‘Sprinkles or Mirrors’?

Exploring the true nature of VHF propagation via sporadic-E

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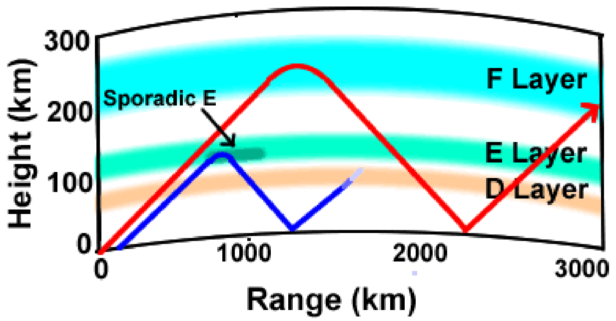
What is the mechanism for 50 MHz propagation via sporadic-E (Es)?

Scatter?

Specular?

Magneto-ionic?



The polarization state of the reflected wave is a key indicator of the propagation mechanism

Image sources:
Wikipedia (CC BY-SA 4.0)
US Navy Postgraduate School met.nps.edu

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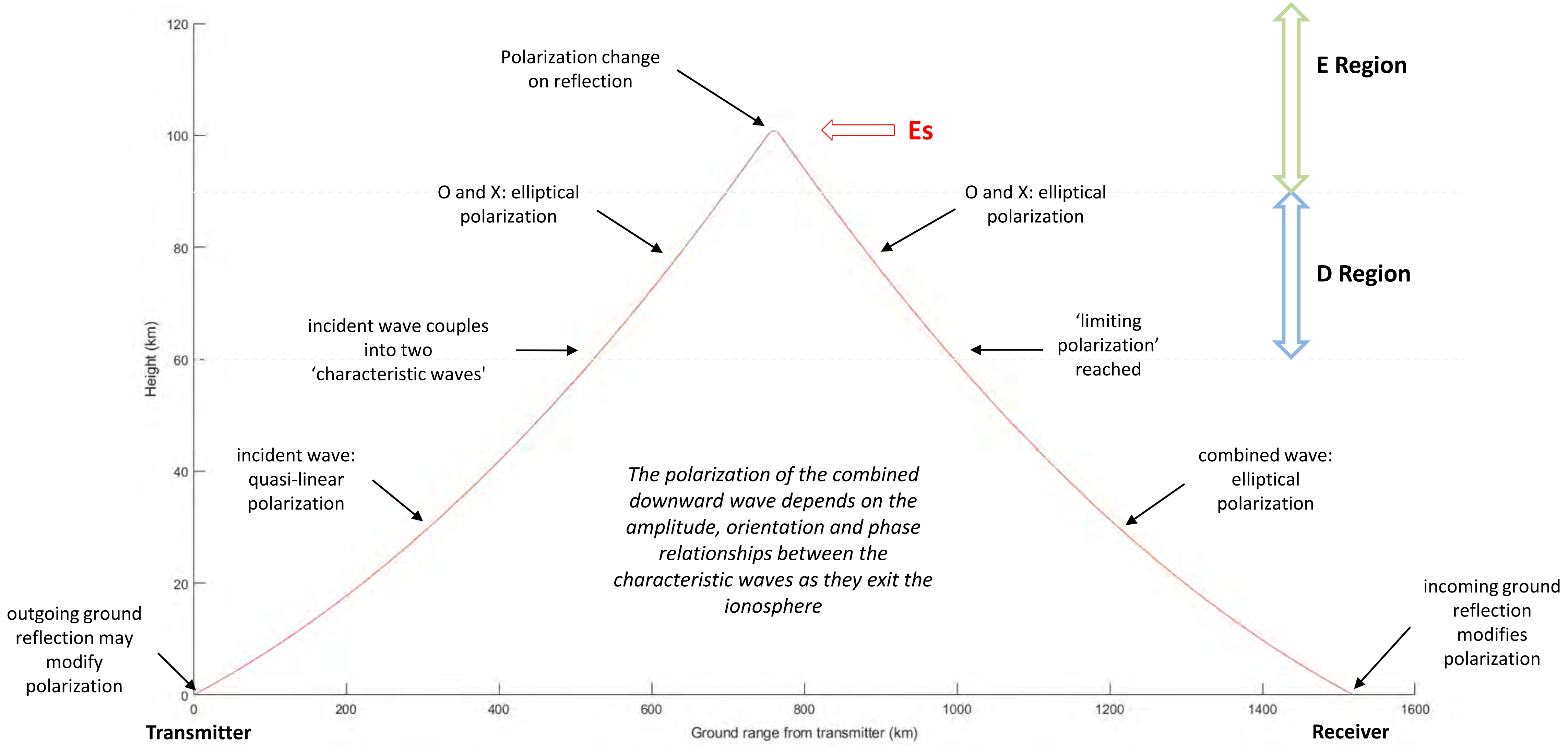
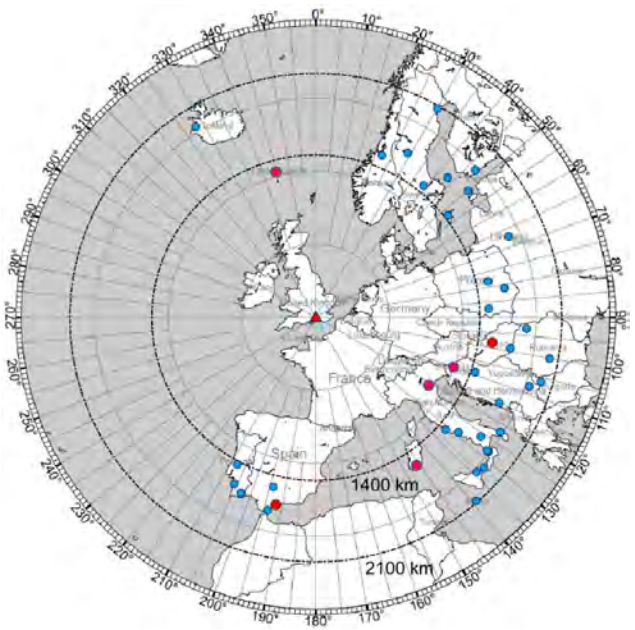
Polarization changes over a typical midlatitude 50 MHz path

