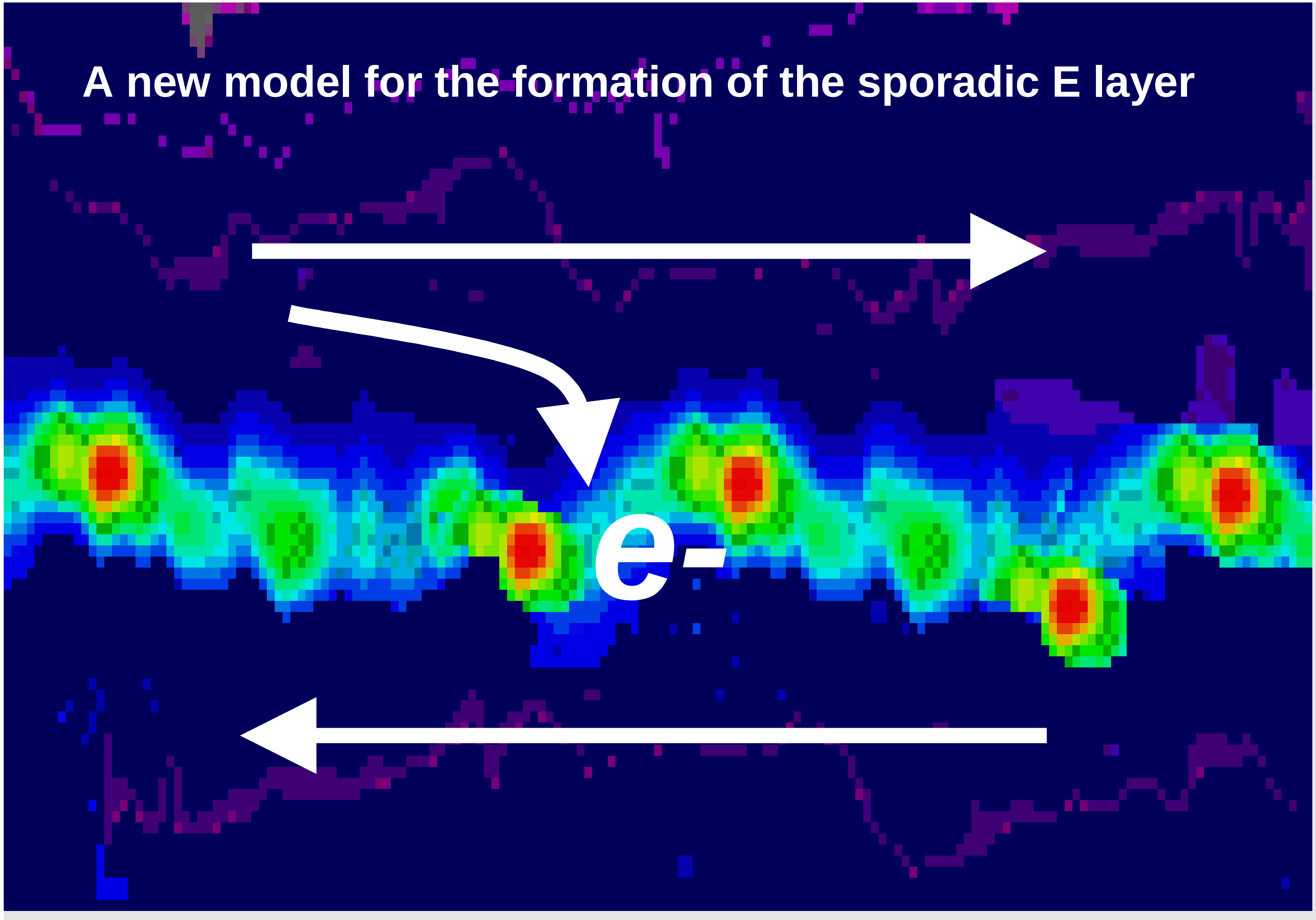
Meteors + Wind Shear + Lorentz Force



Flavio Egano, ik3xtv www.qsl.net/ik3xtv ik3xtv@gmail.com published : July 2012 ARI Associazione Radioamatori Italiani-Sezione di Thiene (VI)

Meteoric Input

- The "raw material" is provided from <u>meteorites entering the atmosphere</u> and burning due to friction, caused by the very high entry speed. The result of this vaporization is both ions and oxidized ions, by combination with oxygen ions present at that altitude (created by the UV rays). The metal atom loses an electron and becomes an ion + and an electron-.

