WORLD of VHF

Ready for VHF & UHF DXing?

by **Jim Bacon, G3YLA***

HAVE YOU NOTICED how there are those amateurs who always seem to be around when the bands start to buzz? You may be one of them, but if you're not, read on!

There are a bewildering variety of propagation modes, and all seem to come with their own collection of folklore and operator wisdom. There are three popular methods of working DX on VHF and UHF. These are via Tropospheric Propagation (Tropo) and Sporadic E layer ionization (Es), which occur at very different altitudes, and through totally different causes (see **Fig 1**), and Aurora (Au).

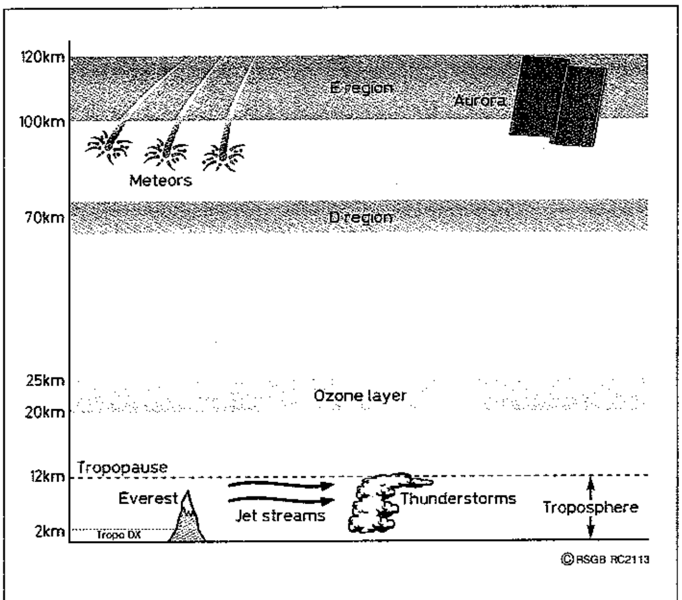

Fig 1: Troposphere up to the E region, showing weather and propagation regions/layers.

TROPO

THE TROPOSPHERE is the part of the atmosphere where you will find our weather. It extends from the surface to about 12km altitude and most major Tropo openings occur because of special conditions in the lowest 2km.

REFRACTIVE INDEX

You may well ask how the weather can make a radio wave change its direction. If so, put a pencil in a beaker of water. The pencil appears to bend because of changes in the refractive index from the air to the water. In this extreme case it is a ray of light being refracted, but it is still electromagnetic radiation, just like 2m.

Tropo is slightly different, but again depends upon changes in the refractive index. The vertical changes in temperature, and especially moisture, are the most important parameters to measure.

For the refractive index to change in the correct sense, we need cool, moist air underlying warm, dry air. The easiest way to visualise this is to picture a cold fog in the valley with warm sunshine on the hills above (see **Fig 2**). Remember; it is the change of moisture across the fog or cloud top that makes the biggest impact upon the refractive index.

If the change of refractive index is large enough, the radio wave is bent back towards the earth and may become trapped in a duct where signal losses are very low. A duct may exist at the surface or at higher levels and stretch along the whole length of a major High, giving ranges in excess of 1500km.

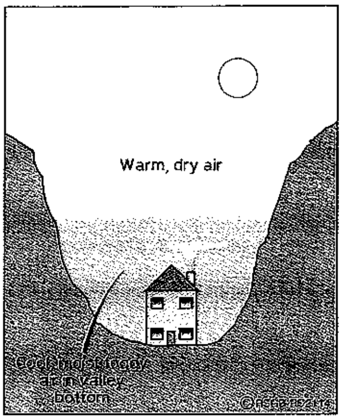

Fig 2: Fog in the valley and sunshine on the hills leads to a temperature inversion.

TEMPERATURE INVERSIONS

Now, if we are to capitalise on these free 'air miles' of propagation distance, we need to understand some basic meteorology. Air temperature usually decreases with height, because air is a good insulator and the temperature soon falls off as you move away from the heat source, ie the ground (see **Fig 3a**).

Highs are frequently associated with gently sinking air, and one effect of this sinking motion is to dry and warm the air. This warm, dry air eventually finds itself directly above the undisturbed surface air that is quite often cool, moist and foggy. The change of temperature across this boundary is called a temperature inversion, because it reverses (inverts) the usual decrease of temperature with height (see **Fig 3b**).