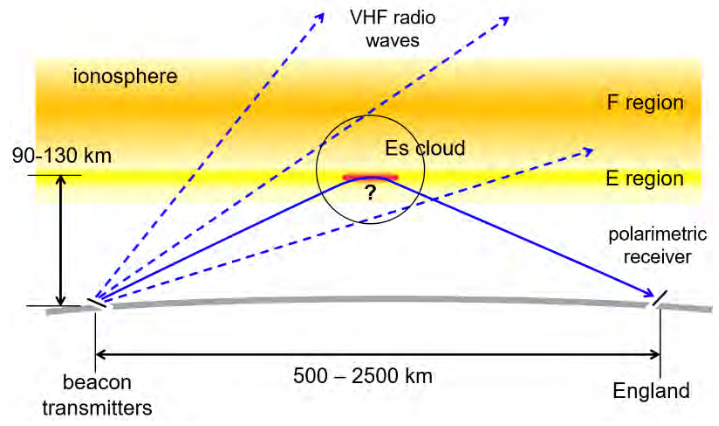


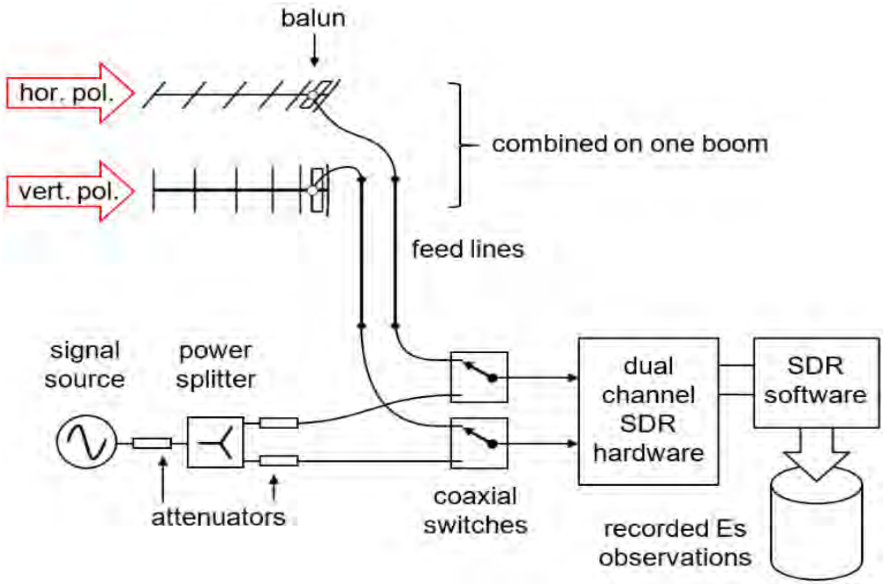
Polarization measurement using 50 MHz amateur beacon signals

C. J. Deacon, B. A. Witvliet, S. N. Steendam and C. N. Mitchell, "Rapid and Accurate Measurement of Polarization and Fading of Weak VHF Signals Obliquely Reflected from Sporadic-E Layers," IEEE Transactions on Antennas and Propagation (in press) doi: 10.1109/TAP.2020.3044654



Measurement campaign May – August 2018
Six target beacons (red on map)
48 recordings over ten different dates





Antenna: Seven-element LFA X-POL @ 18 m above ground
Receiver: OpenHPSDR Apache ANAN-8000DLE

1: Select useful time segments from recorded data

↓

2: Identify beacon, calibration signal and noise frequencies

↓

3: Separate beacon, calibration signal and noise data

↓

4: Measure calibration values for differential power, differential phase and absolute power

↓

5: Apply calibration values to selected data

↓

6: Remove keying profile and noisy samples

↓

7: Determine differential amplitude and phase and calculate polarization ellipse parameters per sample

Filtering, calibration and post-processing.