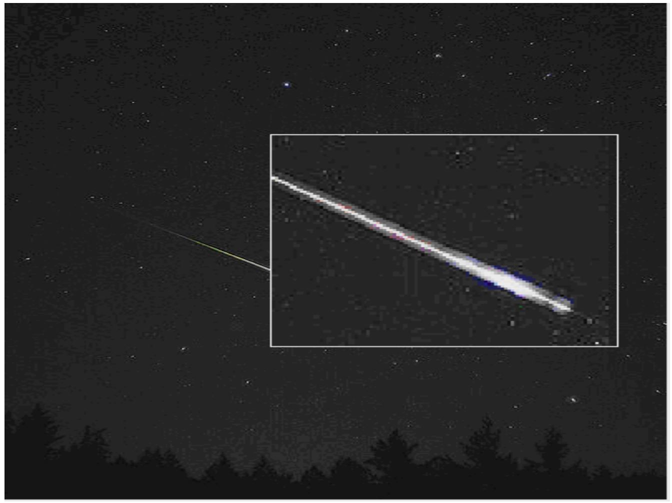


Image credits: Wikipedia
Creative Commons Attribution

The ionization from UV rays, although higher in summer months, does not allow sufficient electron densities in the E layer to allow sporadic E

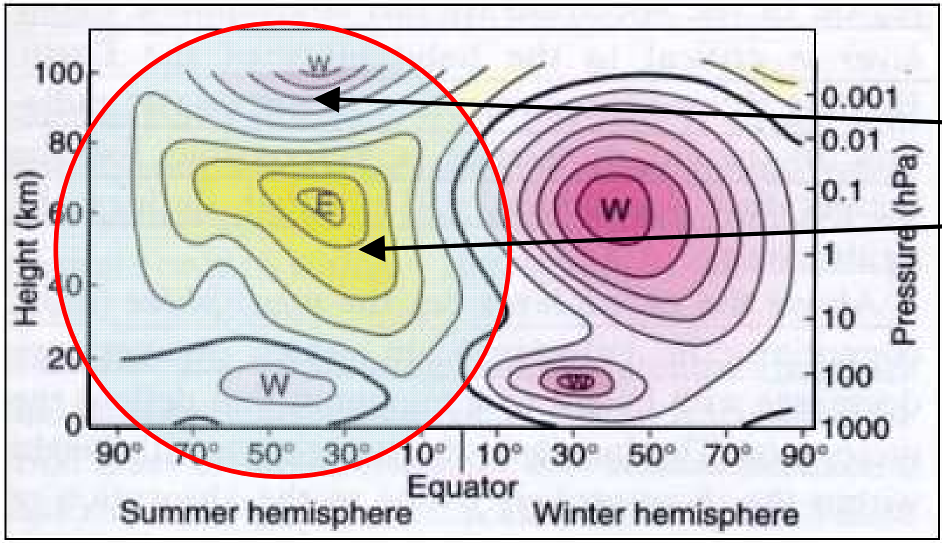
Neutral Winds in the Ionosphere

The key to understanding Sporadic E is the meteorological science, and specifically the mesospheric winds.

There is a significant **seasonal trend in mesospheric winds**. These winds, in the summer months, **show a clear trend from west to east at higher altitudes** (about 95-100 km) and **in the opposite direction at the lower level** (about 80-85 km), that is from east to west . The Earth's magnetic field, oriented South-North, is orthogonal to the direction of the reverse Winds

The winds

- **Jet stream in the troposphere, always from west**
- **Jet stream in the mesosphere (reverses seasonally)**
- **zonal currents in the stratosphere with seasonal inversion**



Courtesy: Istituto di Scienze dell'Atmosfera e del Clima – CNR, Italia.