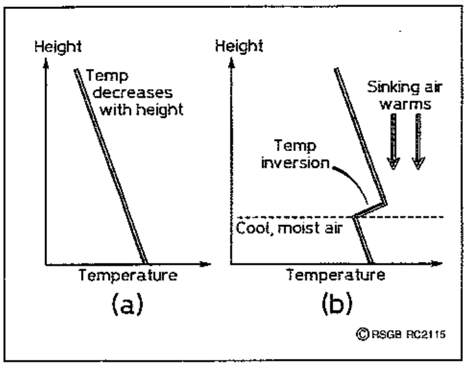

Fig 3(a): Normal temperature lapse-rate, and (b): how the lapse-rate during a termperature inversion.

In the world of meteorology, balloons carrying meteorological instruments called radiosondes are launched to measure the detailed temperature and humidity structure of the atmosphere. The data not only confirms whether an inversion is present, but allows the calculation of the refractive index itself. The plotted data usually contains two temperature lines, as shown in **Fig 4**. One shows the measured air temperature and the other a dew point temperature, but don't worry too much about this new temperature; it is a way of showing the moisture in the air. If the two lines are close together, the air is moist and fog or cloud is likely. When these lines are widely spaced, the air is very dry. So understand just these two things - refractive index and inversions - and you'll soon be amongst the DX.

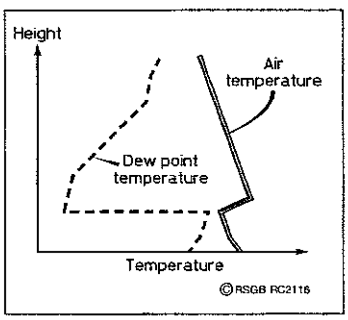

Fig 4: A Tephigram.

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TROPO FROM THE SHACK - TOP 20 TIPS

1. Use the weather chart and barometer to locate the High (see **Fig 5**).
2. Use forecast charts to predict how the High will move.
3. Note the central pressure of the High. Is it building or declining?
4. If the High is declining, hurry up with the DX.
5. If the High is building, expect conditions to improve.
6. The inversion is strongest in light winds (isobars widely spaced).
7. In the centre of the High, inversion may be so low that the signals are ducted into the ground. Check radiosonde data from the web.
8. For maximum range, point your beam around the edge of the High.
9. Large Highs are slow moving, so the lift may last some time.
10. Check reports for sunny skies and no fog - no surface moisture under inversion.
11. When the High moves away eastwards (falling pressure) the air below the inversion will have extra moisture, as surface winds begin to blow from the Atlantic or Biscay.
12. Small Highs between Lows move as quickly as the Lows themselves. They rarely have time to develop lift conditions.
13. Lift conditions often improve overnight, as a strong surface inversion develops when the ground cools.
14. Conditions may deteriorate again when this low-level inversion is broken down by the sun's warmth the following day. This often applies to DX paths over the continent, particularly in the summer.
15. Be wary of taking your rig to the nearest hilltop during a lift. If you are above the haze, fog or cloud layer, you will be above the inversion and out of the lift.
16. Sea paths are often very productive during the summer, having cool moist air near the sea surface, overlain by warm dry air from the surrounding land.
17. Sea breezes occur when cool sea air moves inland during the day, when the land is strongly heated by the sun. This can act like a moving duct that couples the inland stations into the sea paths from 16 above. This can be particularly useful to stations in the valleys of South Wales, who suddenly find their high sided valley sites are getting a prime path down to the coast and across to Spain.
18. There is one type of lift when winds are stronger, these occur when warm air blows across a snow surface. At the end of a cold snap it becomes misty as the warm air arrives and there are often sunny skies above this layer of stratus cloud.
19. Highs tend to be stronger during the autumn, winter and spring, with better inversions.
20. The change of refractive index across an inversion is more effective at higher frequencies, hence, UHF and SHF will produce a lift when VHF might not. Check the higher frequencies first.

SPORADIC E

SPORADIC E layer ionization is one of the most fascinating modes of DXing available to the amateur, but for many this is purely by chance. Research scientists and amateurs alike are still seeking a complete understanding of Sporadic E.

