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H4. SMR/1247
Lecture Note: 26

WORKSHOP ON PHYSICS OF MESOSPHERE-STRATOSPHERE-TROPOSPHERE INTERACTIONS WITH SPECIAL EMPHASIS ON MST RADAR TECHNIQUES

(13 - 24 November 2000)

D-REGION MEASUREMENTS

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D-region measurements

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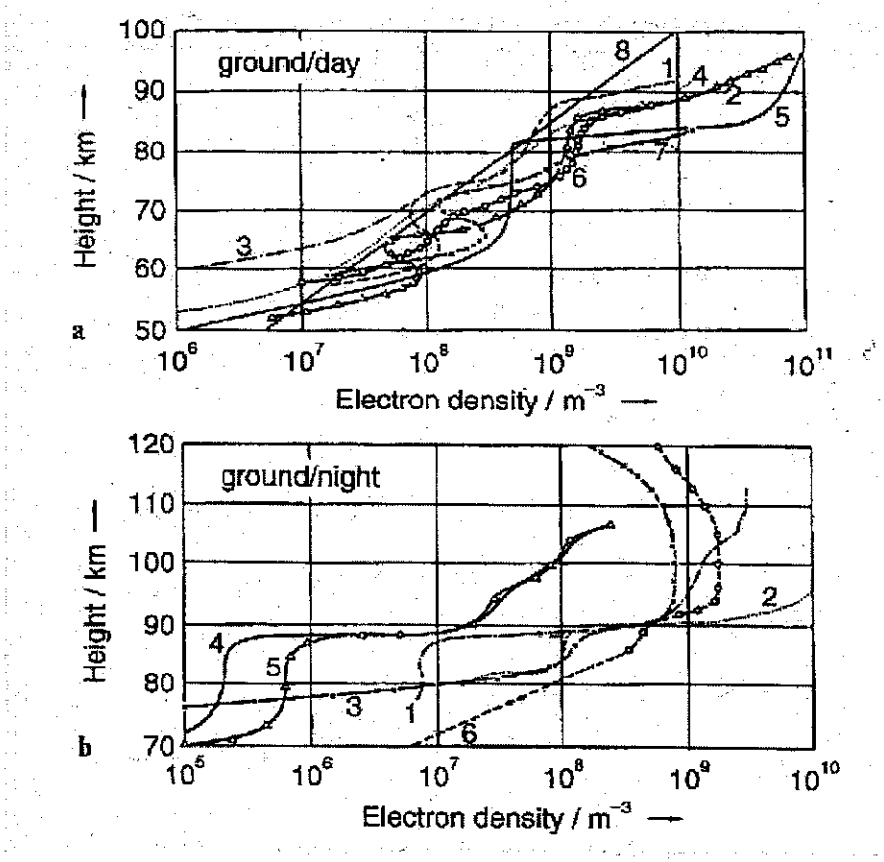
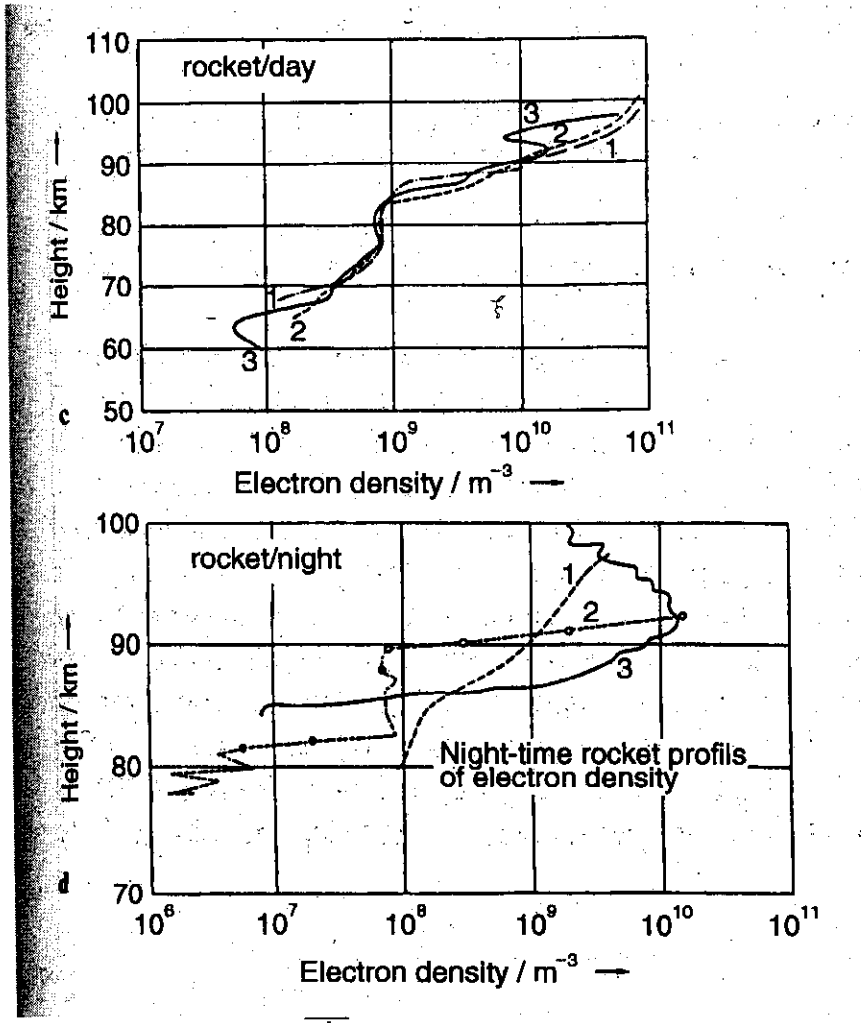
D-region

- **A critical parameter for ionospheric physics studies and applications is the electron concentration distribution in space and time.**
- **Electron concentration in the D-region has been measured by means of different rocket techniques but also by using ground measurements like the partial reflection technique using MF radars.**

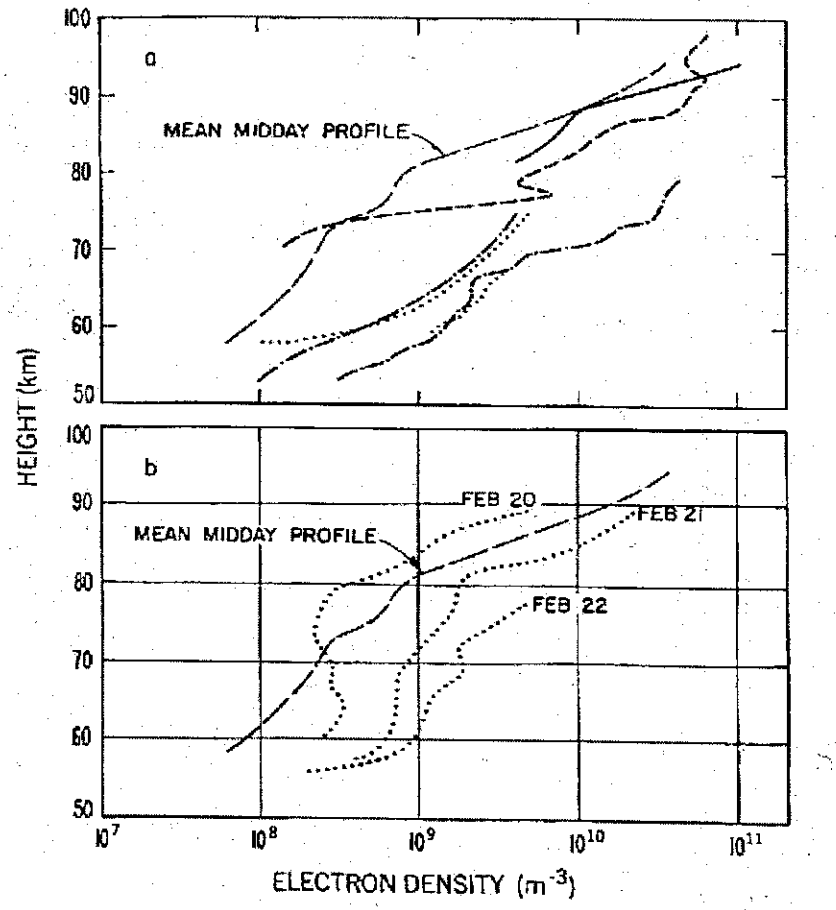
D-region electron concentration (ground)