Eastward Winds W=from west

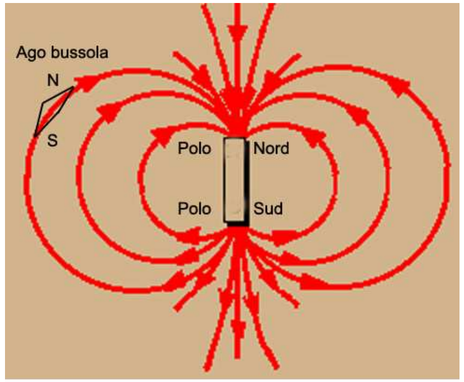
Westward Winds E=from east

Highest probability for Es

The Lorentz Force

Direction of lines of force of the Earth's geomagnetic field:

From South to North (Geographic)



Lorentz Force

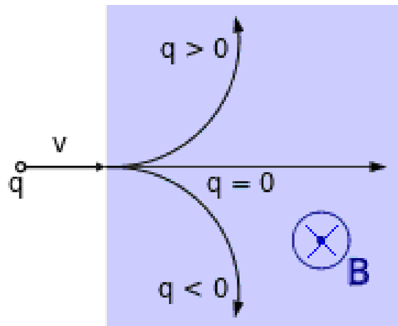
In physics, the force acting on an electric charge that moves in a magnetic field is called Lorentz force . The principal characteristic of the Lorentz force is that it is always perpendicular both to the direction of motion of the electric charge and to the magnetic field.

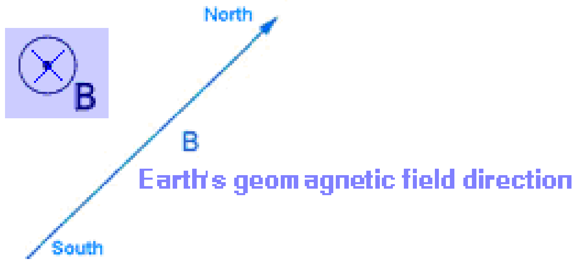
$$\mathbf{F} = q(\mathbf{E} + \mathbf{v} \times \mathbf{B})$$

Where **q** is the electric charge

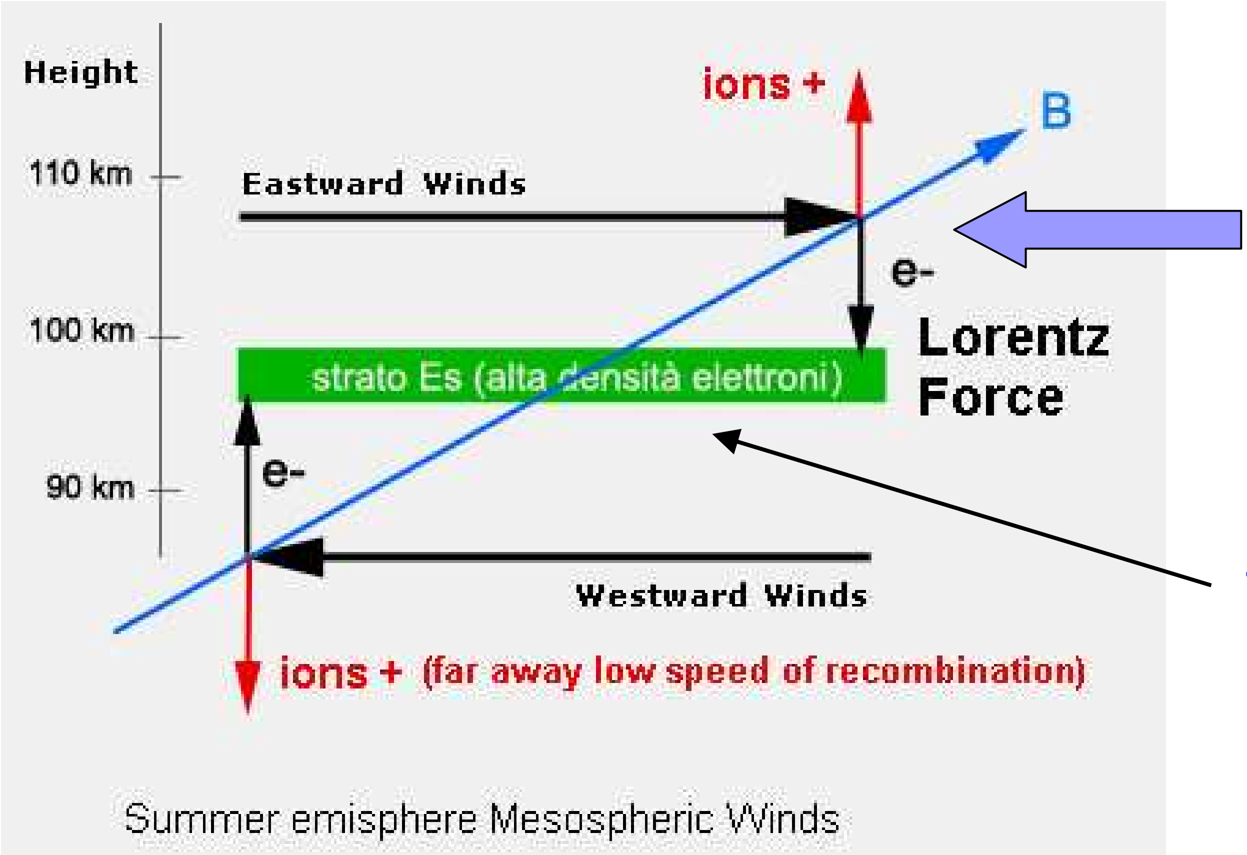
vxB is the vector product between the velocity V and the magnetic field **B**