Filter bandwidth: 25 Hz
Sample rate: 6 kHz or 24 kHz

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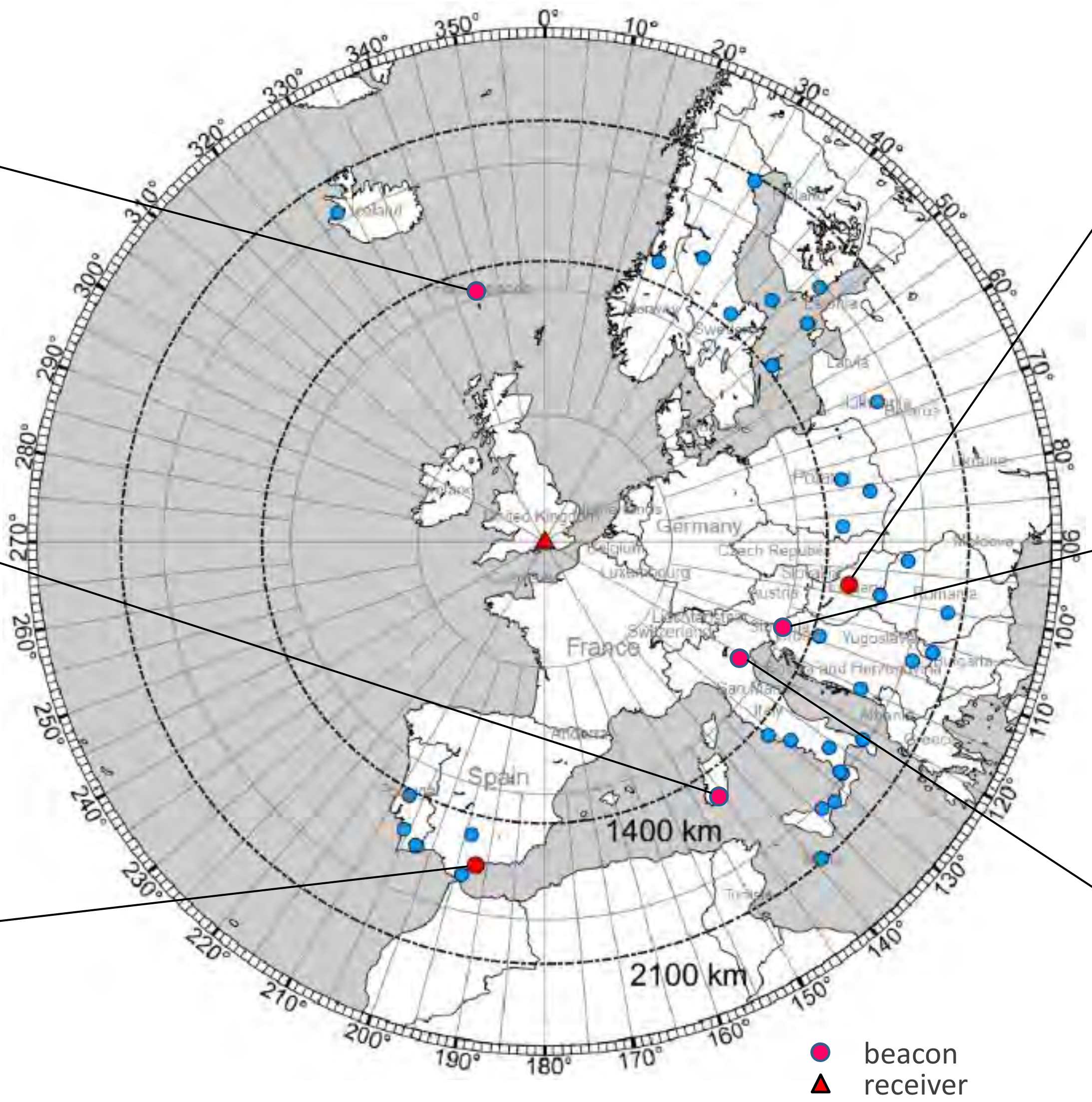
Results: signals from all six beacons were consistently elliptically polarized

Faroe Islands
Received polarization: mainly **LH** elliptical
Ellipse tilt angle: variable
Transmitted polarization: horizontal
Number of dates: 1

Sardinia
Received polarization: mainly **RH** elliptical
Ellipse tilt angle: variable
Transmitted polarization: vertical