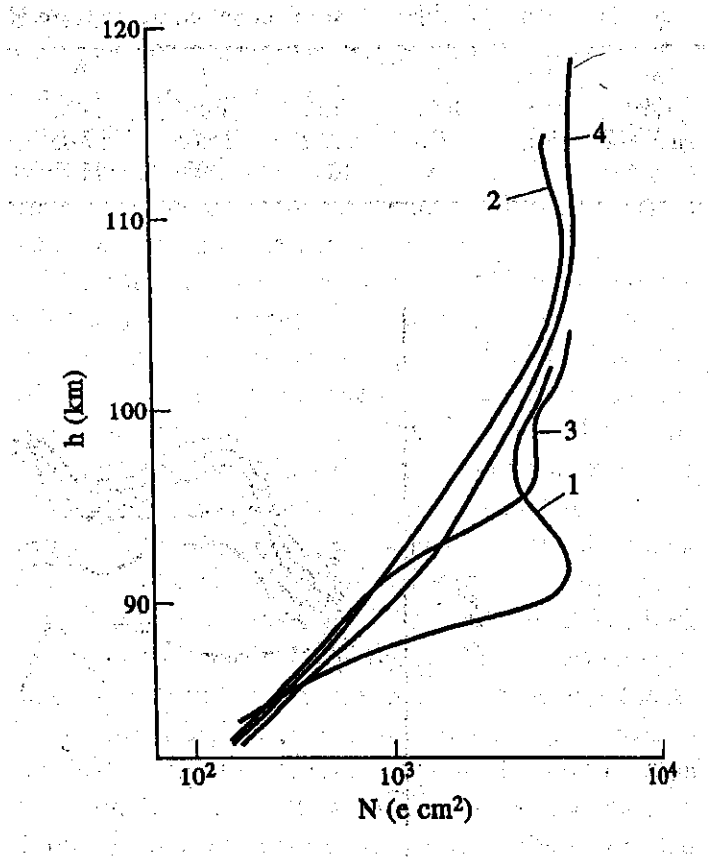
D-region electron concentration (rocket)



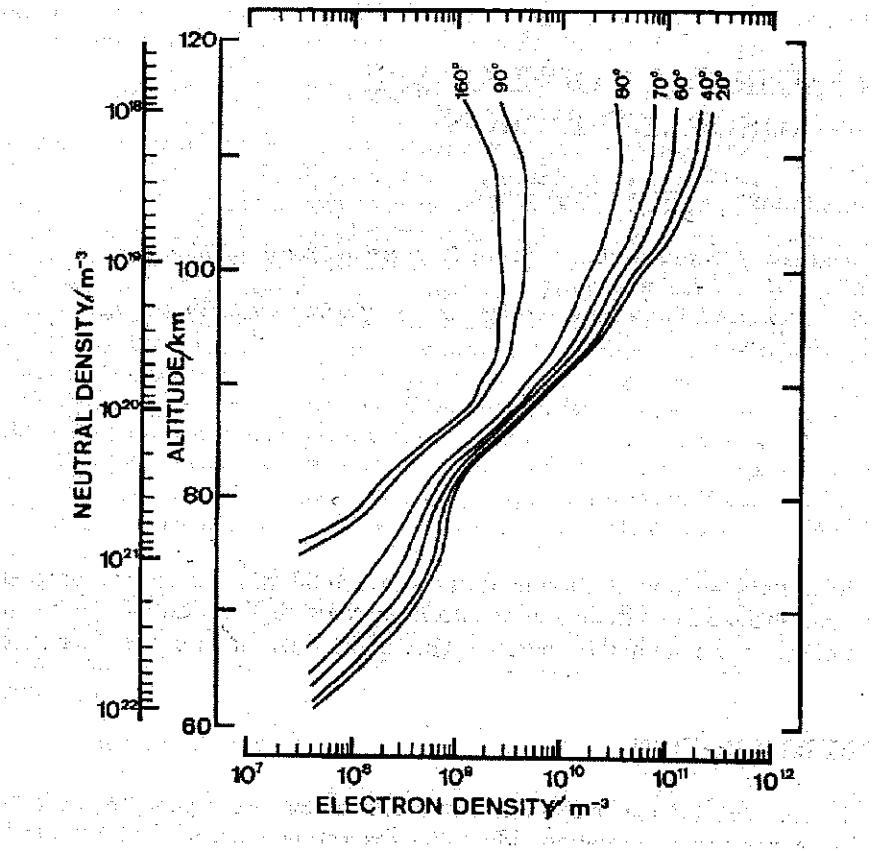
High variability of D-region electron concentration (day)



High variability of D-region electron concentration (night)



D-region electron concentration (emp. model)



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Characteristics of electron concentration profiles

- **The main feature of the profile is an inflection point and a steep gradient in the region between 80 and 90 km.**
- **The presence of the step is still more defined during nighttime conditions.**
- **Another characteristic is the high day-to-day variability of the profile.**

D-region related radio measurements

- Ionospheric propagation of radio waves can be used to monitor D-region behaviour.
- Different techniques allow to study the overall variability of the electron concentration but do not permit to obtain vertical profiles.
- Two techniques will be reported: absorption of manmade emissions at Low and High Frequencies and RIOMETER measurements.

Ionospheric absorption (1)

- **Absorption is the process by which the energy of radio waves (mostly in HF band: 3-30 MHz)is converted into heat and electromagnetic noise by electron collisions with neutral molecules and ions. Most of the absorption occurs in the ionospheric D region (50 - 90 km altitude).**

Ionospheric absorption (2)

$$L_a = -8.68 \int \kappa \, ds$$

in the absence of geomagnetic field

the Appleton formula gives:

$$\kappa = 4.6 \times 10^{-2} \frac{N\nu}{\mu(\omega^2 + \nu^2)} \text{ in dB per km}$$

where

μ **the refractive index (real)**

ν **the electron collision frequency**

ω **is the angular wave frequency in radians/s**

Nondeviative and deviative absorption

1) Nondeviative absorption when $\mu \approx 1$ and $N\nu$ large
   (HF and VHF waves absorption in the D-region)

$$k = 1.15 \times 10^{-3} \frac{N\nu}{f^2}$$

   where f is the wave frequency in Hz.

   Nondeviative absorption is proportional to the inverse f^2.

2) Deviative absorption near the top of the wave trajectory when $\mu \to 0$

Basic equation

For nondeviative absorption:

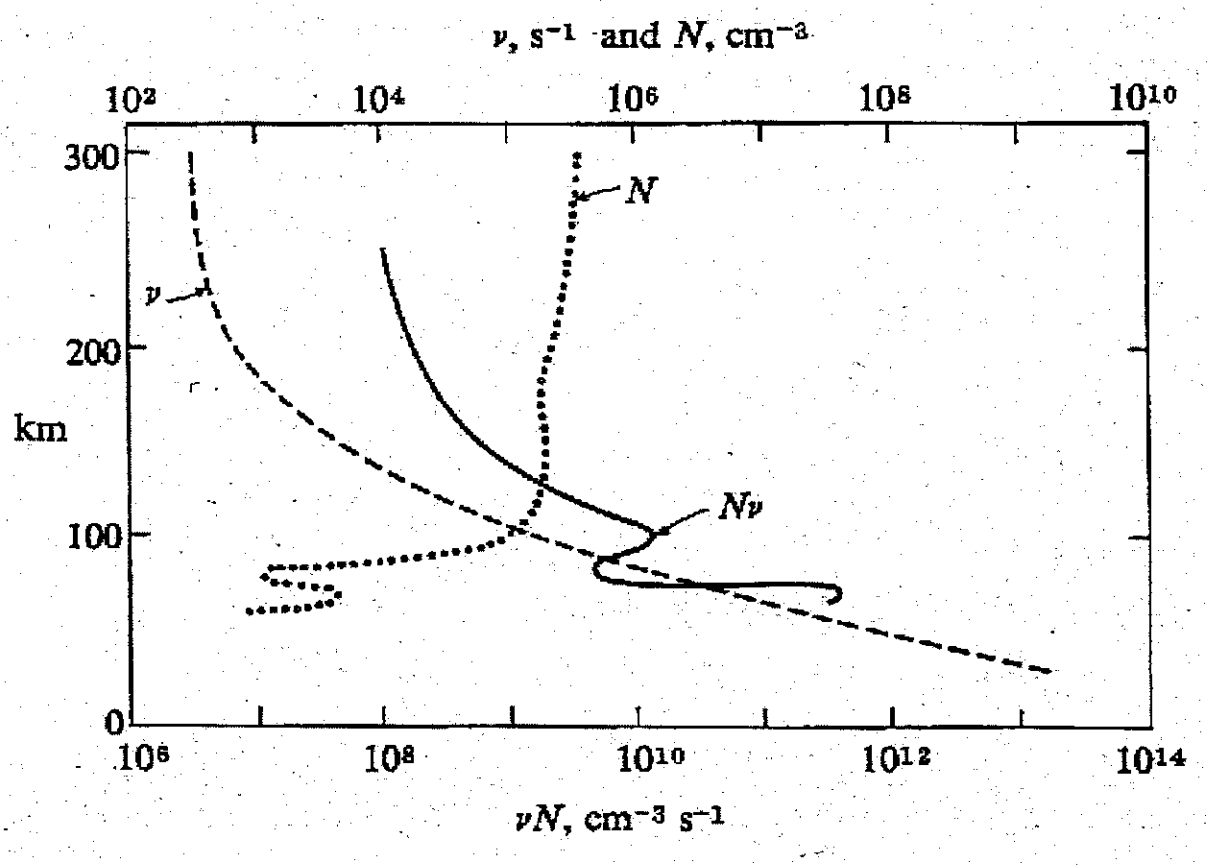
$$L_a = 8.68\int \kappa ds = \frac{-9.98}{f_2}\int N\nu ds$$