Lorentz force





The combined action of the zonal winds + Lorentz force



As a result of the Lorentz force the electrons e- are moved downward and ions + are moved upward

The result is a layer with high concentration of electrons

Graphic by Giorgio,ik1uwl

Graphic diagram of the model Wind Shear + Lorentz force, responsible for the concentration of the electrons layer. The figure refers to the **summer months** where the **dominant trend of the winds is Eastward above and Westward below** . **Only with this zonal neutral wind direction, the accumulation of free electrons is possible.** The refraction index of radio waves in the ionosphere is related to the concentration N of free electrons.

The ionospheric refraction depends on the free electrons

When an electromagnetic wave impacts on the ionosphere, the electric field of the wave produces a displacement of the electrons and ions; **the displacement of the ions is much more limited than that of the electrons**, because the mass of a ion is much larger than that of electrons (about 2000 times more in the case of atomic hydrogen, the lightest gas)

The Refraction index in the Ionosphere

The refractive index n, seen by a wave at frequency f which is propagated in a ionized gas, depends on the number of charges N per unit of volume, according to the relation:

$$n = \sqrt{1 - \frac{Ne^2}{4\pi^2 f^2 m \epsilon_0}}$$

where m is the mass of the electron, e is the electric charge, and ε_0 is the dielectric constant of vacuum

Electrons, and not ions, interact with electromagnetic waves

Practical verification

Situation analysis, using the meteor radar of Collm in Germany that records the speeds of the zonal winds at high altitude. This is the upper wind pattern (marked Eastward wind) with amplitude influenced by semidiurnal tides. The lower wind, has a predominant Westward trend, especially in daylight hours, with a marked amplitude in the central part of the day. I circled the phases of wind shear with possible accumulation of electrons.

Reverse high speed Winds

(High Es probability)

