All you should know about riometers

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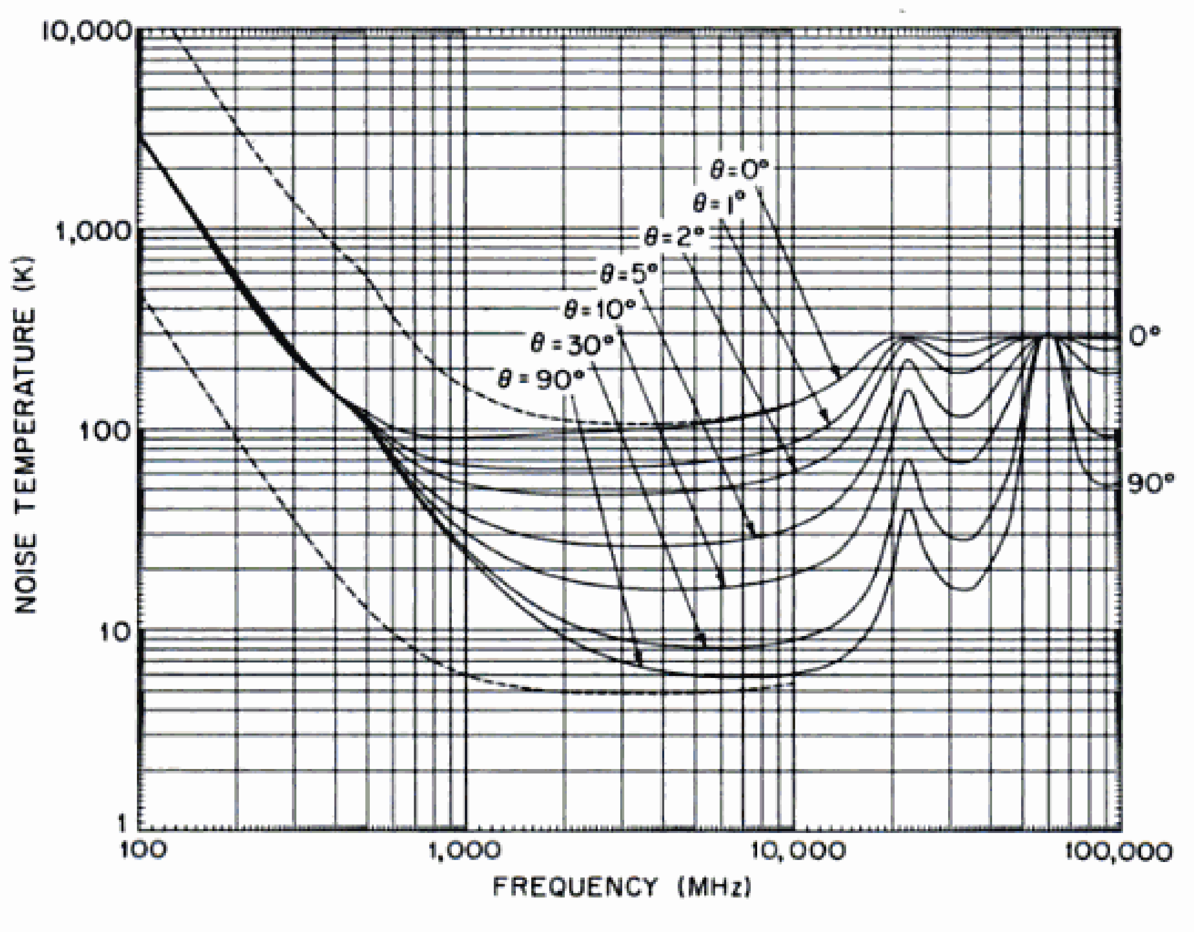
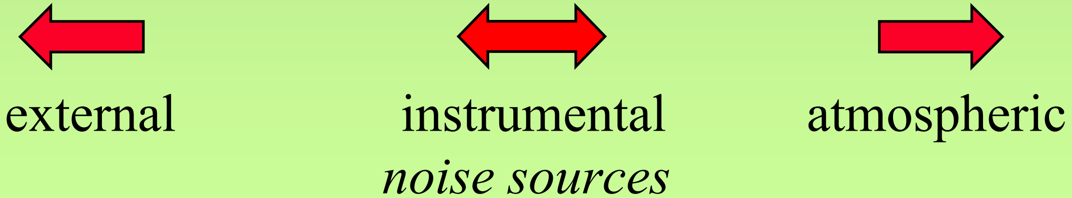
RIO-meter

= *R*elative *I*onospheric *O*pacity meter

(aka: absorption method A2)

what the heck is that?





