Forecasting E-Sporadic (ES)

New point of views falling from the space on E-Sporadic events

By Flavio Egano, IK3XTV and Tony de Longhi, IZ3ESV

Abstract
There is strong evidence that the E-Sporadic layer at the tempered latitudes should origin from events occurring outside the Earth. Investigations in last years showed a high amount of meteoric powder inside E region, which is subsequently stored in ultra-dense layers thanks to the turbulence generated by the so called jet stream. In this way E-sporadic layer is caused by the metallic ions scattering as meteorites fall over the atmosphere. This meteoric ablation is not the only reason, but should strongly work as a primer for ES propagation. We can assume that ES is the outcome of the combination of these agents:

- Meteoric Ablation (as primer event).
- Ionosphere winds;
- Solar Flux;
- Atmospheric Gravity Waves (AGW)

Thus the knowledge of some events and the availability of several data concerning these agents should help hams to try to implement a forecast model for the activity in upper HF bands and VHF; this model cannot be completely fail-proof, but it can be a good starting point for systematic and deep observations.

E-Sporadic Theory: the nature of ES curtains

Inside E region there are strong winds, blowing horizontally, moving across Ionosphere, layered over few Kilometers. Their action, combined to the gravitational waves raising from the Troposphere, pushes gas ions inside E region as new ion clouds are formed. This mechanism is a true vertical compression, that generates thin layers with high electronic concentration (called *N*), with a thickness of 2-4 Km, localised between 90 and 110 Km over the Earth surface. Normally their extension doesn't exceeds 50 or 100 Km in diameter (at tempered latitudes) but the main feature is that volume concentration (ions/cm^3) is higher than ordinary E layer.
The possibility to have an increased ions concentration inside these highly ionised layers is granted by metallic ions, which have slower recombination rates than other chemical elements: among them we can recall Magnesium (Mg^+), Iron (Fe^+) an Nickel (Ni^+). A slower recombination rate means that ion-state can be maintained for a "long" time before ions can go back to a stable configuration of the atomic structure, as an ion is chemically an atom which has lost (positive ion) or has gained (negative ion) one or more electrons.
Recently it has been shown that ES curtains have a high amount of metallic ions, beside Oxygen and his Nitrates ions (default present as normal atmospherical composition). Metallic ions come completely from meteorites entering Earth's atmosphere, thanks to the gravitational attraction (as it happens to any satellite losing his orbit and entering back on Earth at the end of his high-mile life). In this way meteorites and their ablation can catalyse intense ES events, not being the main cause for the event itself (specially for frequencies between 50 and 144 MHz).
We can assume that, as a main concept, the ES event intensity depends on the residual ionisation of the layers (as their ions are by default and statistically located in the ionosphere), the extent of heavy ions (metallic ions, indeed) generated by meteorites and the strength of the high-altitude winds mentioned above (in particular their speed-change rate related to the altitude, as they're responsible of the ions storing in the curtains).

Chemical composition of a meteorite

The main composition of a meteorite is shown in the table. The main elements are Iron, Magnesium, Nickel and Aluminium. Meteorites can be Irony or Stony, regarding the elements they contain. In ES formation there is no difference amongst them, the difference is, naturally, in the extent of irony ions they can provide.
Entering the atmosphere, meteorites are heathen up to 3000°F and if they are large enough can emit light. High temperature depend on a mechanism called dynamic pression, where the meteorite's body and Earth's air mutually compress each other causing an exchange of kynetic energy. Vaporisation of these fragments causes the ions scattering on the Ionosphere; flashes (fireballs) and thunders can be seen and heard from long range observers (as it happens in that clear, lovely and warm nights in summertime). Destruction of meteorites inside the atmosphere depends mainly on their composition and the degree they crash on it, and naturally it depends on the speed. Irony meteorites are more resistant than stony ones, and can burn 10-12 Km beneath, where atmosphere is fairly more dense.
The amount of material entering the atmosphere can reach easily many tons and the number of meteorites falling over the atmosphere can be about ten billions, mostly as heavy powder.