Speed conversion: 100 m / sec = 360 km / h

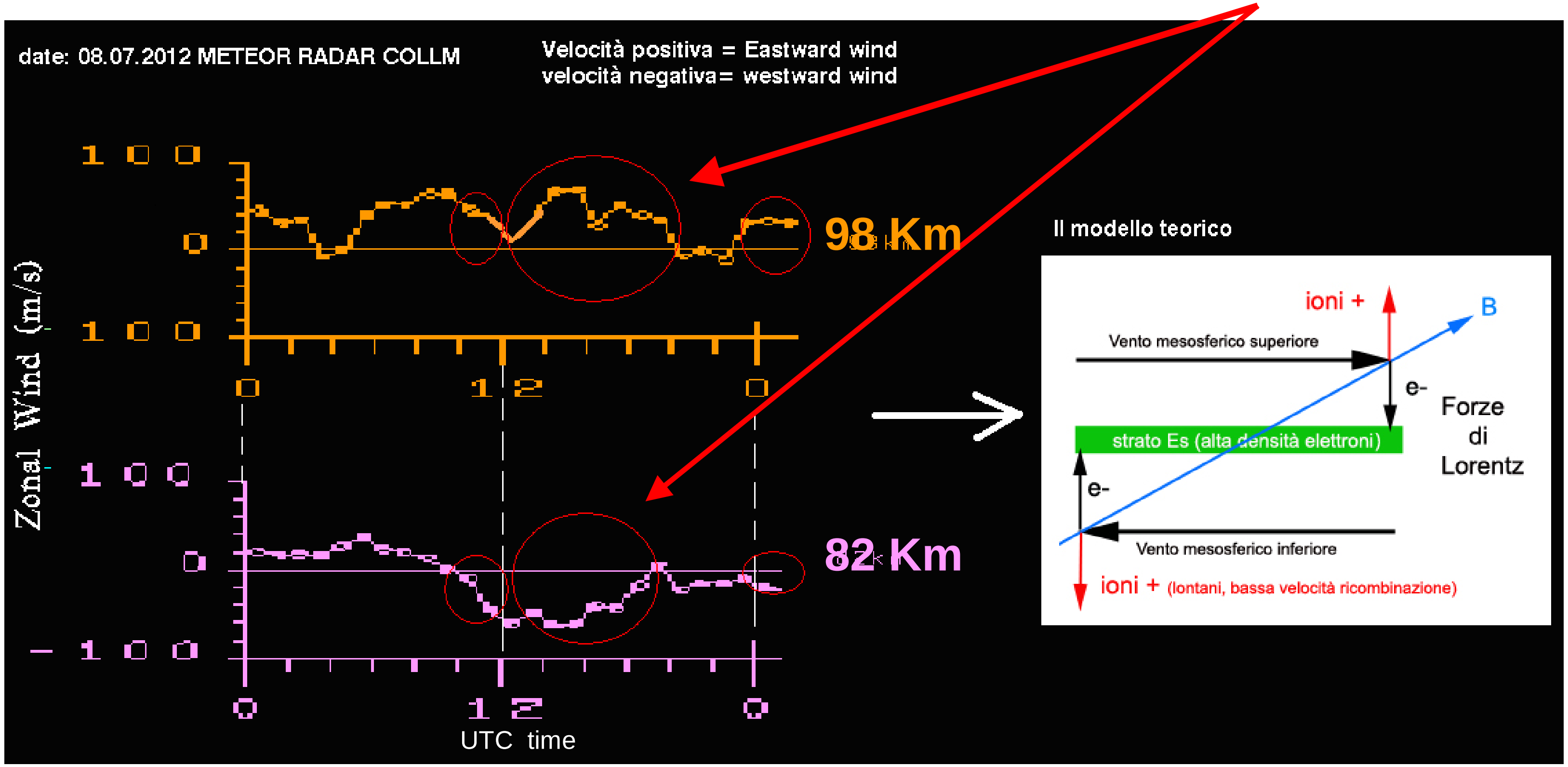
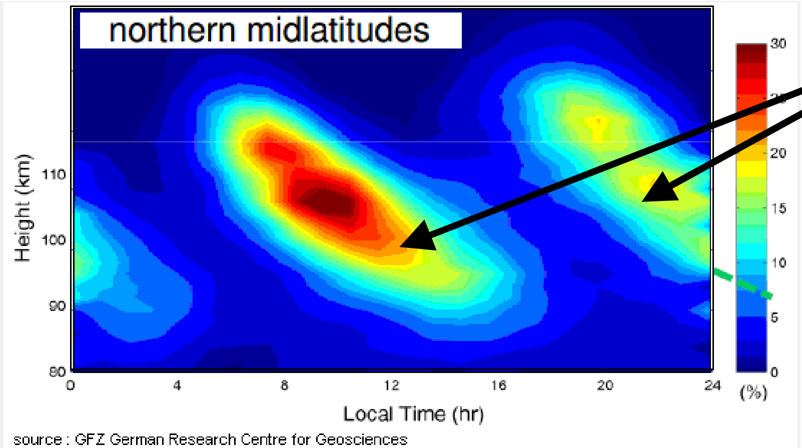