L_a **measures** $\int N\nu ds$

$$\nu = (6.4 \pm 0.4)10^7 p$$

where p is the pressure in mb.

Collision frequency and electron concentration



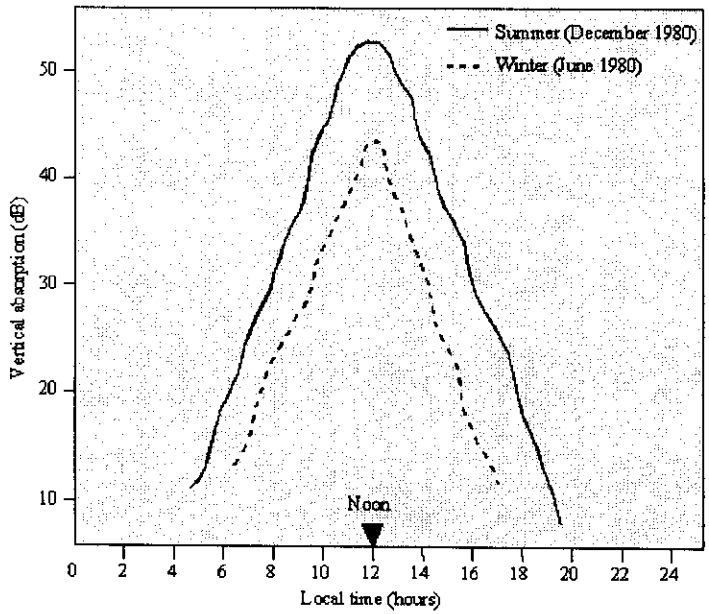
Dependence of absorption on electron concentration

- In the ionospheric D region the product of the electron density and the electron/neutral collision frequency attains a maximum.
- Within this region the pressure is relatively constant over time, so variations in the local electron concentration drive the total amount of absorption.

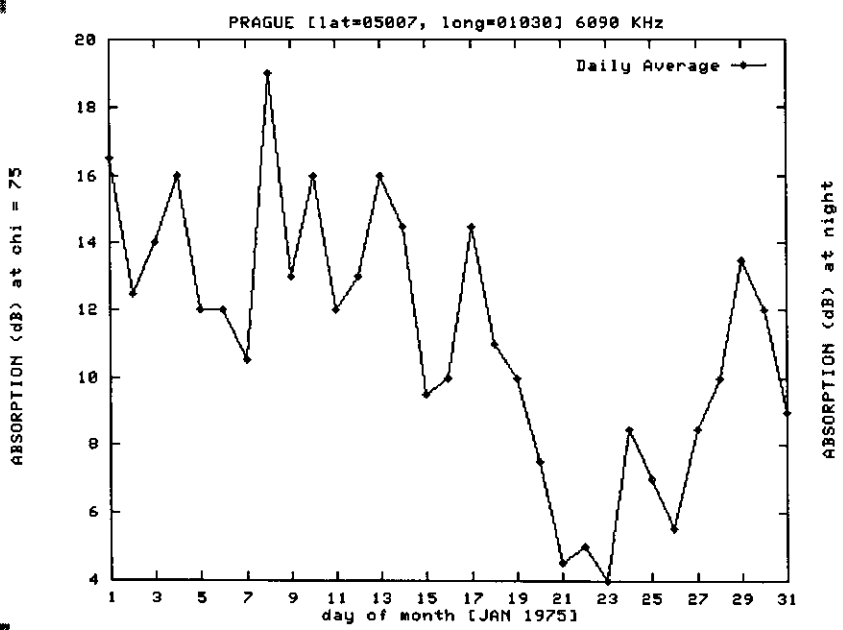
Measurements of absorption (CONTINOUS WAVE method)

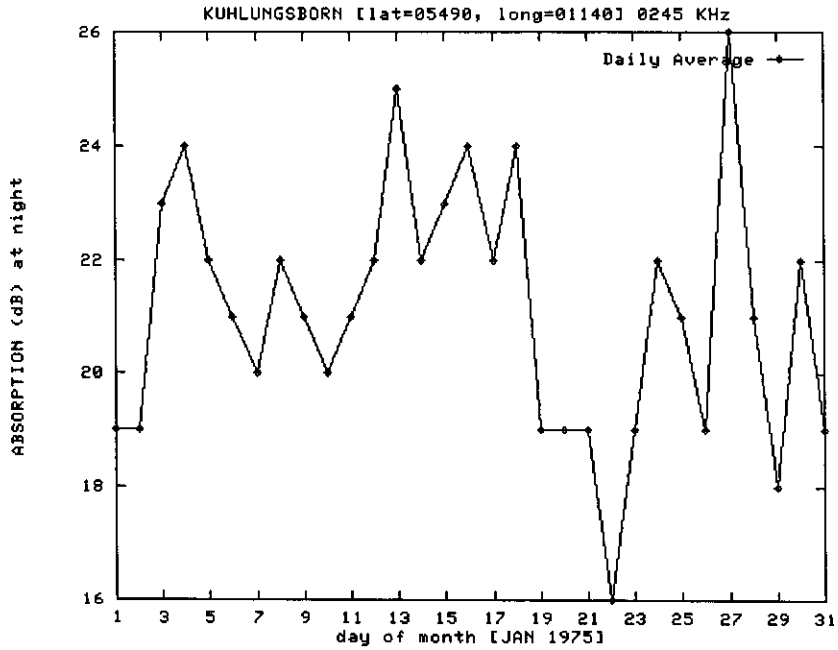
- It is based on the recording of the signal of a CW trasmitter.
- Such transmitters are widely available
- Frequencies used are between 0.2 and 7 MHz.
- The systems are calibrated by assuming zero absorption at night.

