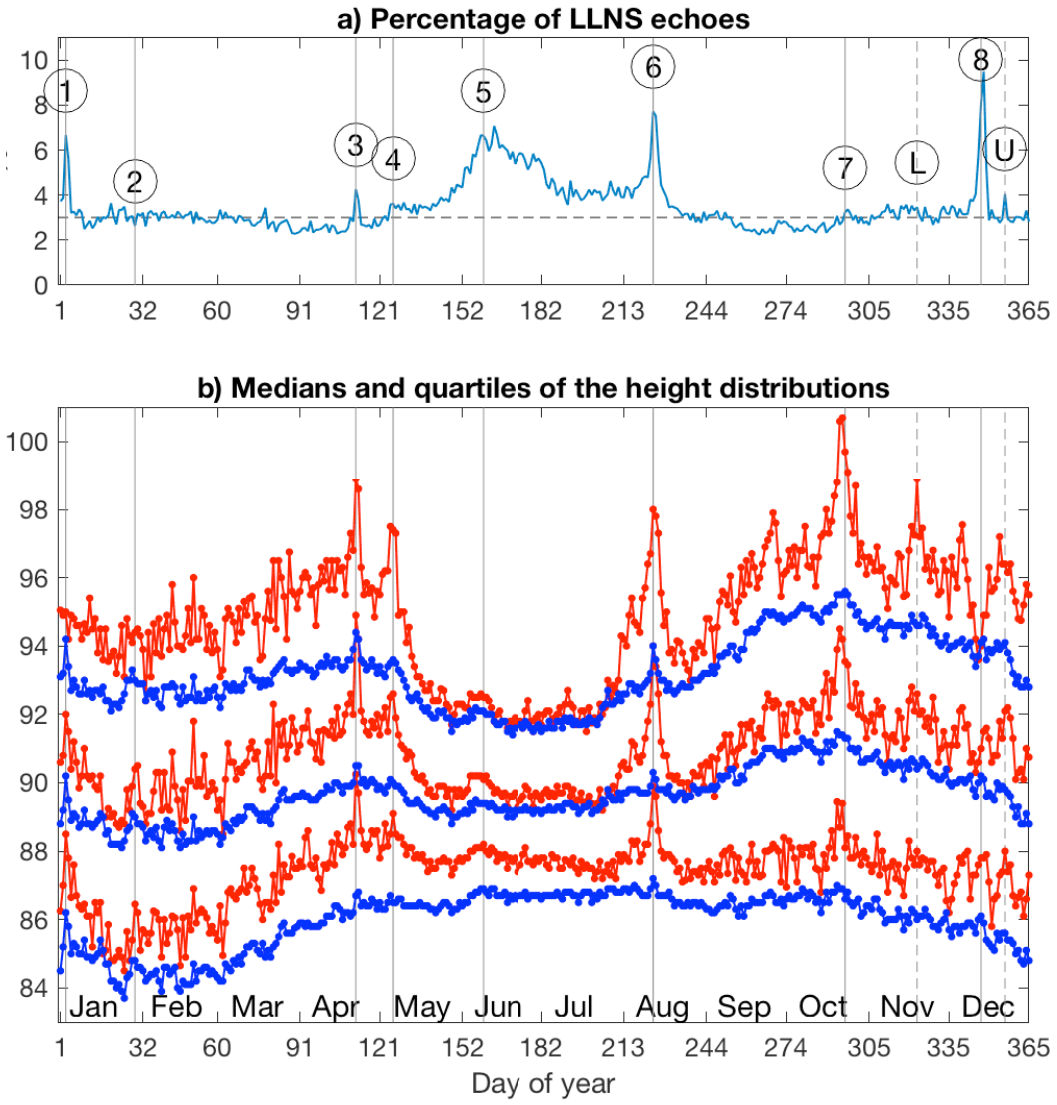
About 10^7 echoes were analyzed and about $4 \cdot 10^5$ of them were LLNS

Enhanced percentage:

Quadrantids (1)
Lyrids (3)
Arietids/Daytime ζ-Perseids (5)
Perseids (6)
Geminids (8)
Ursids (U)

Enhanced height (Uq) by 4-5 km

Lyrids (3)
η-Aquariids (4)
Perseids (6)
Leonids (Nov-19)
Orionids (7)



P: V≤39, PH: 47≤V≤61, H: V≥65

#	Date of max	Showers	%	ΔLQ km	ΔM km	ΔUQ km	Type	V_G km/s	Mass index
1	**Jan 3**	**Quadrantids**	**6.7**	**2**	**2**	**1**	**P -**	**29**	**1.65**
2	Jan 28-29	Unknown	3	1	1	2	- -		
3	**Apr 22**	**Lyrids**	**4.3**	**4**	**4**	**5**	**P H**	**47**	**1.93**
4	**May 6**	**η-Aquariids**	**3.6**	**3**	**3**	**4**	**- H**	**65**	**1.85**
5	**Jun 9**	**Arietids** **Daytime ζ- Pers.**	**6.6**	**1**	**1**	**0.4**	**P -**	**39** **26**	**1.7**
6	**Aug 12**	**Perseids**	**7.7**	**4**	**4**	**4**	**P H**	**61**	**1.5-1.6**
7	**Oct 23**	**Orionids**	**3.2**	**3**	**3**	**5**	**- H**	**65**	**1.7-1.8**
	Nov 19	**Leonids**	**3.4**	**2**	**1**	**4**	**- H**	**67**	**1.7**
8	**Dec 13**	**Geminids**	**9.5**	**1**	**1**	**0**	**P -**	**35**	**1.55**
	Dec 22	**Ursids**	**4.0**	**2**	**2**	**2**	**P -**	**36**	**-**
		Sporadic	3	1-2				30-60	2.17

Summary

- One of two factors, the larger percentage of LLNS trails or the larger height of LLNS trails, or a combination of both are manifested in statistics of LLNS echoes during some meteor showers
- The first factor is essential for slower speed meteor stream (29-39 km/s, the Quadrantids, Arietids or/and Daytime ζ-Perseids, Geminids, and Ursids), having relatively small mass index (1.55 − 1.7)
- The second one is important for higher speed streams (65-67 km/s, the Orionids, and Leonids), while both factors play role for the medium speed streams (47-61 km/s, the Lyrids and Perseids).
- To summarize, the most important finding of the present study is that major meteor showers (Quadrantids, Lyrids, η-Aquariids, Arietids or/and Daytime ζ-Perseids, Perseids, Orionids, Leonids, and Geminids) are identified in the height distributions and/or occurrence of long-lived non-specular echoes from the non-field-aligned irregularities associated with large meteoroids. On the base of obtained data we estimate the minimal initial mass of meteoroids producing LLNS echoes as about 0.02-0.03 kg (size of the order of 2-3 cm).