Image elaborated by ik3xtv on graph of meteor Radar Collm

Forecasting model

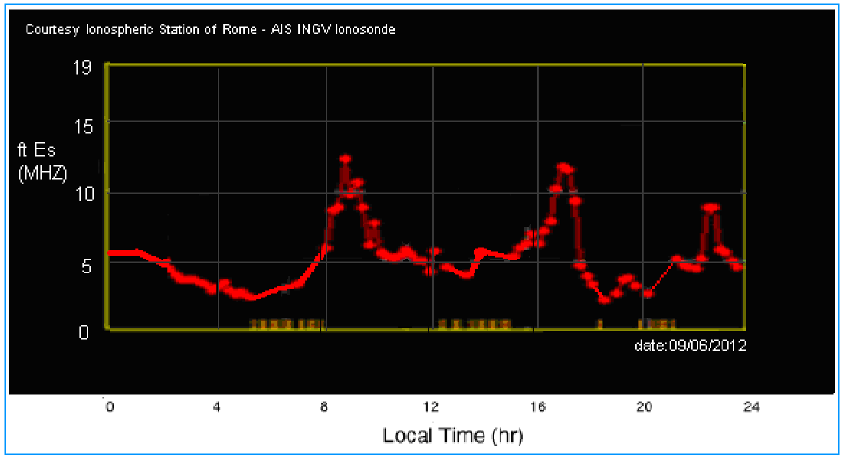
<u>A reliable prediction is currently **not possible because we cannot have real-time data on the amplitude and phase of the winds at high altitude**</u>. it is possible to create a probabilistic model starting from the crucial fact that the time of possible openings is governed by atmospheric tides, i.e. is the amplitude of the diurnal variation of winds.

Sporadic E Occurrence Rate at 40-45° Latitude



Semidiurnal Tides

The wind shear exhibits two daily peaks. Near these peaks is the best chance of sporadic E. (Semidiurnal Tides) We highlight two maxima and two minima per day (24 hours)



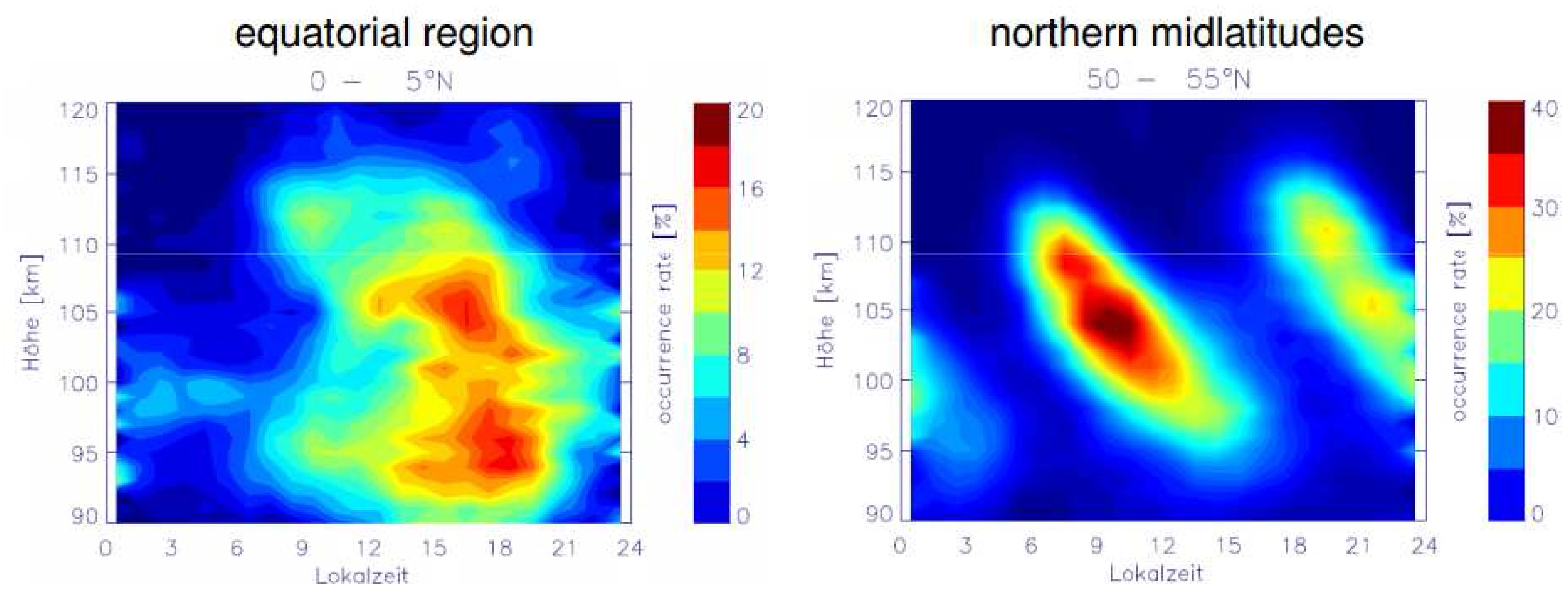
Comparison of daily ftEs with the probability of sporadic E. It shows a significant correlation between the Es curve of Rome's ionosonde and the probabilistic graph above.