$$P_N = kT_sB_n$$

P_N...noise power, W

k ... Boltzmann constant

T_s ... noise temperature, K

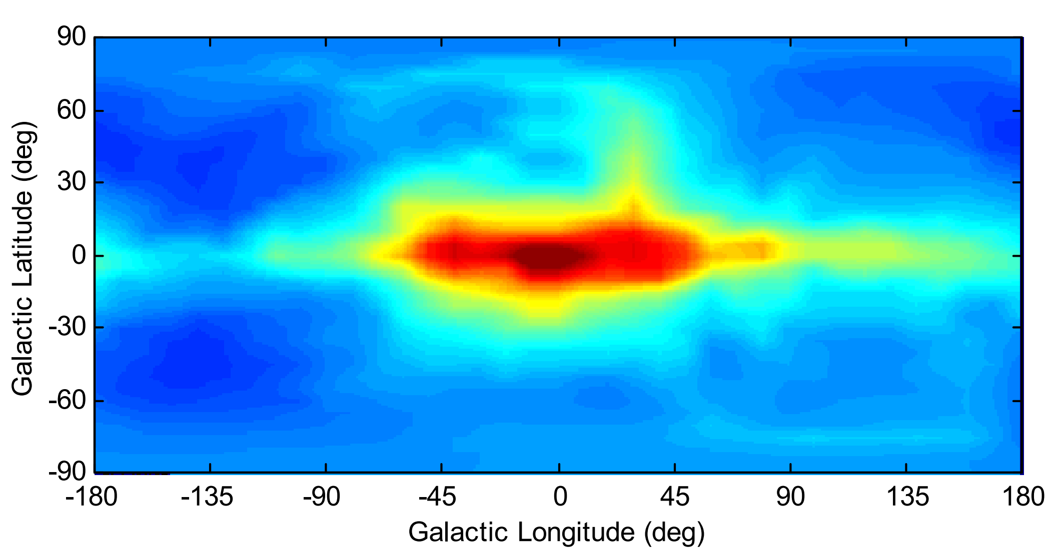
B_N ...bandwith, Hz

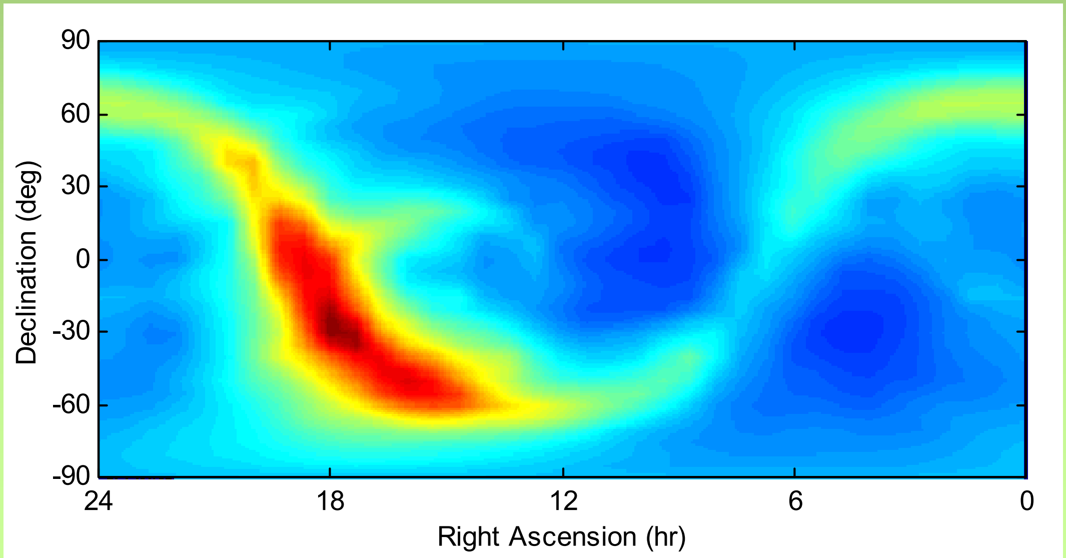
fundamental for radio engineering

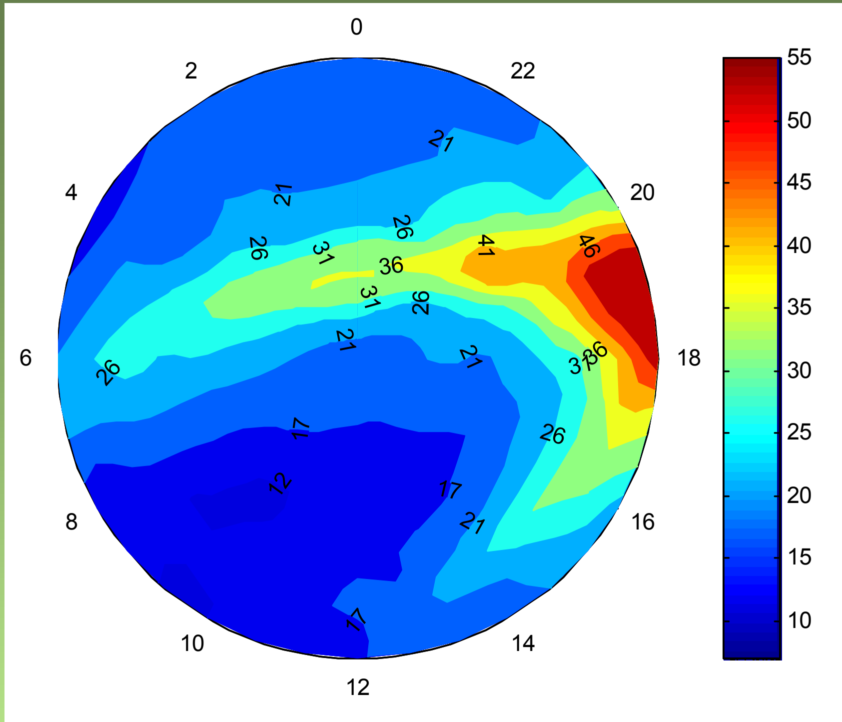
<u>(wo)man-made</u>: - discrete frequencies
- harmonics of 50/60 Hz (fall off with frequency)

<u>natural</u>: - various extraterrestrial sources in the sky

<u>preferred frequencies</u>: - too low: can not penetrate *F*-region peak
- too high: not sensitive
- *e.g.* 38.2 MHz internationally reserved