Number of dates: 1

Spain
Received polarization: mainly **RH** elliptical
Ellipse tilt angle: variable
Transmitted polarization: horizontal
Number of dates: 2



Hungary
Received polarization: strongly **RH** elliptical
Ellipse tilt angle: + 45°
Transmitted polarization: vertical
Number of dates: 6

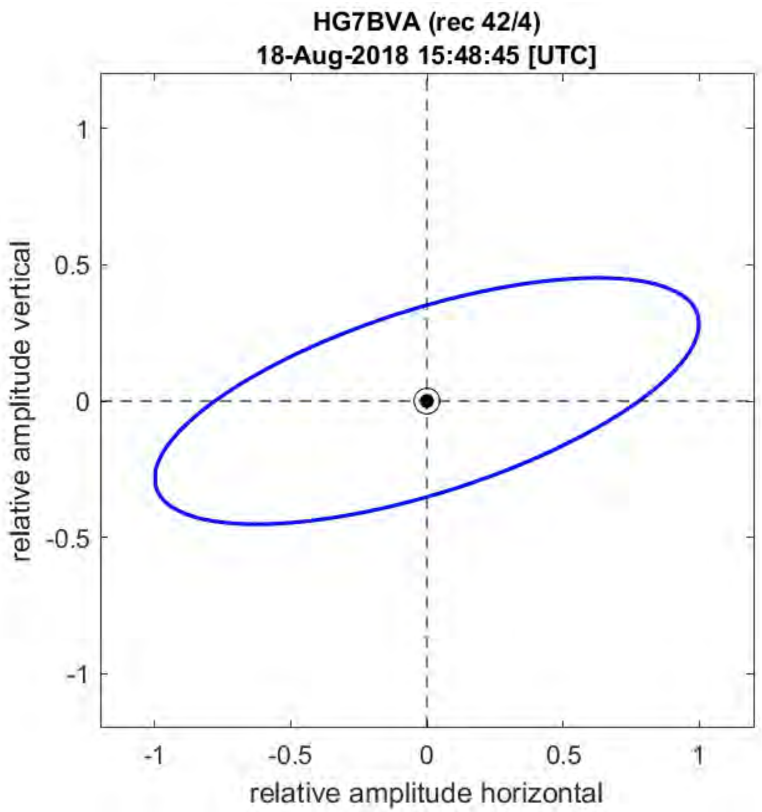
Slovenia
Received polarization: strongly **LH** elliptical
Ellipse tilt angle: - 45°
Transmitted polarization: vertical
Number of dates: 4