Images elaborated by ik3xtv on data of GFZ - German Research Centre for Geosciences and INGV Rome Ionosonde

Sporadic E occurrence rate

Tables of the probability of sporadic E in relation to local time

Graphs subdivided by latitude



influenced by Diurnal Tide:
one maximum and minimum per day

influenced by Semidiurnal Tide:
two maxima and minima per day

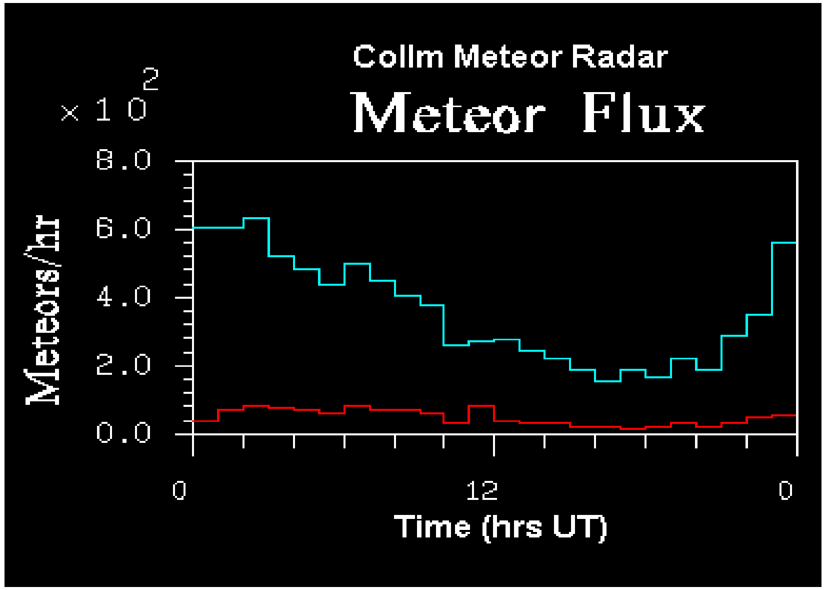
Image credit: GFZ German Research Centre for Geosciences

Variation of Meteor stream

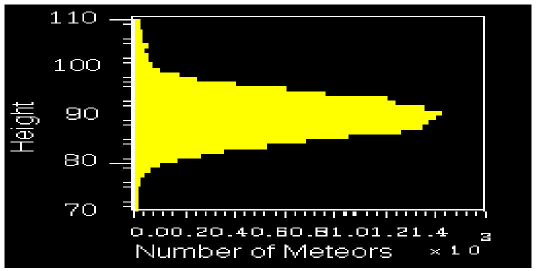
The Meteor stream is not constant but has some variation:

- Seasonal variation (Mean meteor stream about 6 times higher in summer months)
- diurnal variation (peak in the morning followed by gradual decrease)
- hourly variation