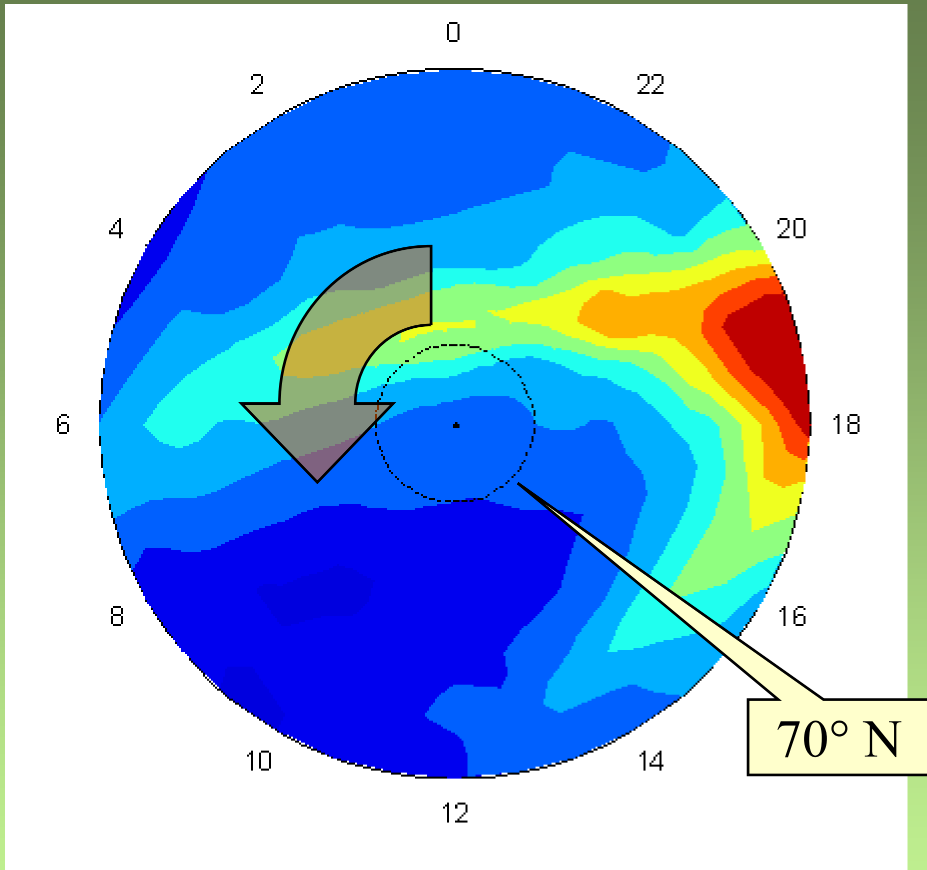


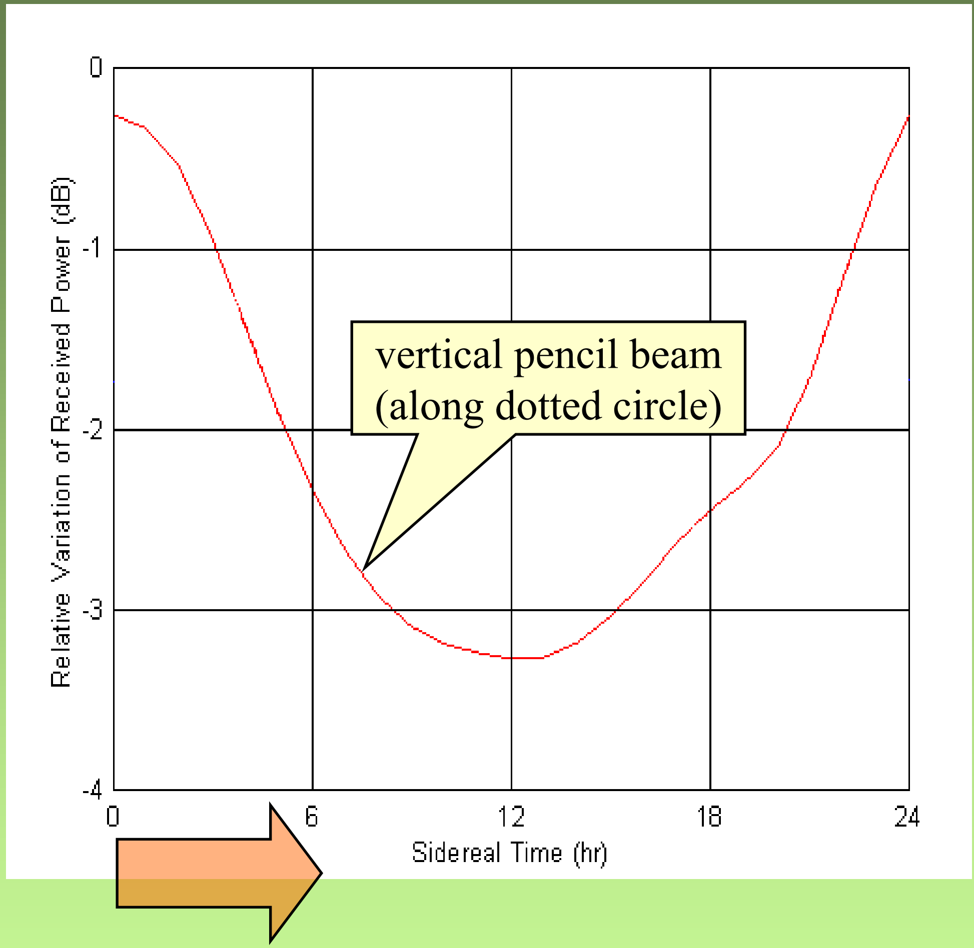


looking to the celestial north pole

sky noise temperature (in 1000 K)
measured at 30 MHz in
different co-ordinate systems (Cane, 1978)

[a newer sky map from 2008 is available]