CONTINOUS WAVE method, diurnal variation

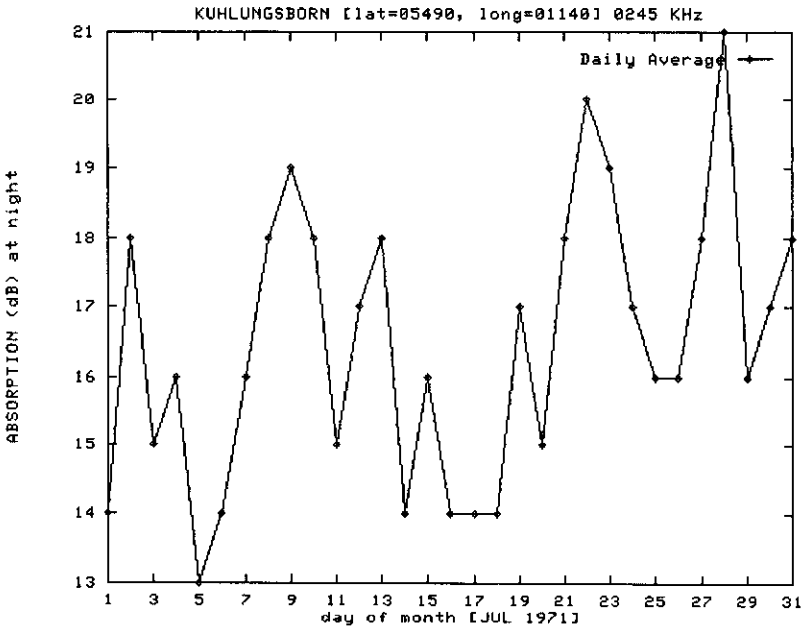


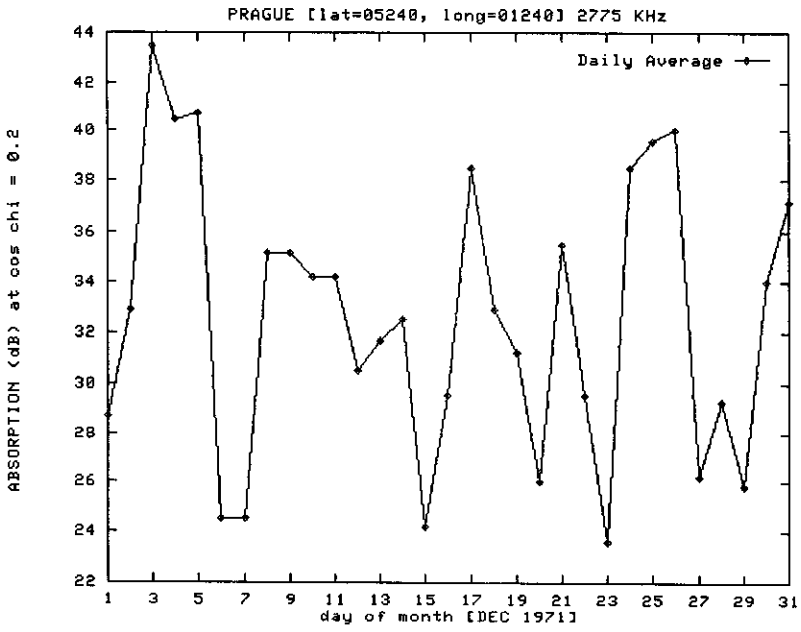
Day-to-day variation of absorption (1) Different loc. and freq..



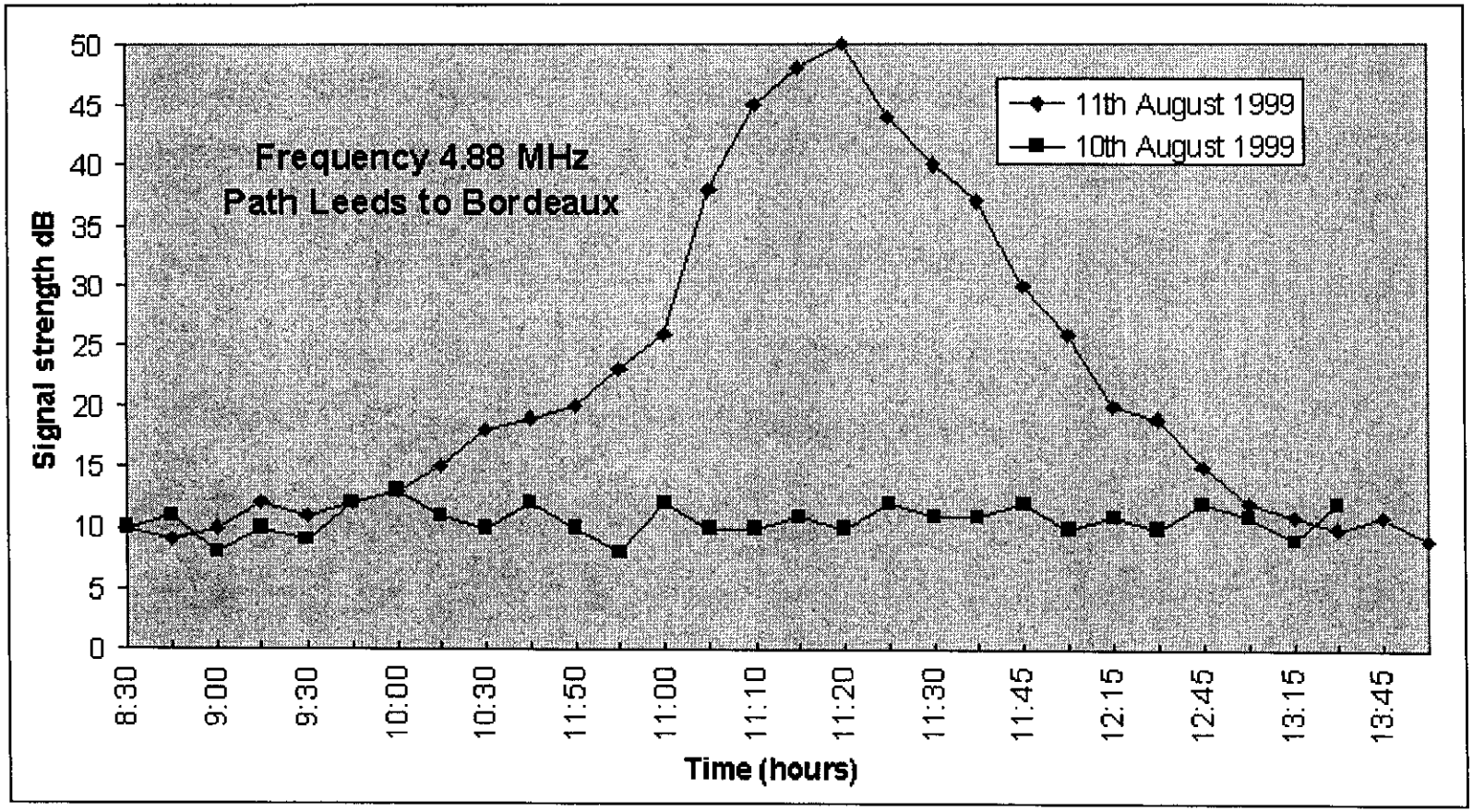


Day-to-day variation of absorption (2) Diff. month and freq.