Italy
Received polarization: mainly **LH** elliptical
Ellipse tilt angle: variable
Transmitted polarization: vertical
Number of dates: 1

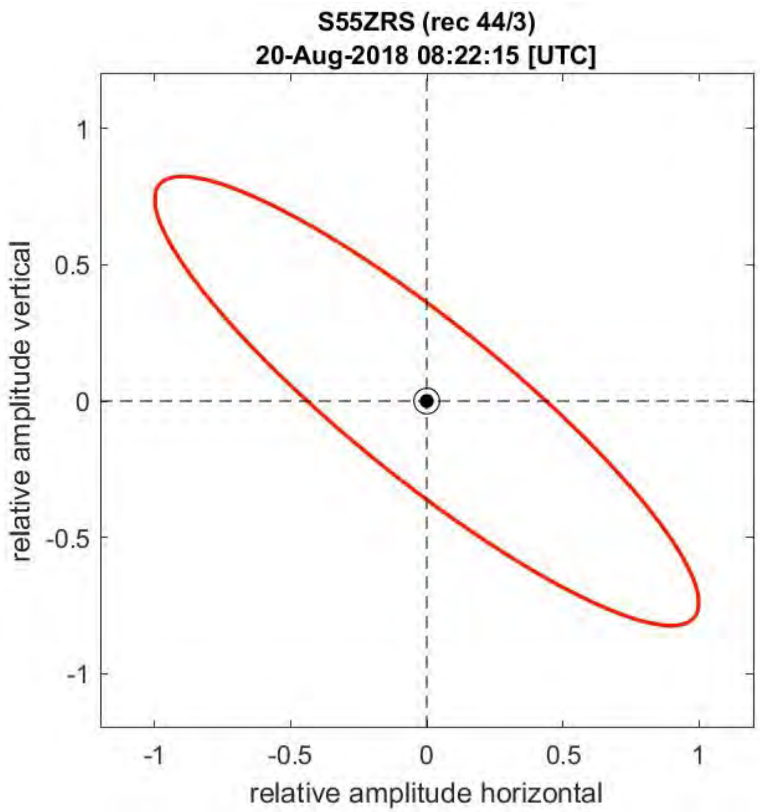
Background map courtesy Tom Epperly NS6T, http://ns6t.net/azimuth/