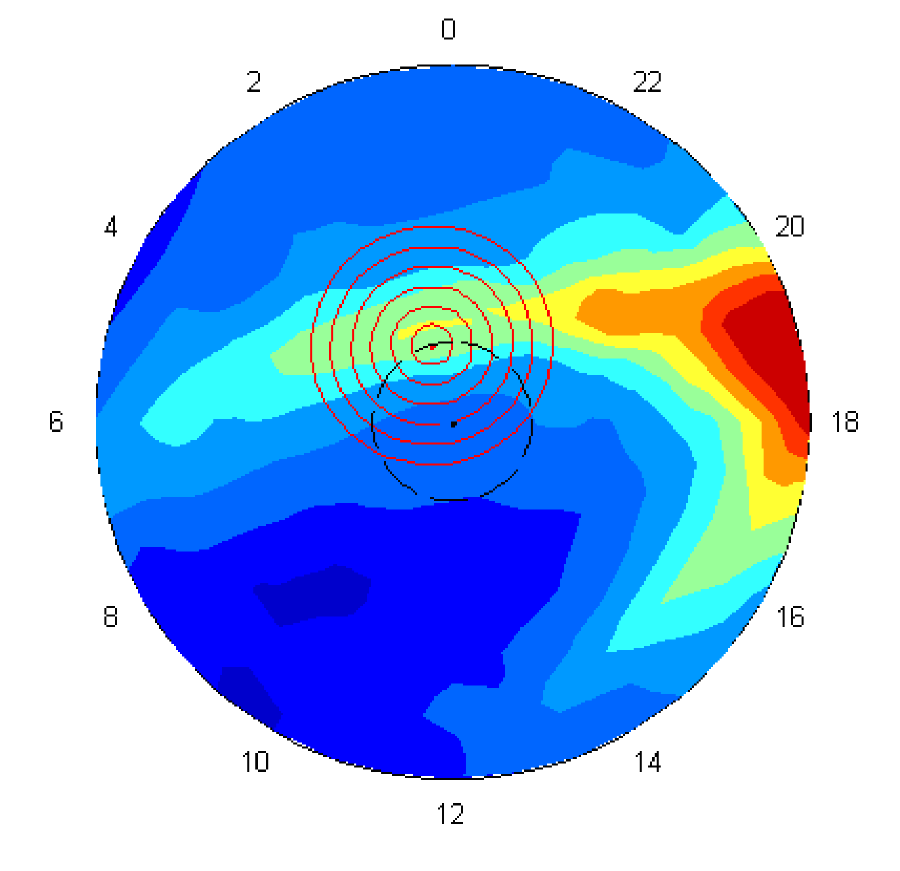


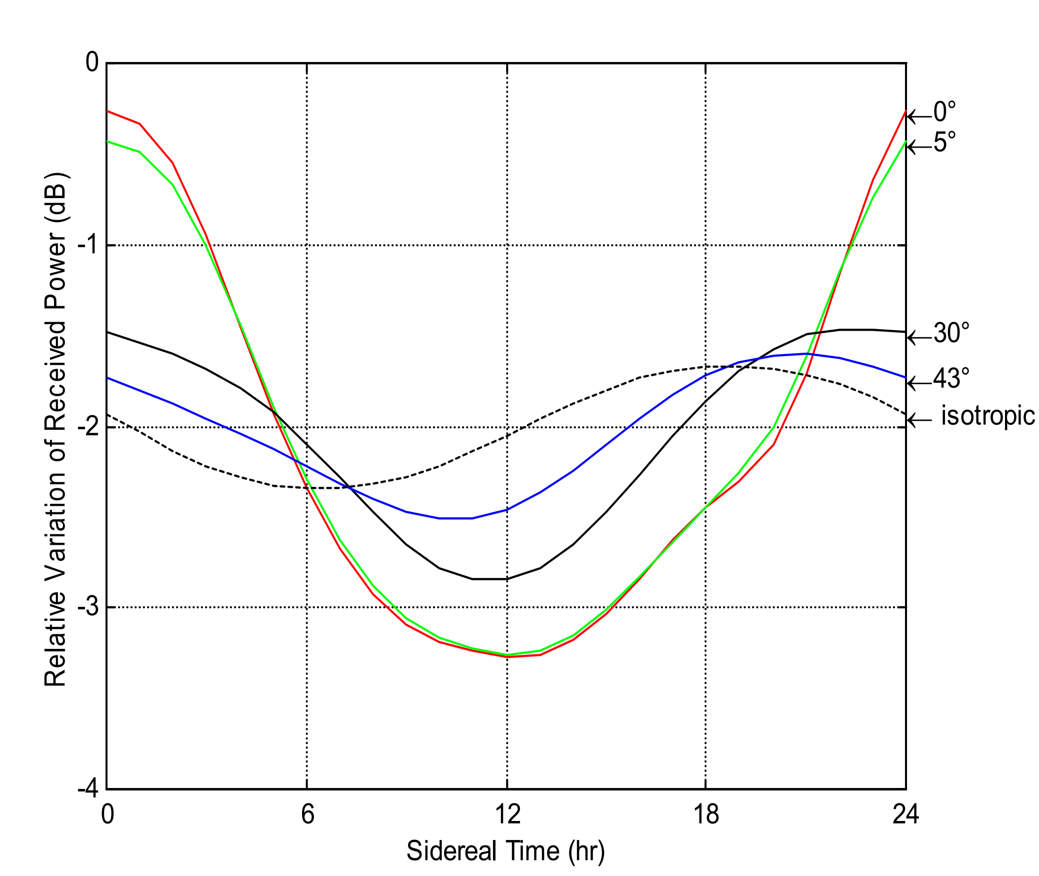
Sky noise between the equator and the north pole. Sidereal midnight at the top.

Received power at 70°N over a sidereal day

(power [theoretically] constant when pointed to pole star)

All you should know about riometers





Red circles represent antenna opening angles between ±5 to ±30°

Received power at 70°N over a sidereal day for different antenna opening angles

UNOOSA Symposium, Graz, September 20th, 2012

theoretical QDC (2)

Received power is a function of:

- geographic latitude
- sidereal time
- antenna opening angle
- look direction
- (and to a mini-minor extent due to the quiet ionosphere)

All you should know about riometers

IRIS imaging riometer
at Kilpisjärvi, Finland (similar at Andøya)
(69.1°N, 20.8°E)

- 64 antennas
- circulary polarised (x-mode)
- forming 49 beams
- central (vertical) beam ± 5.6°
- most oblique beam (69° off) ± 6.2°
- beam # 50: single antenna (wide beam)

more is better

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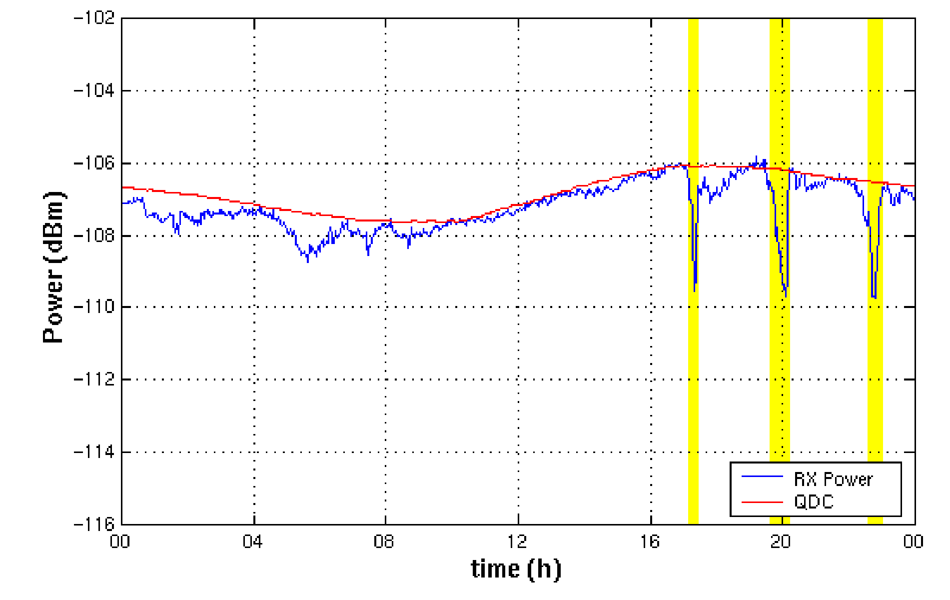

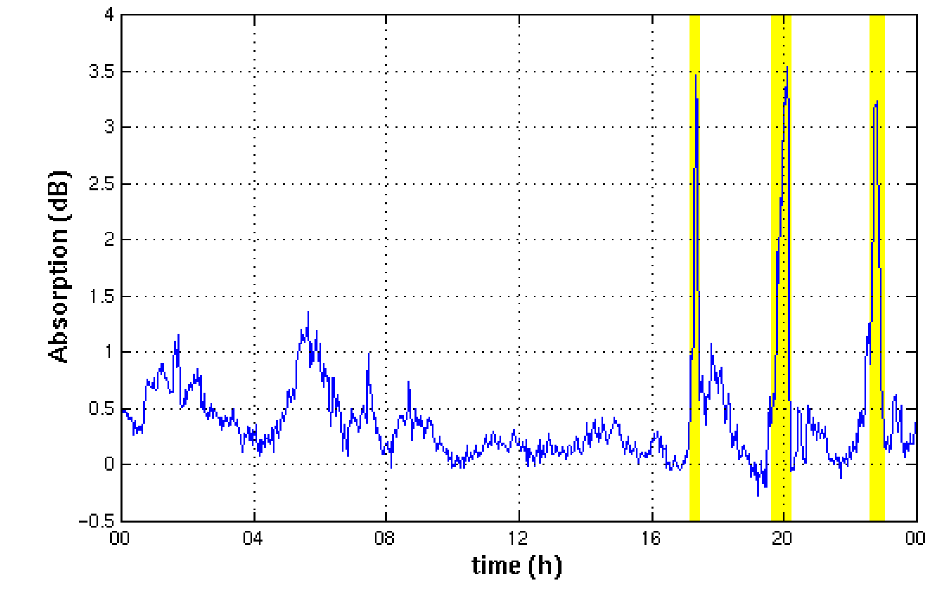

received power

absorption = QDC - received power

► exact QDC is crucial!

real raw data

$$k_L = \frac{1}{\mu} \frac{e^2}{2\varepsilon_o mc} \frac{N_e \nu}{(\omega \pm \omega_c)^2 + \nu^2}$$

(absorption per unit path element; quasi-longitudinal propagation, “classical“ theory)

in other words:

- there are two modes (x-mode a little more absorbed)
- absorption is ~ $N_e \times \nu$
- absorption is ~ f^{-2} (for $\omega >> \omega_c$ and $\omega >> \nu$)

since $\nu \sim p \Rightarrow$

- **absorption is ~ $N_e \times p$**

$$L_i = const. \int_{x=0}^{\infty} N_e p \, dx$$

const. = function of:

- frequency,
- magnetic field,
- propagation direction.

integral absorption L_i

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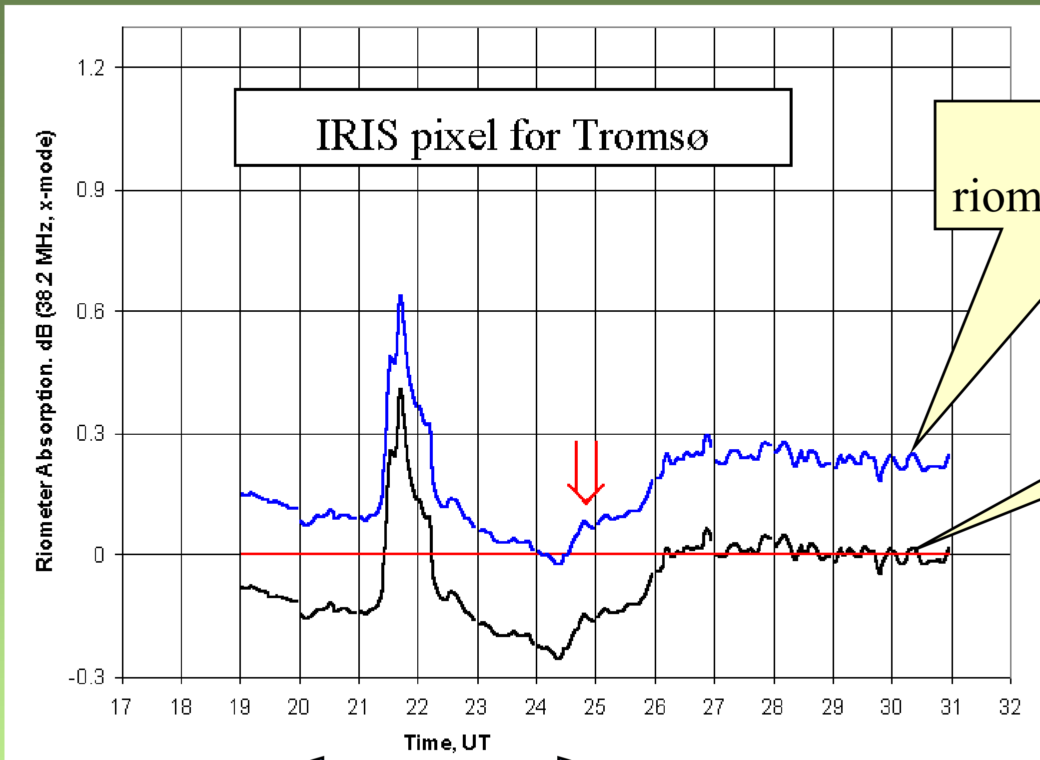

corrected
riometer absorption

nominal (original)
riometer absorption

here be nonsense!
absorption can't be negative

rocket code	**41.033**
date,	July 5, 2002
time, UT	00:47
solar zenith angle	85.9°
integral absorption, dB	0.303
quiet absorption, dB	0.012
measured absorption, dB	0.025
riometer offset, dB	**-0.266**

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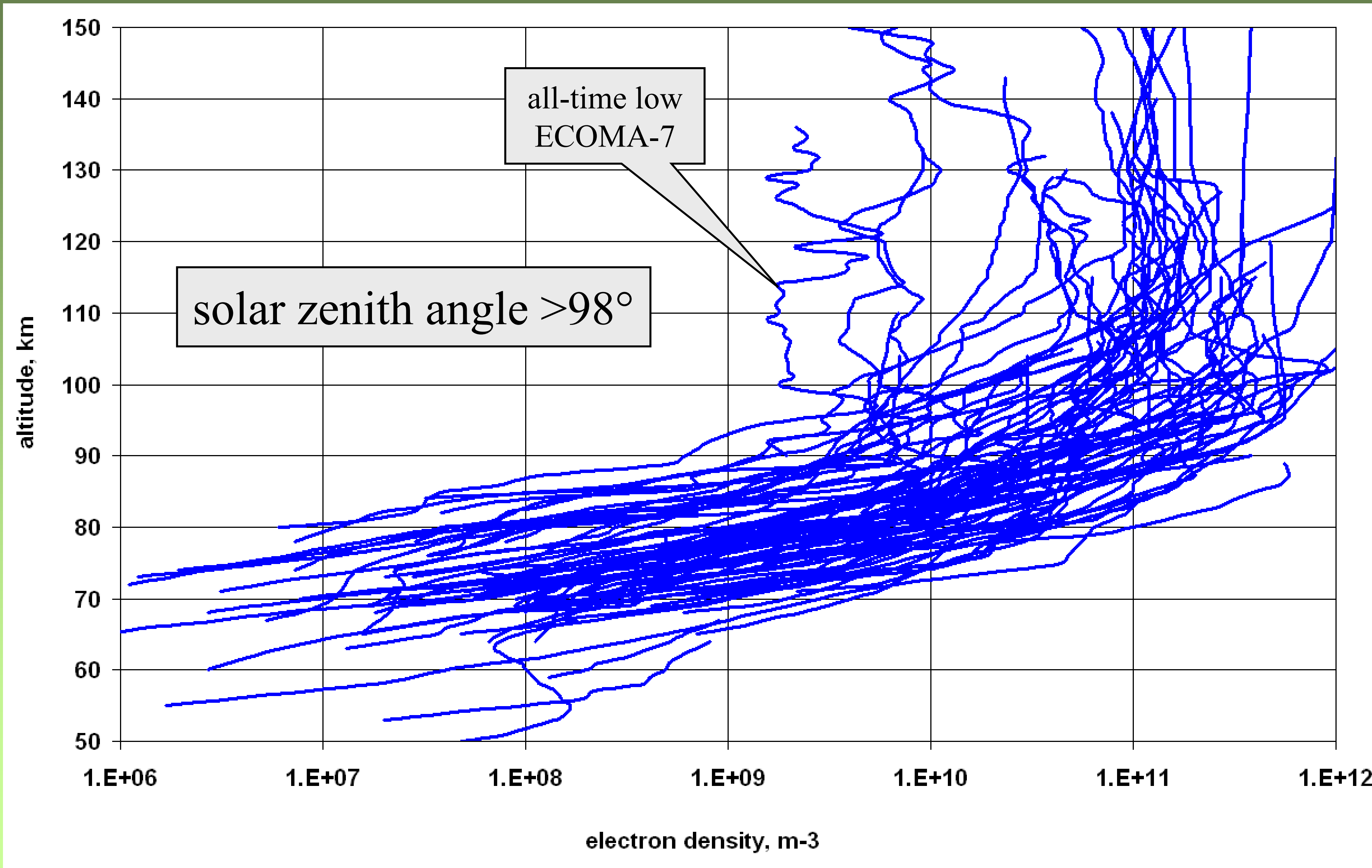