CONTINOUS WAVE method, effect of solar eclipse



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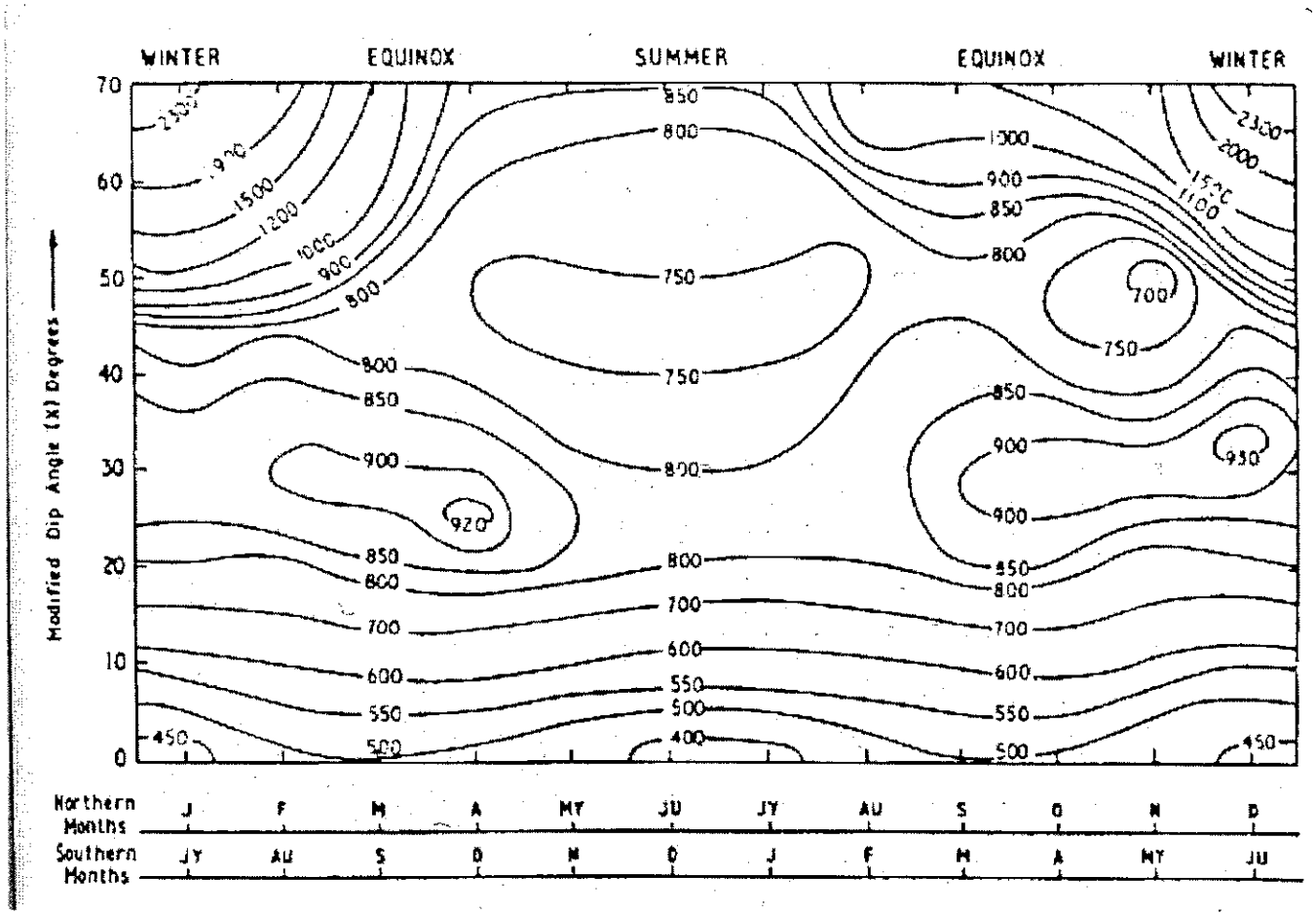
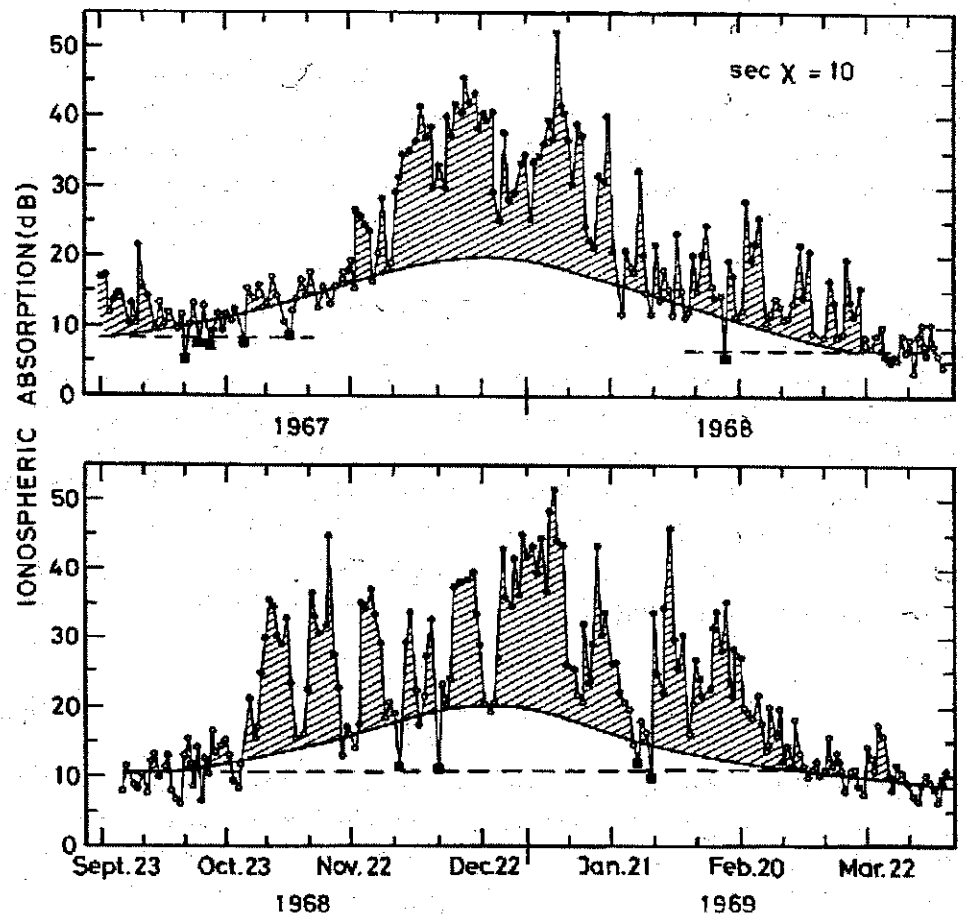
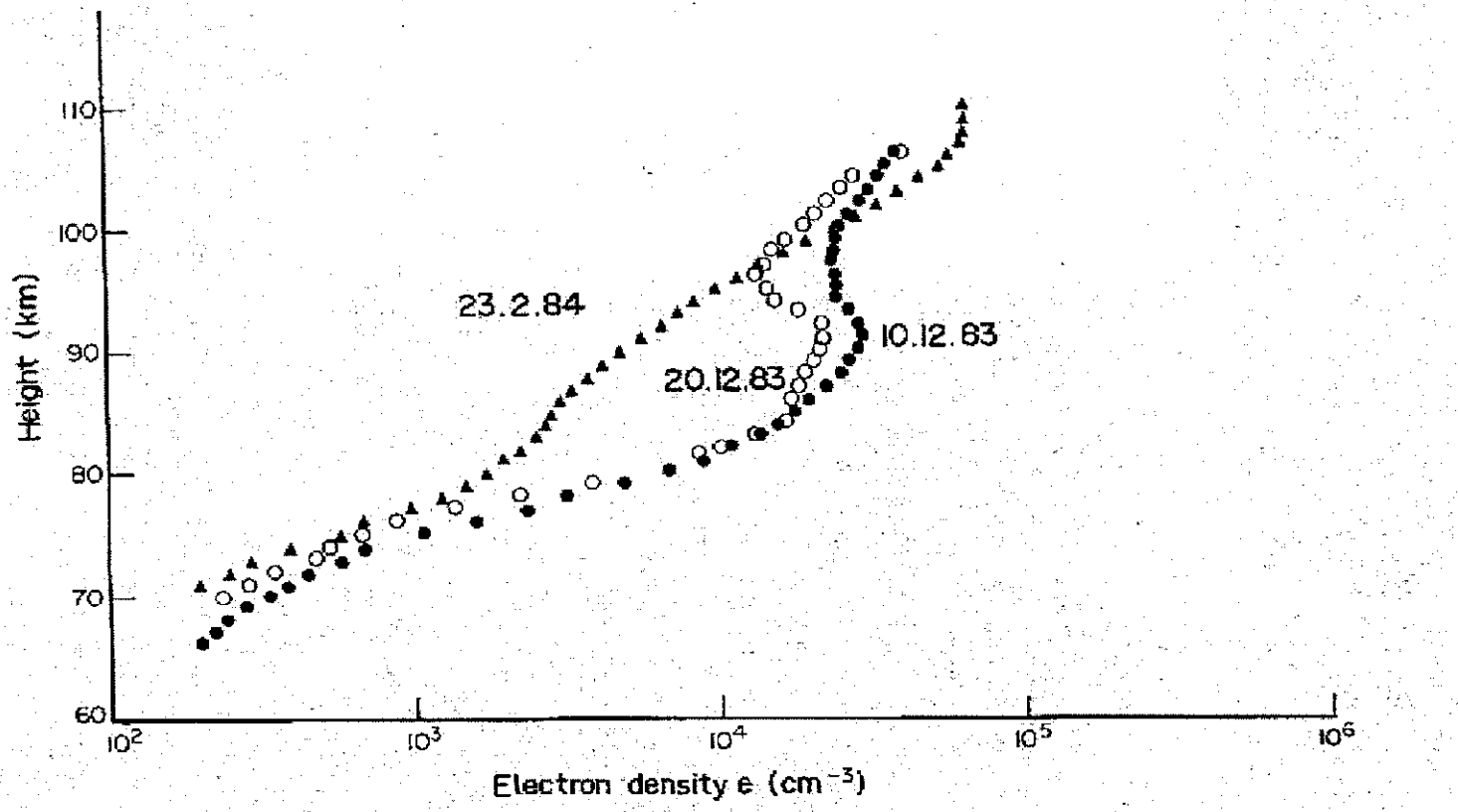
Global distribution of radio absorption