Diurnal variation



Height distribution



Migration time for the Lorentz force:

note the time difference between the arrival of the bigger amount of meteorites and the hours of highest Es probability (see the slide of "Sporadic E occurrence rate")

Graphs: Courtesy of Meteor Radar Collm - Leipzig Institute for Meteorology

height of evaporation

Dispersion of meteoric material (depending on its size) before it is compressed by wind shear and Lorentz Force

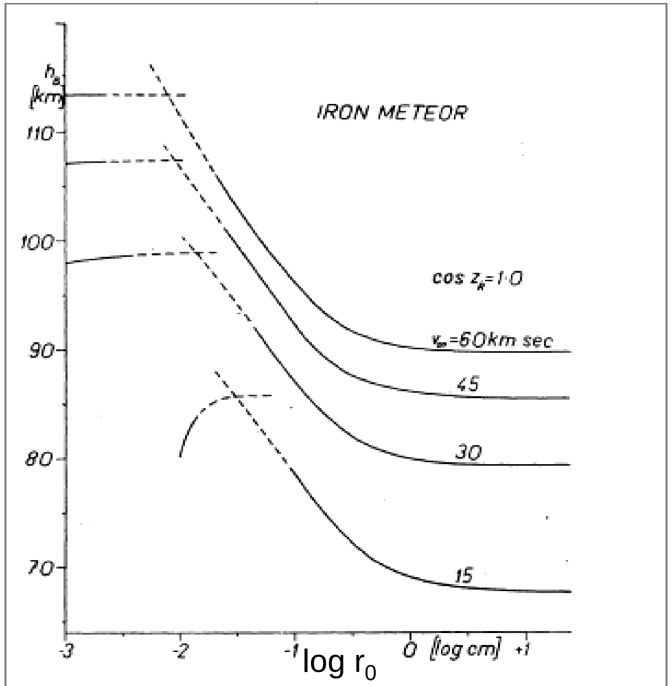


Fig. The theoretical dependence of the height of beginning of rapid evaporation on the radius of the spherical meteor r_0 for iron composition.

Courtesy: SAO/NASA Astrophysics Data System (ADS) (Ceplecha, Z. & Padevěv, T. Astronomical Institute of Czechoslovakia)

Some considerations

This new model is well suited to explain:

- the pronounced summer seasonal occurrence
- the slow process of Ion recombination

The Key factors

- ❑ Meteoric input
- ❑ Reverse high altitude winds
- ❑ Lorentz Force
- ❑ Atmospheric Tides

Assumptions and models are valid for the middle latitudes

references

Università di Lipsia Istituto di Meteorologia
A tutorial review on Sporadic E layers Christos Haldoupis
Physics Department, University of Crete, Heraklion, Crete, Greece
"Global Observation and Analysis of Sporadic E layers using GPS radio occultation measurements“ by C.Arras,J.Wickert,S.Heise,T.Schmidt. Helmotz Centre Potsdam
"An explanation for the seasonal dependence of midlatitude sporadic E layers“ JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 112, A06315, doi:10.1029/2007JA012322, 2007
Articoli vari di Marino Miceli, I4sn (Radio Rivista –ARI)
Dynamical Meteorology - (IMAU, Utrecht University)
GFZ German Research Centre for Geosciences
Università di Padova- Corso di Elettronica e Telecomunicazioni G. Lullo
INFN Istituto Nazionale di Fisica Nucleare sezione di Trieste Edoardo Milotti
Wikipedia
Department of Physics, Chinese Culture University, Taipei, Taiwan, R.O.C.
Institute of Space Science/Center for Space and Remote Sensing Research,
National Central University, Chung-Li, Taiwan, R.O.C.

collaboration

Thanks for the collaboration to Giorgio Marchi, IK1UWL
Thanks also to Christina Arras, GFZ German Research Centre for Geosciences

Flavio Egano, ik3xtv www.qsl.net/ik3xtv ik3xtv@gmail.com published : July 2012

ARI Associazione Radioamatori Italiani-Sezione di Thiene (VI)

Copyright 2012 ©