Examples: real-time polarization ellipses based on live data

Hungary: 18 August 2018

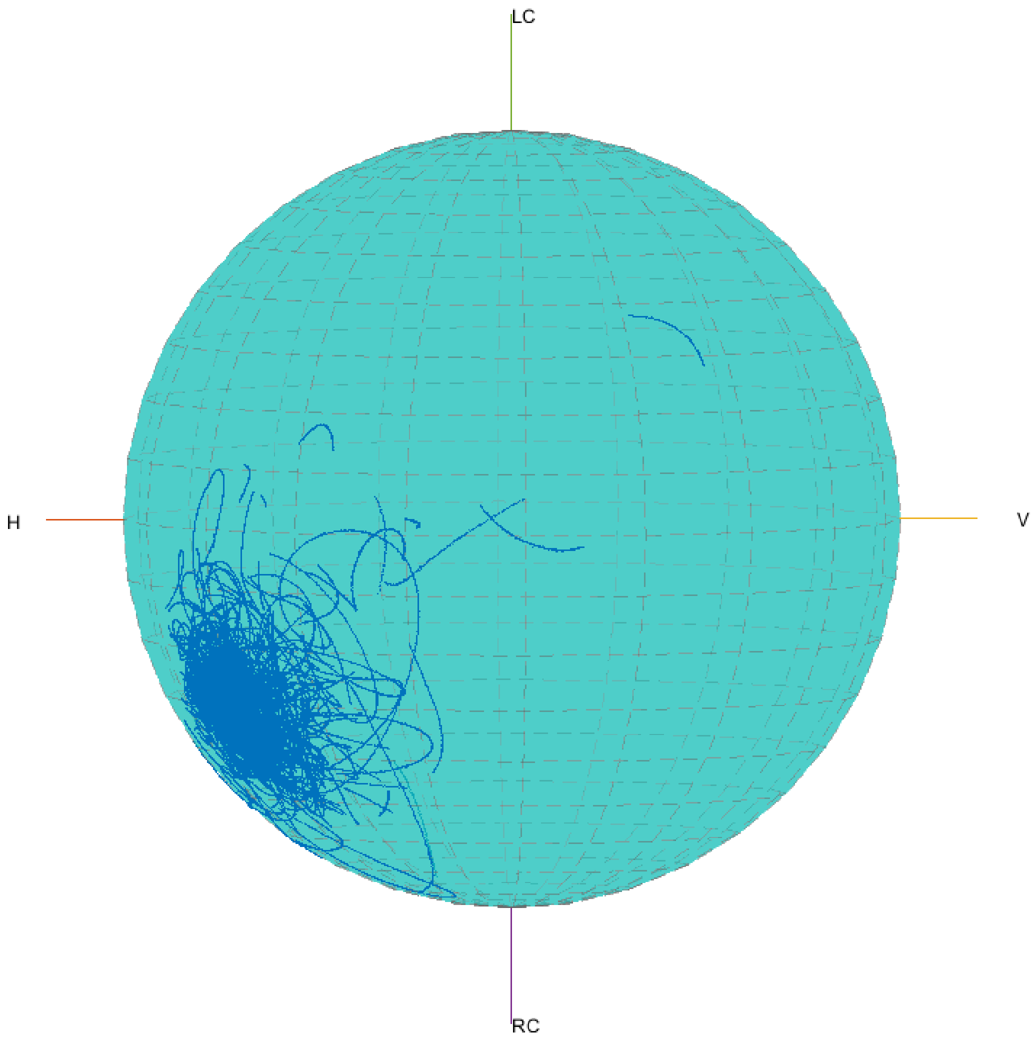


Slovenia: 20 August 2018



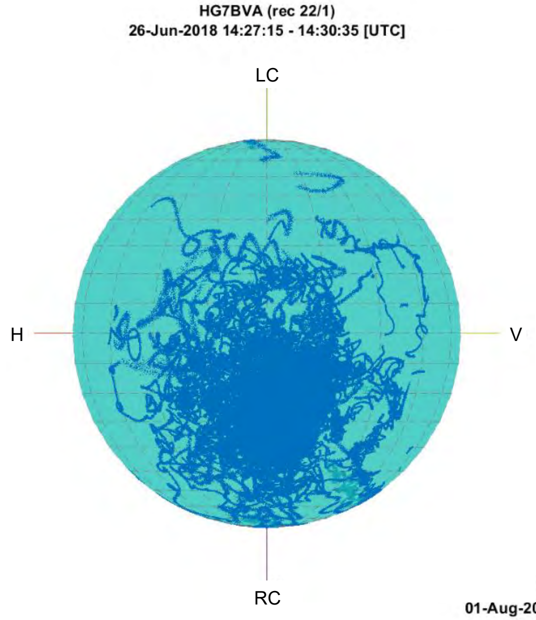
Blue = Right Hand circular polarization
Red = Left Hand circular polarization