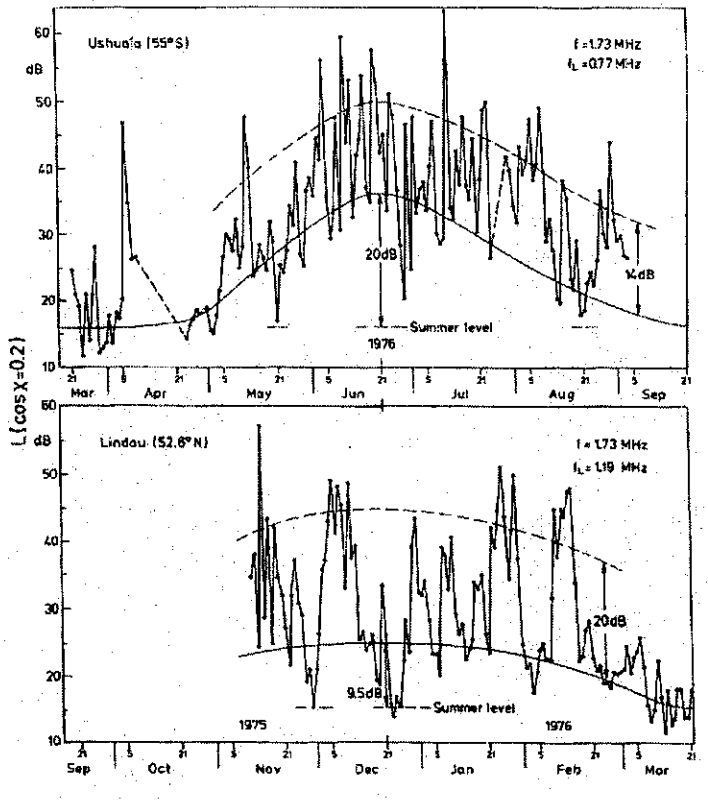
Seasonal variation of absorption (winter anomaly)



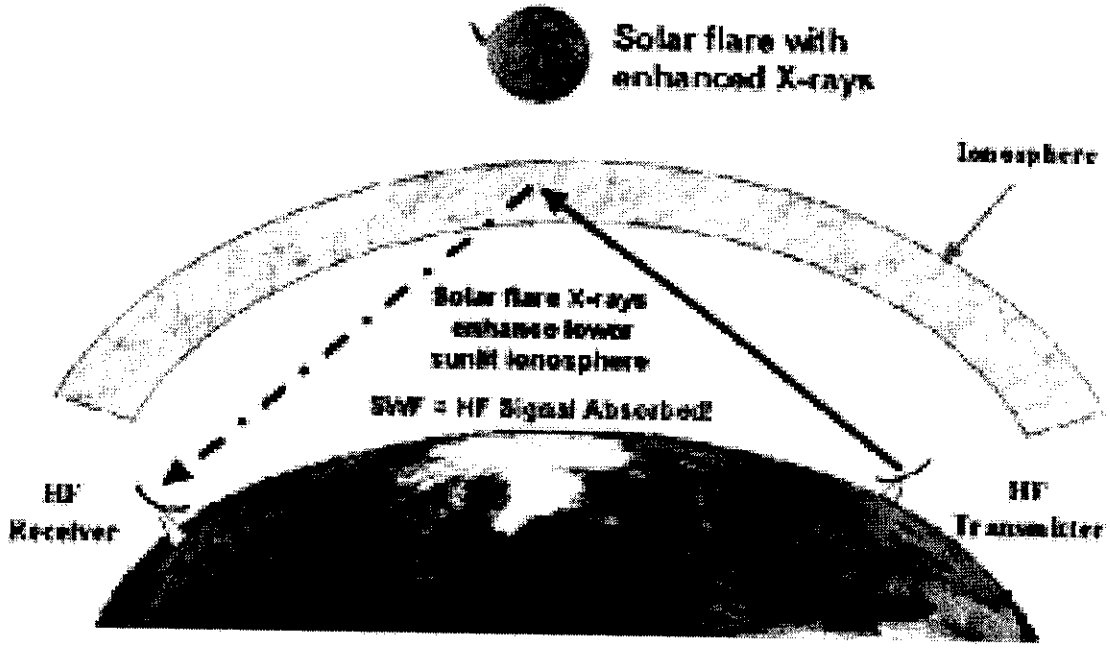
Winter anomaly effect in electron concentration



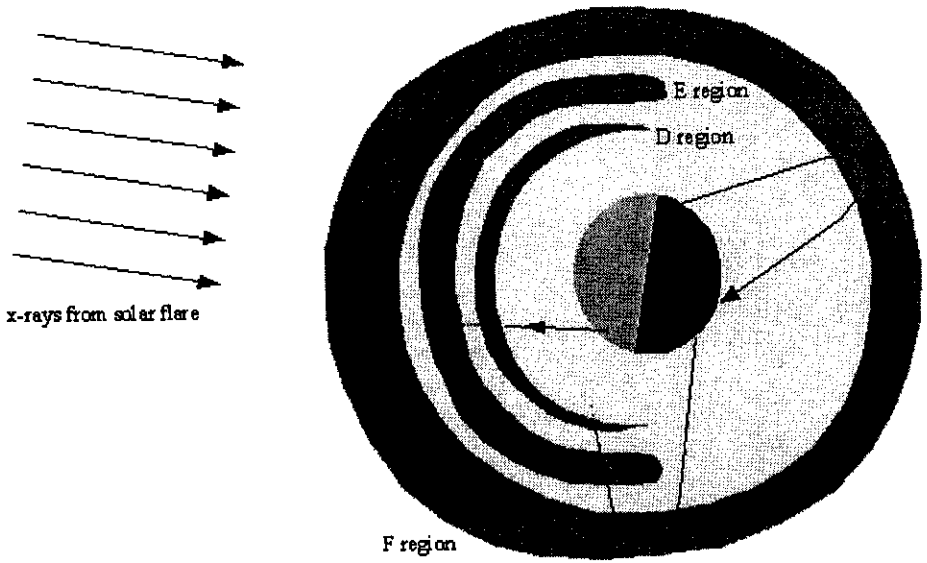
Hemispheric asymmetry in winter anomaly



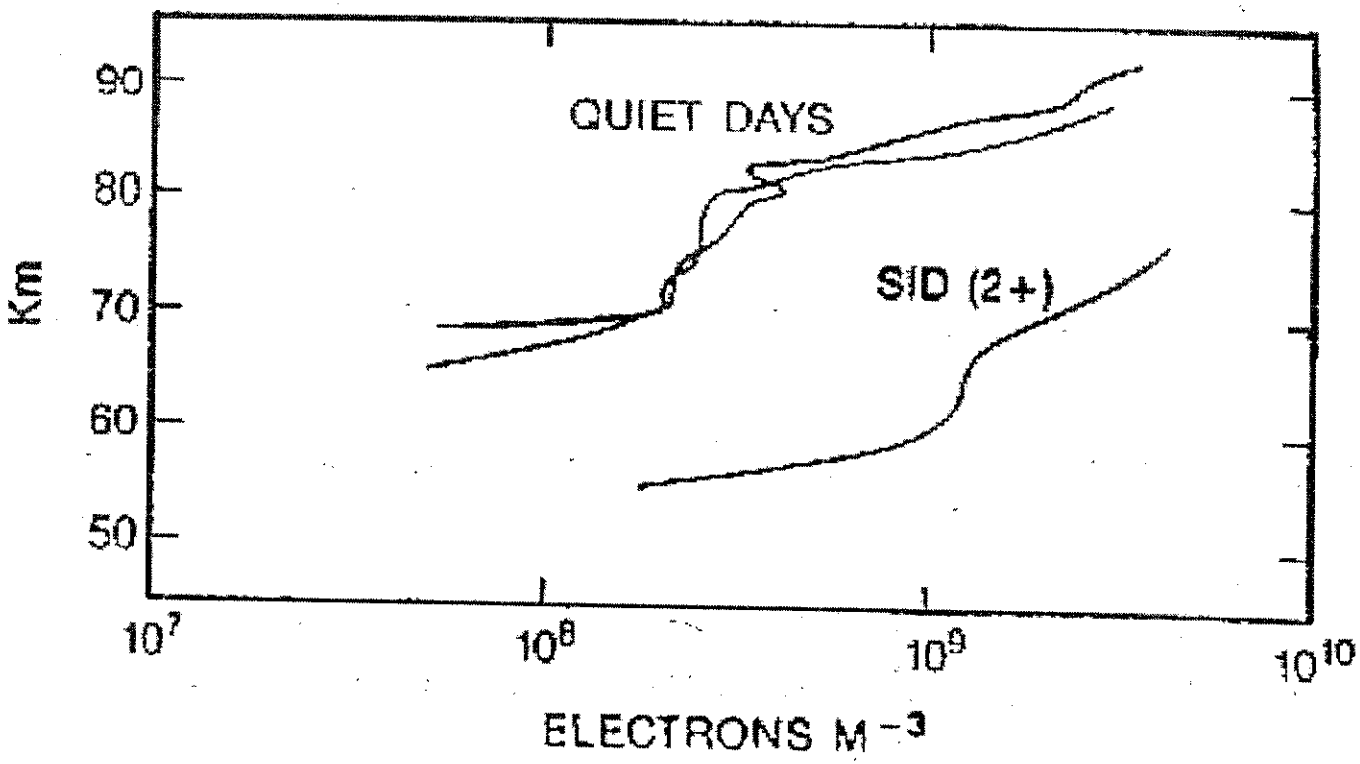
Effect of a solar flare (1)