the "good" profiles

night

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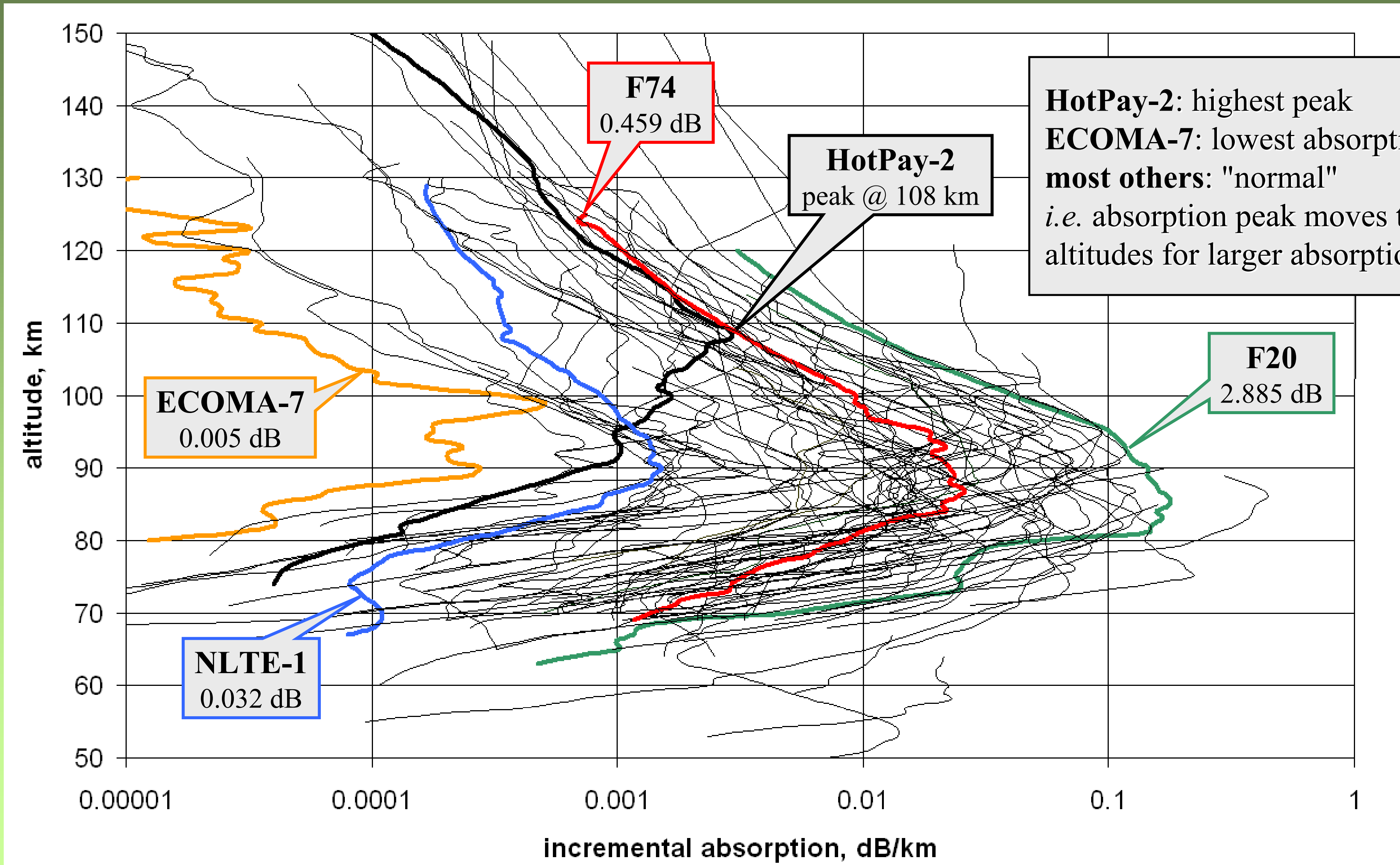

HotPay-2: highest peak
ECOMA-7: lowest absorption
most others: "normal"
i.e. absorption peak moves to lower altitudes for larger absorption