Variations on the Meteoric Flux

It has been calculated that about ten billions meteorites come in touch with the Earth, but they're usually so little, with a diameter of about $1.0x10^{-1}$ mm, and very fast (around 100.000 Km/h). Ablation occurs at the E layer region, where the possibility to collide with gas particles is higher because of the higher density of gas. This flux is not constant and depends on the part of the day, on the season and on the year. These variations can be show on the two graphs provided here, with daily and annual variations.
As ES events are mainly in summertime, this can be confirmed looking at the annual variation, where meteoric flux is higher between June and September, as they're the months statistically significant for ES openings. This direct link between Meteoric Flux and ES is not completely striking, but it is quite strong to be a good evidence.

A field experience: the 19th November 2003 opening

This report comes from IZ3ESV's observations. On 19th November 2003 an event raised MUFs (Maximum Usable Frequency) up to 144 MHz, indicating ES hyper-dense layer formation. The activity was on the early afternoon, in the 10 meters band. Signals were outstanding, coming from Northern Germany, Southern England and Belgium. Under a deeper inspection, the stations' QTHs were mainly on the same latitude. Working conditions of the worked stations were absolutely barefoot, all below 100W and antennas used were verticals or G5RV. At the same time, on the cluster was clear that there were consistent propagation paths between Germany and Italy on 50 MHz, and between United Kingdom and Germany on 144 MHz.

Something about Frequency, Solar Activity and Geomagnetic Activity

Opening reaching 144 MHz are rare: amongst all ES openings they are only a 5%. This means that prevision and forectasts are more and more difficult as the frequency is higher; on summer months openings on 28 MHz and 50 MHz are daily possible with a good probability, but quite different is the situation on 144 MHz. To reflect signals on 2 Meters it is necessary to have hyper-dense ionised curtains on the E layer, and as we've seen this is not so common. But if we consider meteoritic activity peaks, it is not so difficult to notice that on 19th November 2003 probably Leonids helped the opening which raised up MUFs up to the 144 MHz.
Daylight has, by the way, an important role; as openings occur mainly during daylight hours, solar activity should help ES events. But it is not so uncommon to have ES openings during night time, specially during winter months.
There is no statistical evidence that the eleven-year cycle should have something to share with ES events, although it seems that openings happen mainly during low activity, but this probably could be related to a more quiet geomagnetic set.
This enforces the evidence that meteoritic ablation is partly responsible of the ES openings, taking part on what are the complex mechanisms leading to layer formation.
On a long range analysis we have built a map relating ES openings and Geomagnetic activity. We concluded (as you can desume) that ES occurs at the 90% of the cases with a quiet geomagnetic field, with a Kp less than or equal to 3, and Ap index less than or equal to 17.

Jet Stream action

On ES clouds, an important role is led by the so called Jet Stream, a narrow and strong air stream on a horizontal axis, located on the upper troposphere and stratosphere. Its length is several thousands Km, it is large about 100 Km and its thickness is some Km. It is something like a wind river blowin' west-to-east, with a peculiar circumpolar path, with regions at lower speed and some othe with higher rates. During summertime the Jet Stream is at higher latitudes than winter with a relative speed which is slower. This could be related to ES localisation and distribution, with a significant statistical relation.

AGW and Ionosphere winds

AGW (Atmospheric Gravity Waves) should act with ionosphere winds to press together ions, leading to ES clouds, as we already have seen. AGW are waves with a typical neutral pression at a very long wave length (with a T period between 10 and 180 Minutes); they stay on the thermosphere and they're generated by the up-down movement of great air cells, oscillating thanks to convection and the effect of the gravity and thanks to several other events, as thunderstorms, surface winds, hurricanes and the Jet Stream itself. At higher latitudes they are localised on the upper atmosphere and are caused by Joule-effect heating, Lorentz forces and particle 'rains' depending on magnetic field of the Earth and Sun rays. Because of the different insulation on the two emispheres, these waves are deeply different depending on the season, and the effects are somehow seasonal.
E region is completely affected by this kind of waves; this is due to high compression specially during thunderstorms, where there are winds (in the upper troposphere) blowing at 300 Km/h.