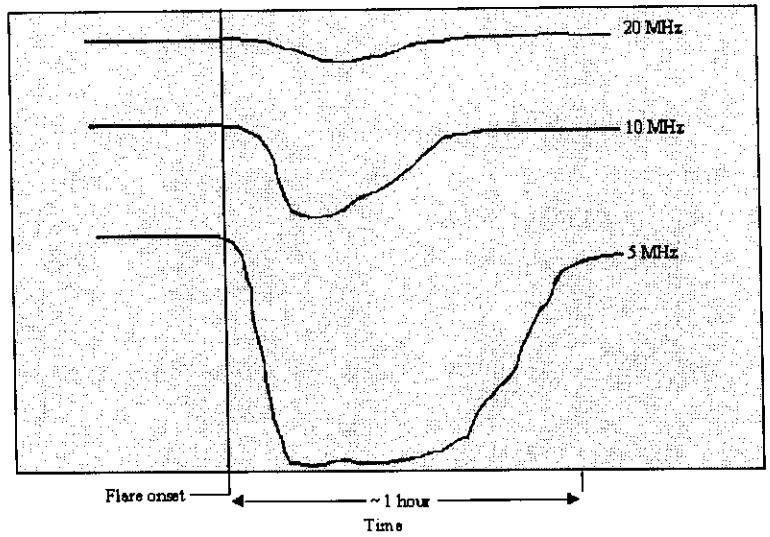
Effect of solar flare (2)

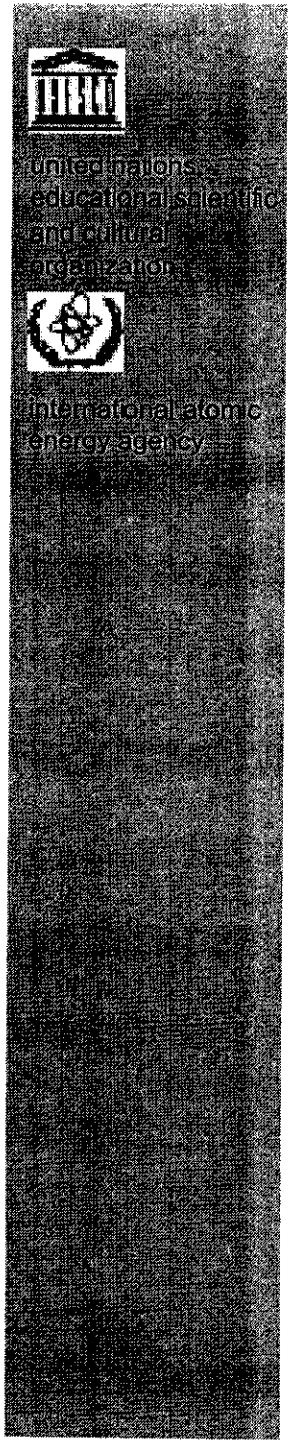


Effect of solar flare on the electron concentration (SID)



Effect of solar flare on different HF signals





Measurements of absorption (RIOMETER)

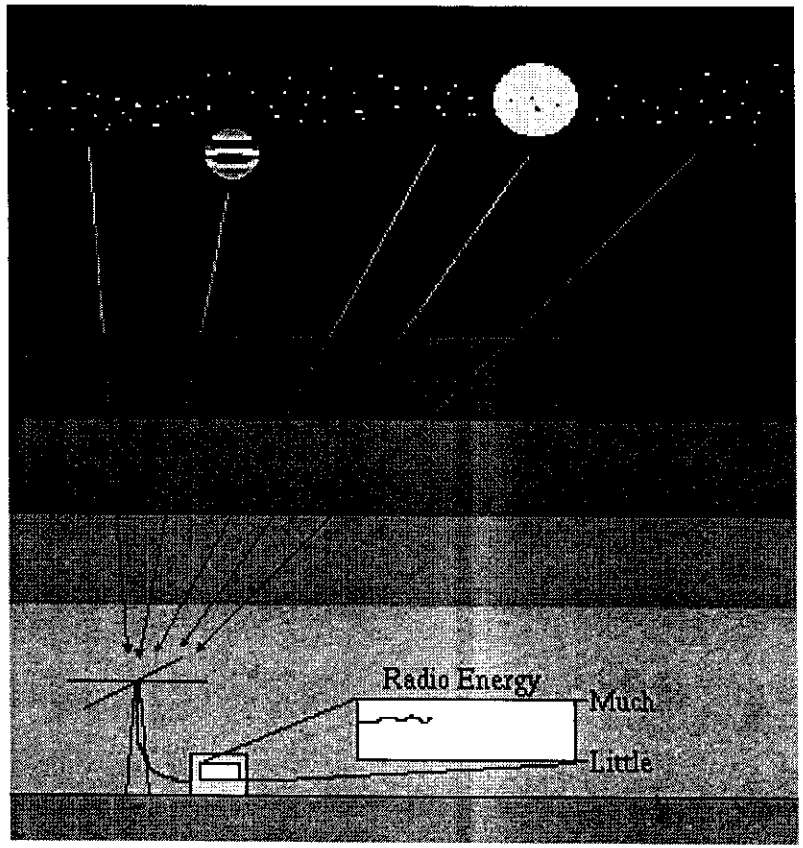
- "*R*elative *i*onospheric *o*pacity *meter*" measures the intensity of wideband deep space noise that impinges on the Earth.
- The received noise is a function of sidereal time.
- The absorption is the difference between the cosmic signal and that of a calibration noise source.

RIOMETER measurements

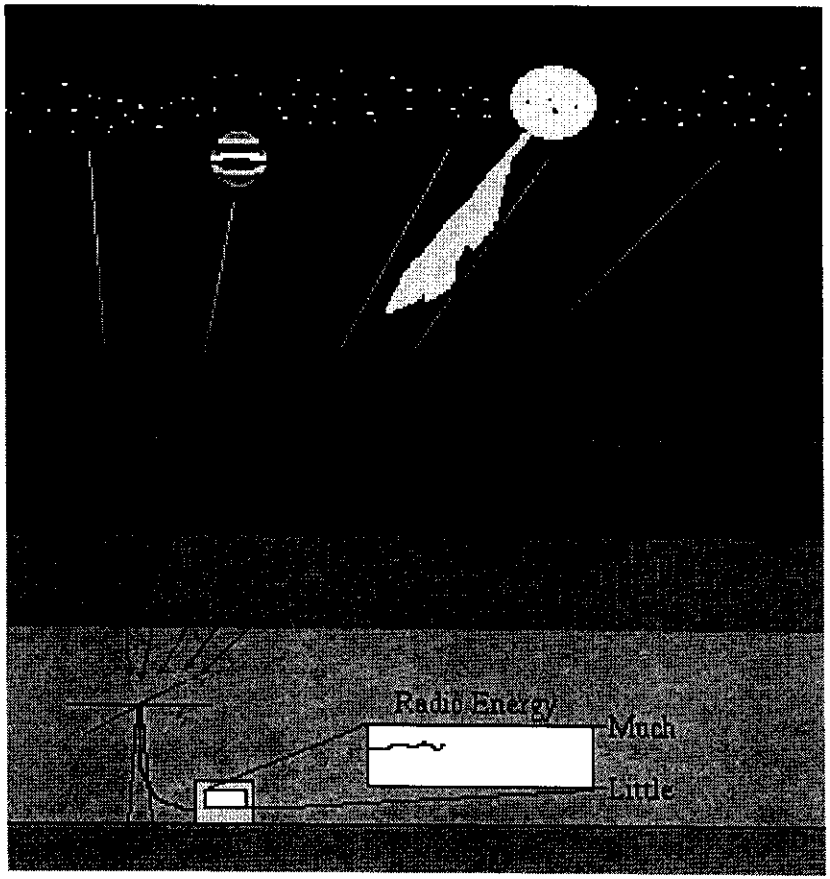
- Riometer measurements are usually made at frequencies in the range of 20 to 50 MHz;
- The absorption of radio energy at these frequenciesis sensitive to changes in electron density in the D - and E - regions.
- The effects are integrated over a large portion of the ionosphere, so small scale details of the actual physical distribution of electron density are lost.