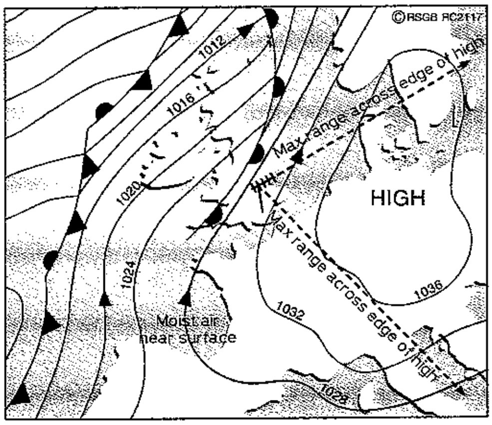

Fig 5: A tropospheric weather map, showing the preferred paths for DXing.

What follows is a guide that should enable you to spend more time DXing and still get the grass cut this summer.

It gets better; Es propagation does not require expensive stations with large arrays and big linears.

CHARACTERISTICS

Firstly, the 'season' for Es seems to be mainly concentrated in the summer months and runs from May to August, as shown in **Fig 6a**. It occurs at preferred times of the day, as shown in **Fig 6b**. The daily plot shows a rather strange double-peaked shape to the distribution of reports. An example of Es observed by the EISCAT UHF radar in Scandinavia shows some remarkable wave-like fluctuations in intensity of the Sporadic E layer, as shown in **Fig 7**.

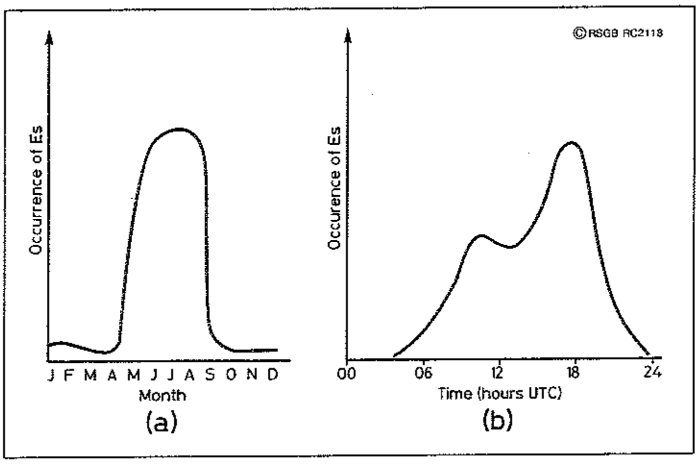

Fig 6(a): A graph of Es by season, and (b): time of day.

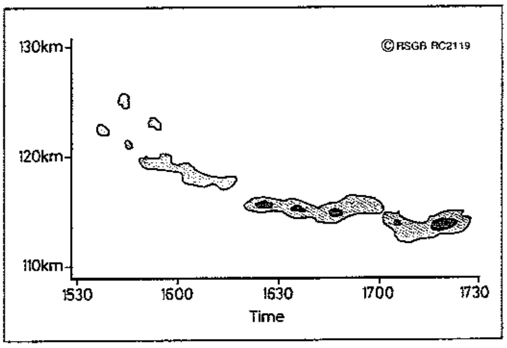

Fig 7: EISCAT Es plot, showing how ther height of the reflection reduces as time progresses.

WEATHER

Some researchers have proposed links between Es and weather features. This is quite a challenge to explain, because most Es are to be found at an altitude of 100km-120km, whereas any weather trigger is, of course, at least 100km lower in the troposphere - below 12km.

Thunderstorms are the most frequently mentioned candidate, and go all the way back to that first paper in the 1930s. However, if thunderstorms are a weather trigger they are not alone, since there have been Sporadic E openings with no evidence of thunderstorms.

Jet streams - currents of fast moving air in the upper part of the troposphere around 12km altitude - are another major player in the weather list. Jet streams are associated with weather fronts (see **Fig 8**), and contain wind speeds in excess of 60m per second.

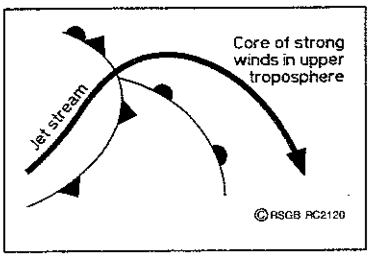

Fig 8: Path of jet stream in relation to frontal systems.

There is a possibility that Clear Air Turbulence (CAT) associated with upper ridge patterns on high altitude weather charts may also have some role to play.

WIND-SHEAR THEORY

The causes of enhanced E layer ionization have been discussed and debated since at least 1933. The generally accepted mechanism for mid-latitude Es was developed by Professor Whitehead around 1960 and is known as the Wind-Shear Theory for Sporadic E.