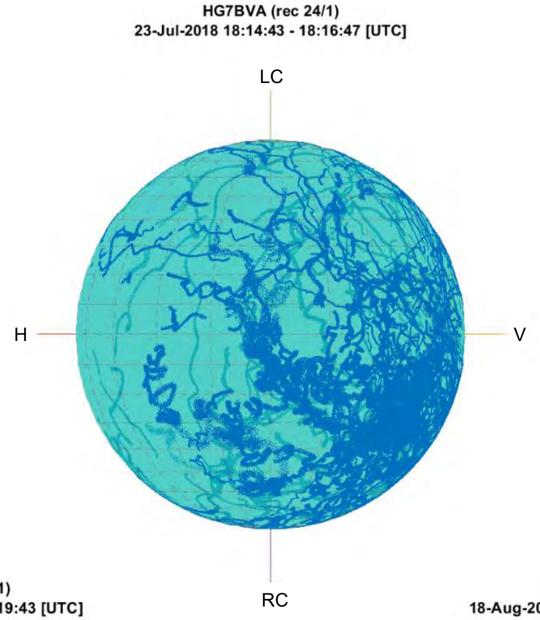
Introducing the Poincaré Sphere

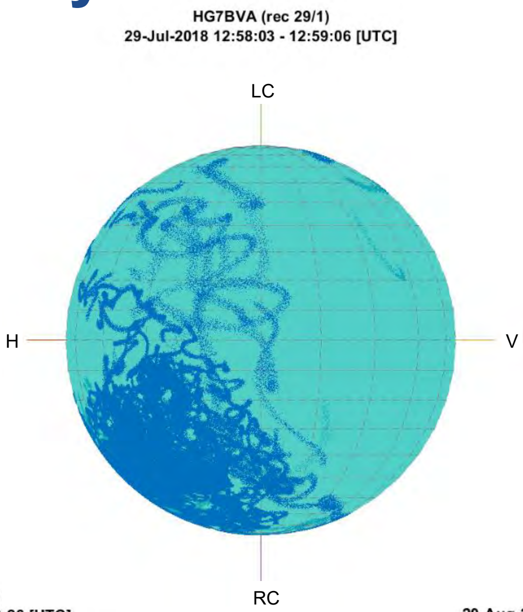


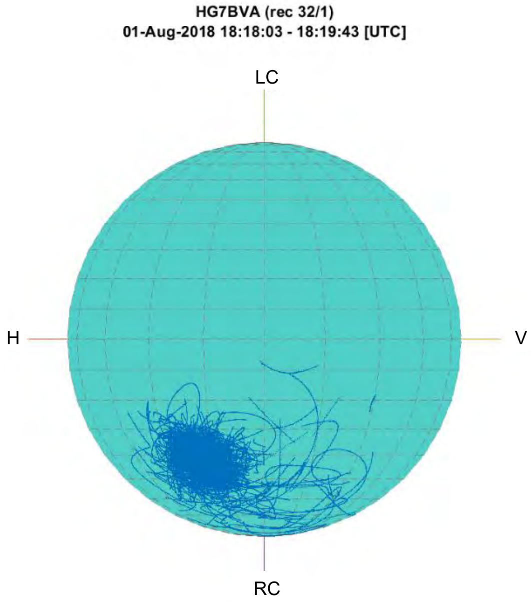
Poincaré Sphere – Hungary on six different days