RIOMETER operation

- **The RIOMETER picks up the natural radio noise produced by stars, planets (Jupiter in particular), and the sun.**

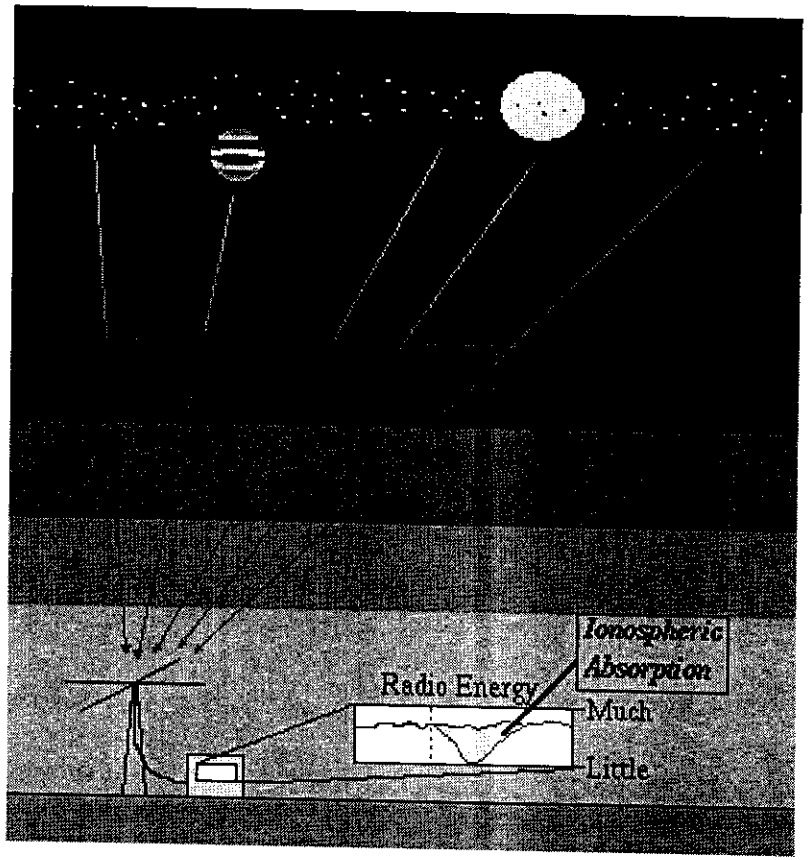


Solar Flare and RIOMETER measurements



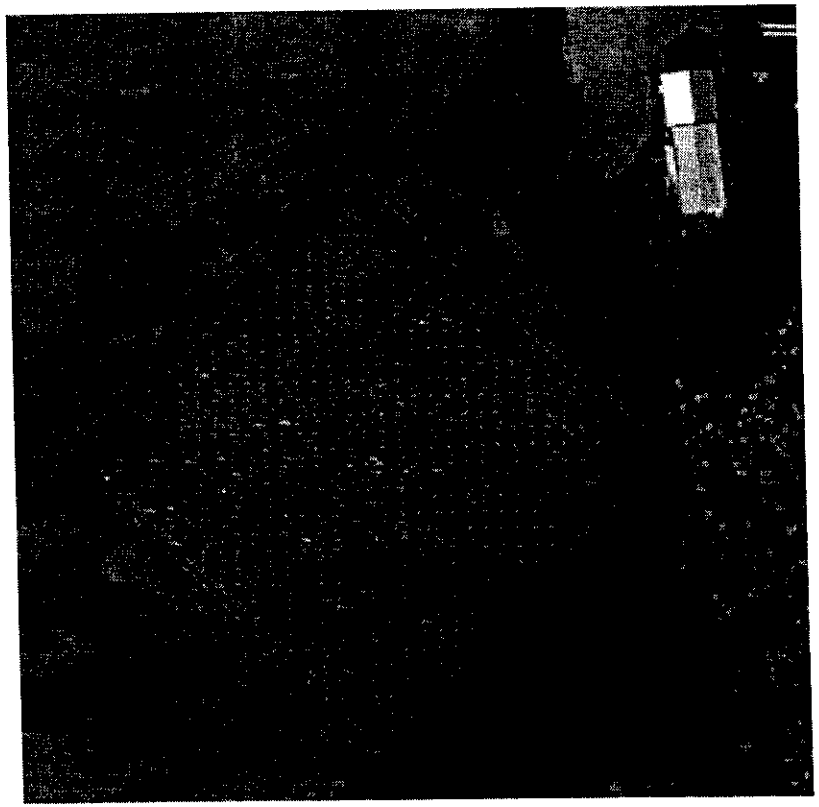
Solar Flare and RIOMETER measurements

- The solar flare produces a cloud of ionized gas in the lower ionosphere, which may be thick enough to absorb the sky noise that the riometer is measuring.
- As a result, the noise that the riometer records will drop.



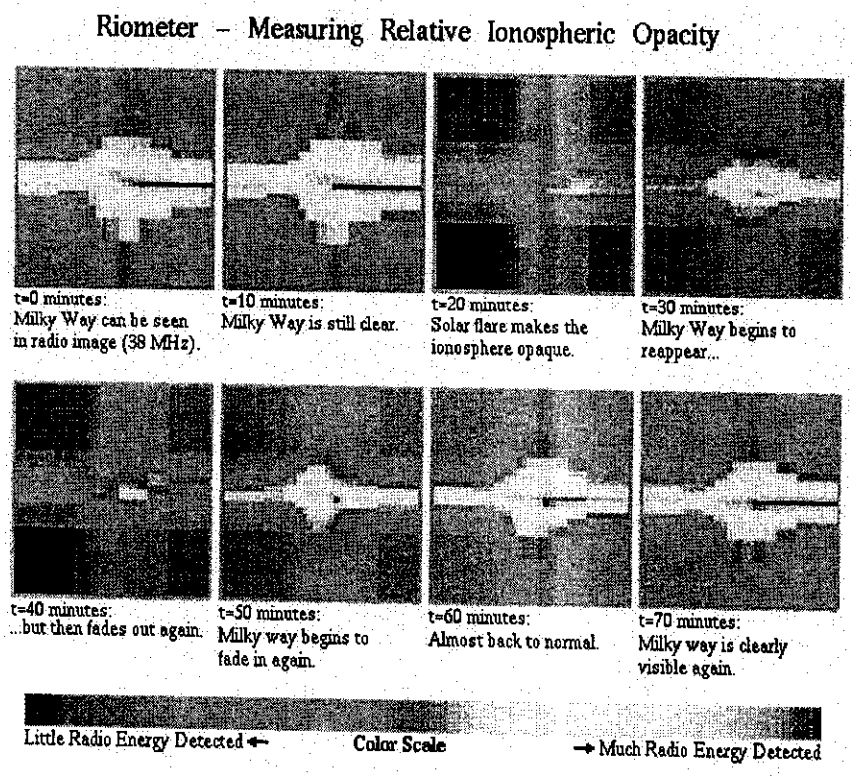
Imaging RIOMETER

- **An imaging riometer is actually an array of riometers set up in such a way that they produce a two-dimensional image of the cloud of ionization.**



Imaging RIOMETER

- **The image above shows a set of sky noise maps from the imaging riometer at Poker Flat. The Milky Way galaxy shows up as a bright band, similar to the way it appears to our eyes at night. It is obscured by a cloud of ionization in the ionosphere for more than half an hour, then reappears**



Same references: Books and papers

Books

- K. Rawer (ed); "Encyclopedia of Physics, Geophysics III",Vol 49/7, Springer-Verlag 1984
- K. Davies; "ionospheric Radio", Peter Peregrinus Ltd for IEE, 1990

Papers

- M. Friedrich and K.M. Torkar; "An empirical model of the non-auroral D-region", Adv. Space Res. Vol 13, pp (3)97, 1993
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Same references: Books and papers

- A.K. Knyazev, Z.Ts. Rapaport, V.M. Sinelnikov and M. Friedrich; "Rocket electron density profiles over Volgograd, Heiss Island and Esrange during the DYANA campaign", A JATP Vol 56, 13/14, pp 1923, 1994
- Z.Ts. Rapaport and V.M. Sinelnikov ; "Experimental electron concentration profiles of the middle latitude lower ionosphere and the winter anomaly" Intern. J. of Geomagnetism and Aeronomy, Vol 1, 1998