ES and Sun Activity

ES layers formation and Sun Activity is not so striking, anyway. A long range analysis on 50 MHz about K index (geomagnetic activity) and related ES events, has clearly shown that is easier to have good conditions with lower activity (K is lower); when K index is higher, ES propagation and overall conditions were defeating.
Generally, a quiet magnetic situation is a good sign for DXers, as propagation should be good. This may be true also for ES.
Geomagnetic calm means that layers are more stable, absorption of radio waves is reduced and the probability for ES clouds to form is higher, as ions are not scattered and recombinate with a slower rate. Turbulence (no

matter what is its origin) is always deteriorating conditions to have reflecting clouds, at any layer (not only ES), at any frequency.
Relationship between ES and sunspots is not so clear; but on long range analysis approach is shown that with a lower number of spots, ES openings are more often. High number on sunspots is improving ionisation in F and Normal-E layers (as we should expect) but seems not affecting ES.

FORECAST MODEL

On what we have said up to now, considering Meteorites as a good way to produce ES events, analysing long range data on 50 and 144 MHz, we can try to forecast ES, although there so many variables that make everything harder (as it is in Natural World), in this way:

- **Geomagnetic Activity should be low, with Kp<3;**
- **Check meteorites streams; on maximum peaks probabilities are higher;**
- **Check day time, referring to the two tables (winter and summer) showing opening probabilities, considering local time;**
- **Consider the month, as there is different incidence;**
- **During summertime (June and July) probabilities are the highest;**
- **Check the frequency; the higher it is, the lower is the probability.**

Last discussion

This is not a fail-proof handbook on ES events; it is a first approach on forecasting something that, by definition, is hard to understand. But day by day professional science is collecting data which are suggesting a deep relation between meteorites and ES. It is known that AGW themselves are really important but they depend on the geographical location, as Earth surface is characterised by magnetic anomalies; this could explain, for example, why ES clouds seem to form over specific areas (specially here in Europe). These anomalies are so huge that only on the Italian area we can consider six of them, making each effort harder to investigators.
Anyway, what we can do is enjoying our beautiful activity, having fun on the air and trying to do a little scientific research; we cannot afford large investigations or field campaigns, but we can do a little. And, of course, little by little, step by step, knowledge is round the corner.

Bibliografia:

Articoli vari di Marino Miceli, i4sn
Lo strato E sporadico M.Martinucci, i2www
SKIYMET Meteor Radar Flux by Andoya Rocket Range-Norway
NOAA (National Atmospheric and Ocean Administration)
Articoli vari di Marino Miceli, I4SN
Lo strato E sporadico R.R. di M.Martinucci, in3www
School of Physics, University of New South Wales, Sydney-Australia "Tle Lunar tide in Sporadic E"
UKSMG Six news Archives
Mid Latitude Sporadic E - Michael Hawk
Newton - Lo spettacolo della Scienza
Dx Radius in Aurora and FAI radio propagation Volker Grassmann, DF5AI
Naval Research Laboratory Washington, DC
Earth's Ionosphere-Tor Hagfors, Kristian Schlegel - Max Planck Institute of Aeronomy, Katlenburg-Lindau, Germany
Atmospheric Gravity waves - Prof. Michael P. Hickey, Dipartiment of Physics and Astronomy-Clemson University, South Carolina
www.vhfdx.de
Department of Physics and Astronomy - University of Western Ontario - A Short Primer on Gravity waves
Geophysical Institute, University of Alaska
What are sprites? Jeremy Thomas
Matt Heavner, Red sprites and Blue jets
IMO International Meteor Organization
SAURA MF Radar
I grafici sono stati elaborati e realizzati da: Propagation Observatory