nighttime absorption

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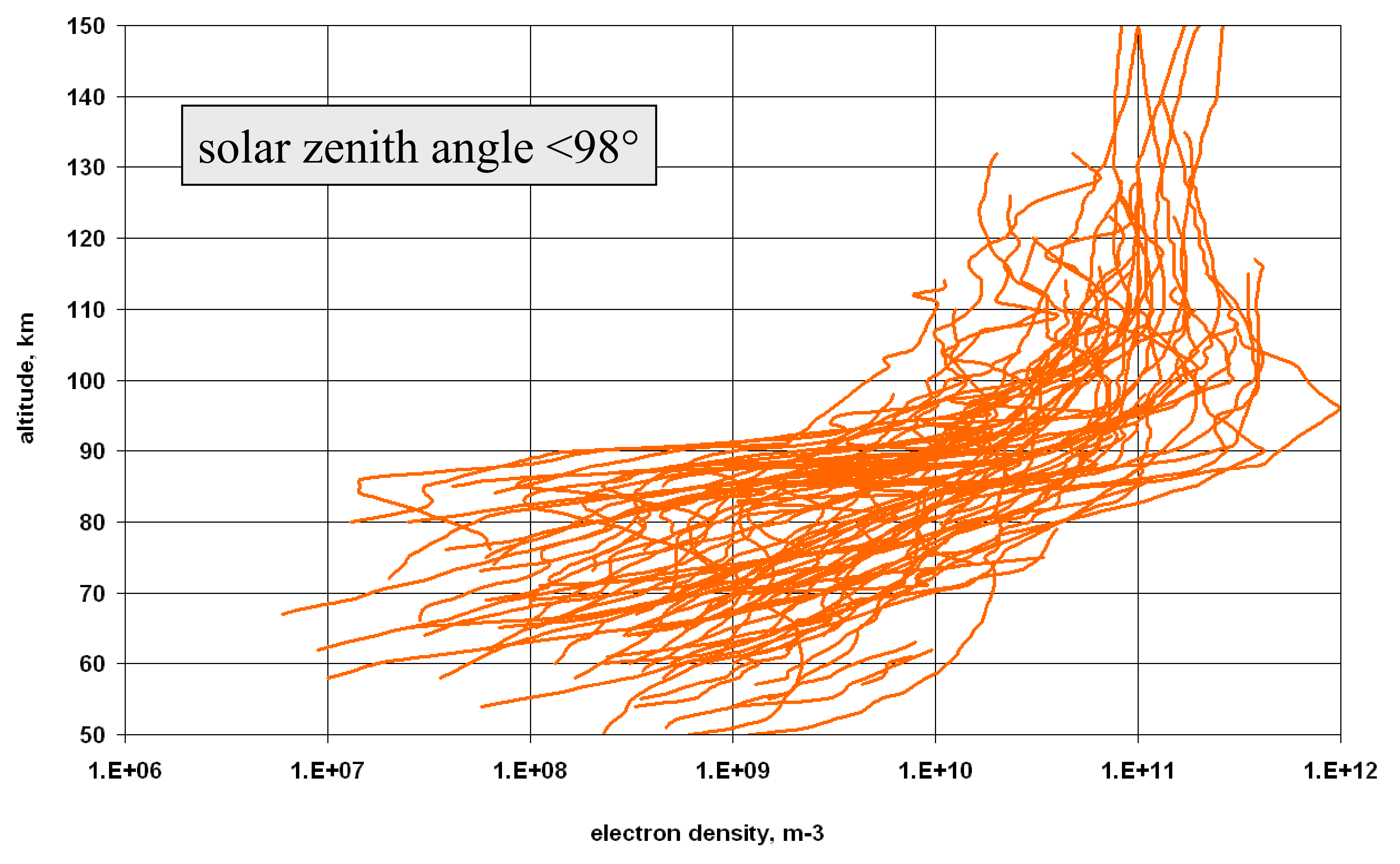
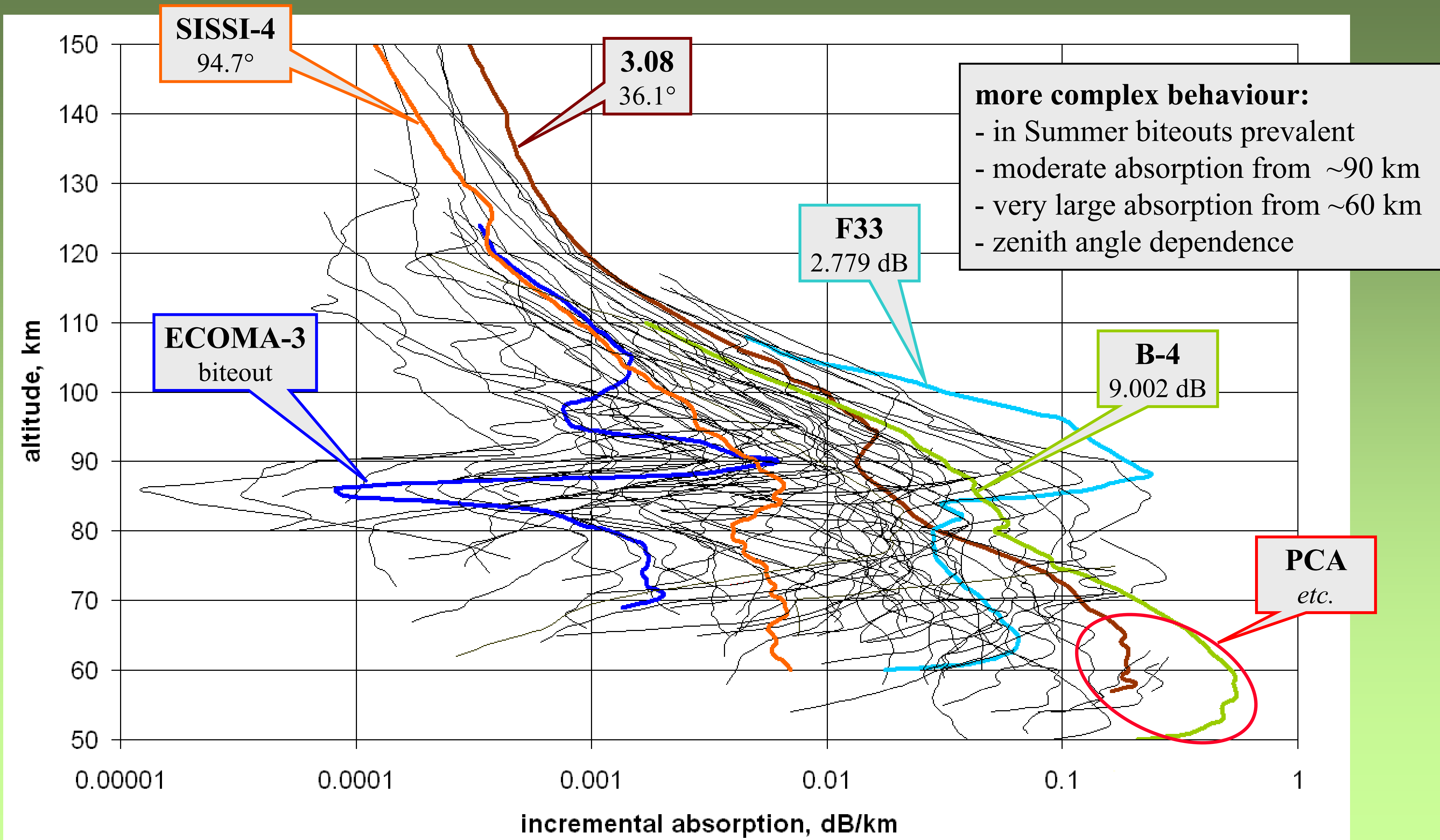