In essence, this utilises the fact that a charged particle moved by the wind through a magnetic field will be deflected.

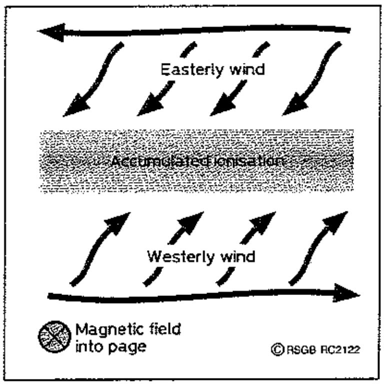

Fig 9: Wind-shear results in accumulated ionisation.

Furthermore, given that the wind often blows from different directions at different heights, the deflected ionization may, in certain conditions, converge into a narrow layer. The ideal case would be a layer of easterly winds above a layer of westerly winds, as shown in **Fig 9**.

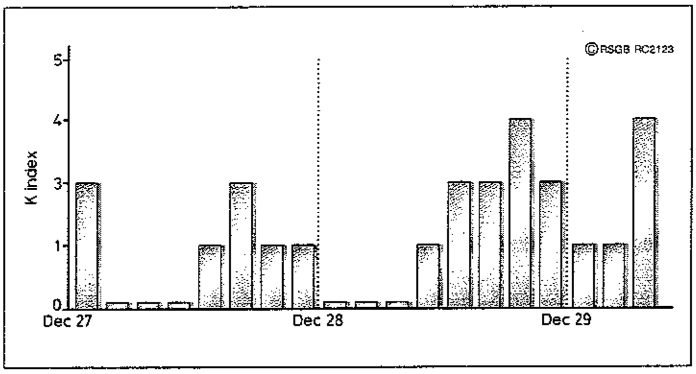

Fig 10: Variation of three-hourly K index.

MAGNETIC FIELD

The K index, which ranges from 0 to 9, is a measure of the disturbance of the earth's magnetic field (see **Fig 10**). When the earth's magnetic field is continuously changing, ie during a geomagnetic storm, the random and varying deflections mean less chance of developing an Es layer by wind shear. Indeed, Sporadic E is rarely observed when the K index is greater than 3.

METEORS

The date of meteor showers is widely believed to influence the occurrence of Es. There are many meteor showers through the year; some coincide with spectacular VHF openings, but not every year. The ions being deflected by the wind shear are, from the result of rocket measurements, believed to be mainly metallic ions like iron, magnesium and silica. The ablation of meteors, as they burn up when entering the upper atmosphere, is a possible candidate for this metallic ionization. These metallic ions have a long lifetime of around 10 days before recombining.

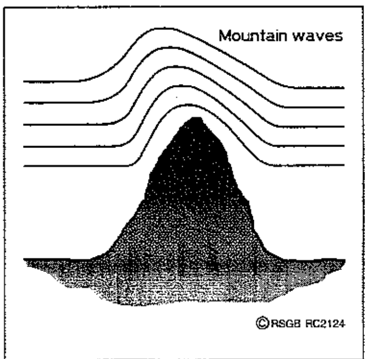

Fig 11: Waves caused by air flowing over a mountain.

WINDS, WAVES AND TIDES

Firstly, we must establish a connection between the weather and the E region, and that link is; Atmospheric Gravity Waves (AGWs). They are called gravity waves because gravity is the restoring force acting upon the initial displacement, like waves on the sea. For Es we need to think of the way airflow is disturbed when it blows over a range of mountains, generating mountain waves. This is illustrated in **Fig 11**. In fact, AGWs generated by mountains can interact with a jet stream flowing above them. This may then cause stronger AGWs to propagate up to the E region and interact with the background winds above 100km. Turbulence in the region of a jet stream can also produce AGWs without being anywhere near a mountain.

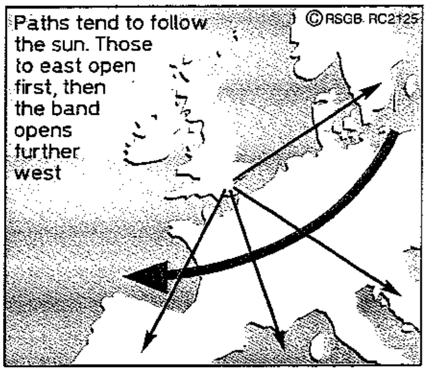

Fig 12: Map showing how Es openings tend to move across Europe.

It may well be even more complex, since the double peak of the Es curve during the day also suggests some form of tidal influence. The winds at Es altitudes also vary through the day and, just as the variation of sea height through the day is known as a tide, this daily or even twice daily variation of wind can also be called a tide. Once the AGWs have reached the E region, they have the effect of modulating the background tidal winds to produce a variation, or shear, as required for the wind-shear theory to operate.

Es FROM THE SHACK - TOP 20 TIPS

1. Main season May to August, contains many 'blank' days.
2. Check 10m beacon band or short skip on 20m.
3. HF before VHF. As each higher frequency band opens, check the next one up.
4. QSOs are often brief, but openings may last hours.
5. Check the VHF net on 14.345MHz (20m) or DX cluster if available.
6. It's safe to go and cut the grass if the K index is greater than 3.
7. Meteor showers may help; early June is very popular, but not guaranteed!
8. Double diurnal peak in activity, approx. 10-12UTC and 16-18UTC (stronger).
9. Success rate improves dramatically if you check the bands at teatime.
10. Spacing of diurnal peaks, typically 5.5 - 6 hours.
11. Daily peaks vary, early am peak can mean early pm peak.
12. Just under 50% of days with Es on 6m also produces Es on 2m.
13. Es openings to given region tend to repeat after about 40 minutes or so.
14. Later QSOs tend to be shorter range (about 15% less) due to descending Es layer.
15. Es openings tend to follow the sun, so paths to Scandinavia etc open first, followed by the Balkans etc., then through the Med. to Iberia (see **Fig 12**).
16. 6m transatlantic paths are open during the evening.
17. Afternoon opening may be in slightly different direction to morning opening because the trigger (jet stream) may have moved (see **Fig 13**).
18. If possible, seek out occasions when jet streams are blowing across mountain ranges.
19. Es seems to depend on many factors. The presence of one is not sufficient for Es to be reported. Equally, a check of one feature will not reveal a true picture of its role in the generation of Es.
20. Keep accurate logs and contribute to propagation research by sending your data to the RSGB Propagation Studies Committee (PSC) or myself.

Fig 14). The magnetotail is like a slipstream of particles from the solar wind which streams away downwind from the earth. During major disturbances, the forces upon the tail are so great that it breaks and part of it catapults back along the field lines towards the polar auroral ovals. These particles somehow acquire enough energy to reach the denser lower parts of the ionosphere in the E region and produce the aurora.

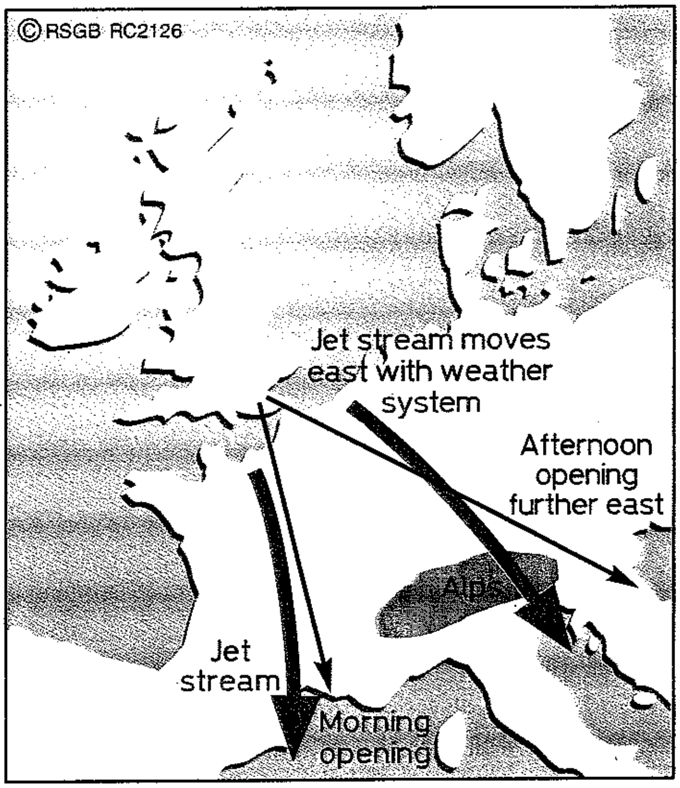

Fig 13: Movement of weather trigger.