the "good" profiles

day



daytime absorption

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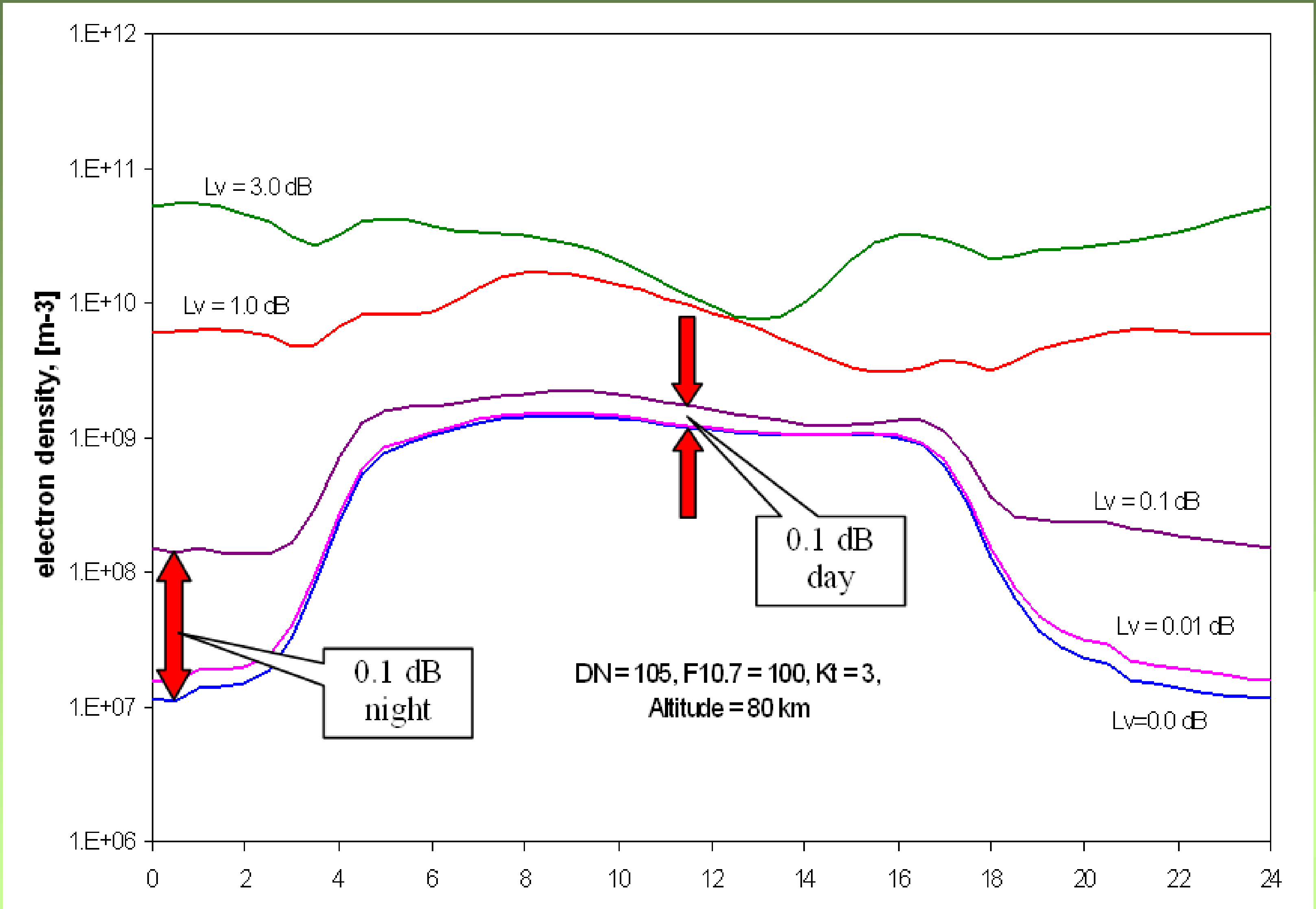

only 0.1 dB makes huge difference at night!

diurnal variation

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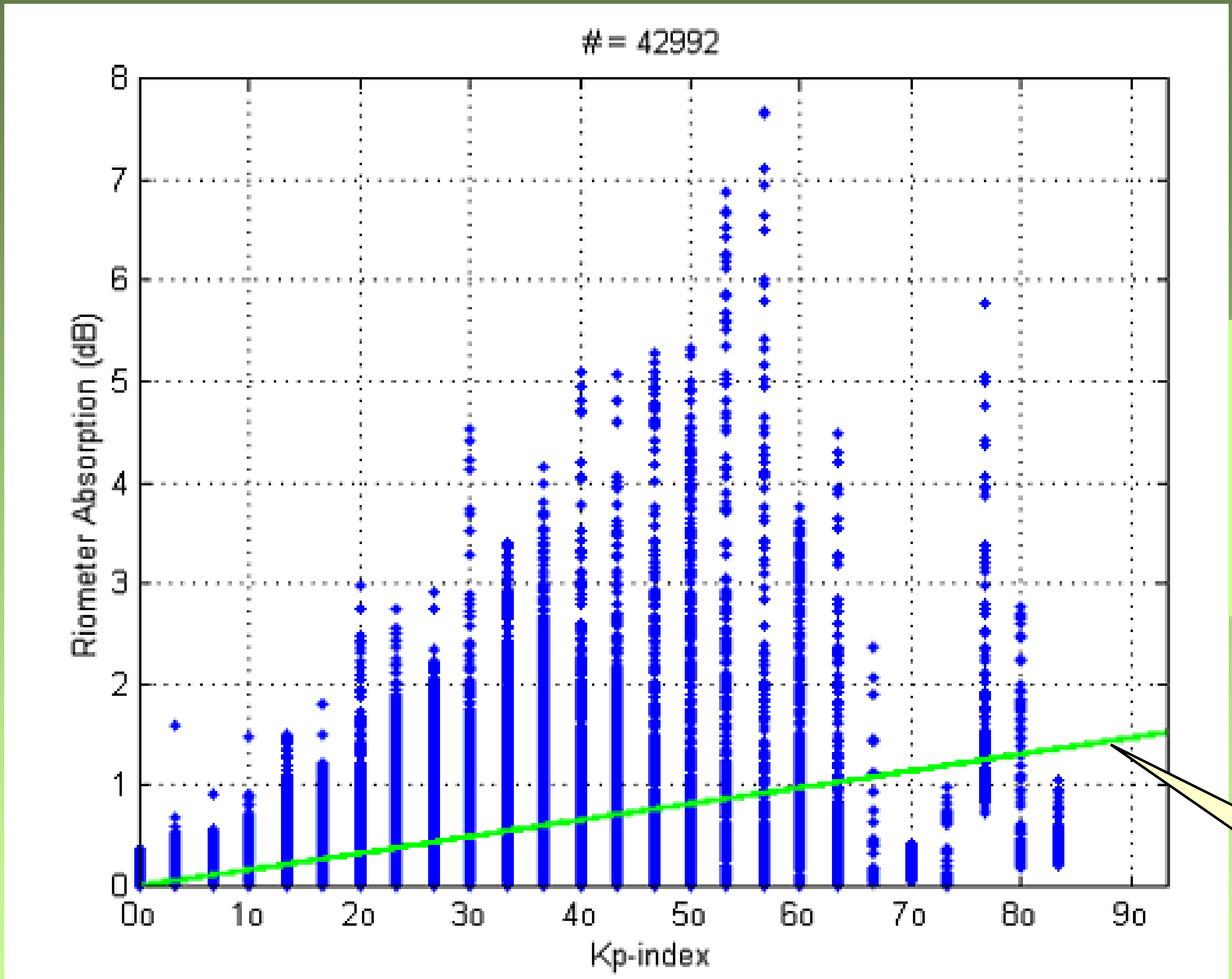

- large L_R is always associated with high K_p,
- but high K_p can occur without large L_R.

best fit
(= ***not*** a good fit!)

can L_R be replaced by K_p?

for quantitative or synoptic studies (involving different riometers) check:

⇒ *the operating frequencies*

⇒ *the opening angles*

⇒ *the mode (o-, x-, or both)*

can riometer absorption be replaced by a geomagnetic disturbance index?

⇒ *definitely not*

does, *e.g.*, 0.1 dB mean a significantly different electron density?

⇒ *yes at night, but not during the day*

can, say, 0.1 dB be measured?

⇒ *it can be resolved, but not (reliably) measured (QDC!)*

is L_R a clue to the shape of the profile?

⇒ *to some extent: larger L_R generally mean N_e bulges at lower altitudes*