CO-ORDINATION

IARU Region 1 maintains a database of Es contacts in an effort to shed light on the many mysteries of this mode of propagation. If you want to help advance our knowledge of Es then please send your logs to me directly or via the RSGB PSC [see RSGB Yearbook]. Data is welcome in any format, but especially if compatible with Microsoft Office software.

AURORA

THIS IS AN equally illusive mode of propagation, but also benefits greatly from a little knowledge of how it works.

SOLAR WIND

The solar wind carries a stream of atomic particles from the sun towards the earth. The solar wind is always blowing, but sometimes has the equivalent of gusts when the output is greater. There are many interesting features on the sun's surface that produce the material that make these gusts in the solar wind. Features like flares, coronal holes and sunspots appear to move across the sun's surface as it rotates. Therefore a period of high activity may be repeated the next time around, approximately 27 days later.

A TWIST IN THE TAIL

Everything that heads our way in the gusty solar wind does not just fall in around the poles to gives auroras. It seems an extra ingredient is required, and that is the disruption of the earth's magnetotail (see Fig 14).

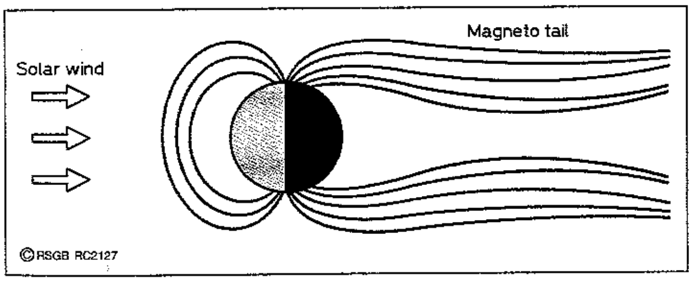

Fig 14: Magnetotail of the earth's magnetic field.

AURORAL OVAL

The auroral oval is the ring around the magnetic pole where charged particles from the solar wind eventually reach the ionosphere. As they spiral down the field lines they excite the atoms of oxygen and nitrogen to give off the blue, green and red glow of the aurora. The visible part of the aurora can extend from about 400km down to 100km. The useful bit for radio propagation tends to be at the lower limit, in the E region around 100km, where the ionization density is greatest. The oval extends further away from the pole as the disturbance gets stronger. A very high K index may allow the aurora to be visible from southern Britain, but this is extremely rare. Because of the strange geometry of auroras there are two periods of activity when the auroral oval is at its more southerly position. These are roughly around 1800UTC and midnight. There also seems to be a seasonal preference for autumn and spring.

AURORA ON VHF

Firstly, not all radio auroras are visible auroras, and even some visible auroras may not be close enough for radio contacts. The strange burbling quality of the back-scattered signal is because the auroral curtain is a region of fast moving particles that impart their own random doppler shift on the signal. Speech becomes husky, sounding like ghostly whispers and, as a result, the use of CW is common.

The best DX direction to beam from Britain is towards the east-northeast, but other directions through to west-northwest can be used if there were anyone there to work. The longest paths, in the range 1500km to 2000km, tend to be more east-west than north-south.

Aurora tends to have weaker signals than the other modes discussed so far, so big stations are the order of the day (or evening). Weaker events are usually only accessible by the nearby Scottish stations and are called Scottish type auroras.

AURORA FROM THE SHACK - TOP 10 TIPS

1. Keep a 27-day solar calendar for possible disturbances.
2. Check the K index on the web or packet.
3. Monitor the northern VHF beacons for auroral tone.
4. Use the DX clusters.
5. Sometimes even HF/LF signals have a warble or flutter.
6. Monitor the VHF net on 20m.
7. Don't saturate the calling frequency during a big aurora - spread out.
8. Check the band at teatime when you get in from work.
9. Make a final check towards midnight.
10. Be especially vigilant around the equinoxes, both spring and autumn.

FURTHER READING

1. *RadCom* May-Aug 1989. An introduction to Sporadic-E, by Jim Bacon, G3YLA.
2. *Journal of Atmospheric & Terrestrial Physics*, Vol.51 No.5 pp401-424 1989, Vol.60 No.4 pp413-435 1998.
3. *VHF Handbook*, Ch.2, Ray Flavell, G3LTP.
4. *The VHF/UHF DX Book*, Ch.2, Geoff Grayer, G3NAQ.
5. *DUBUS* band reports. ♦