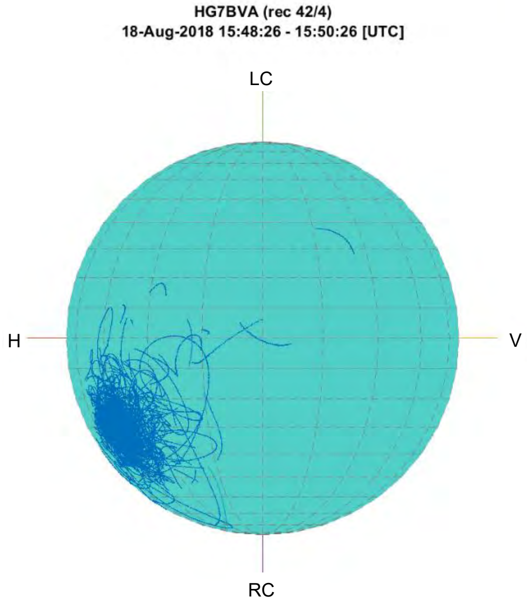
In each case there seems to be a 'home' polarization state, plus periodic disturbances

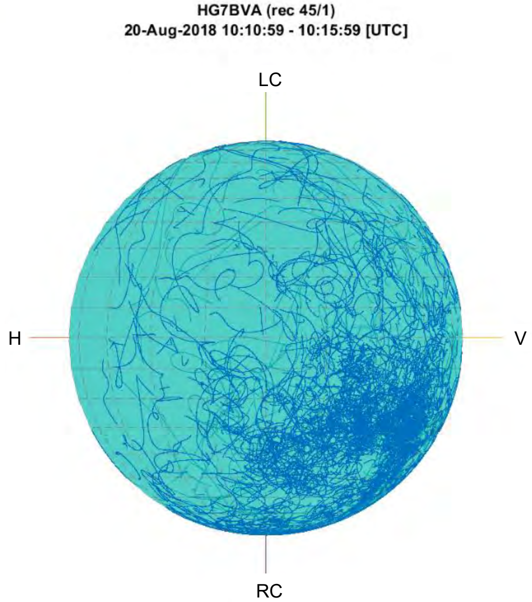






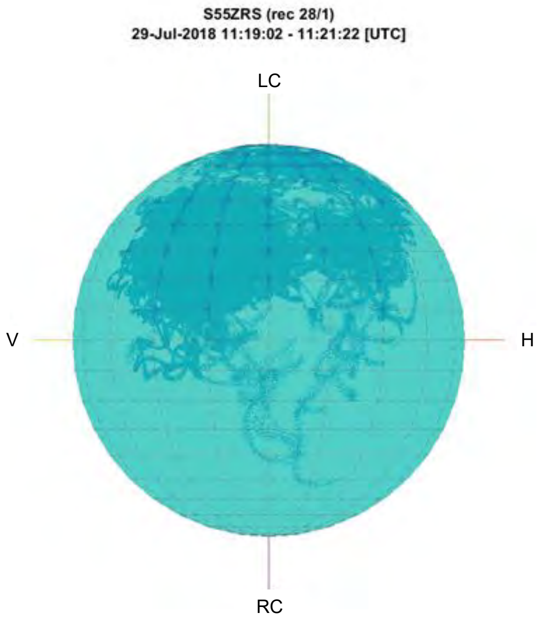


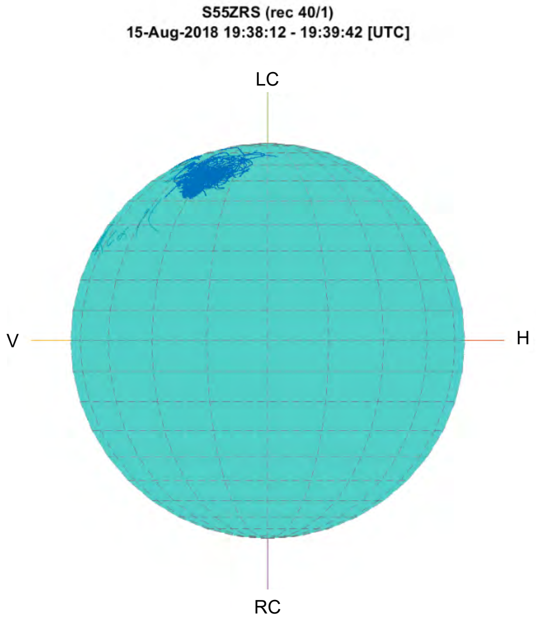


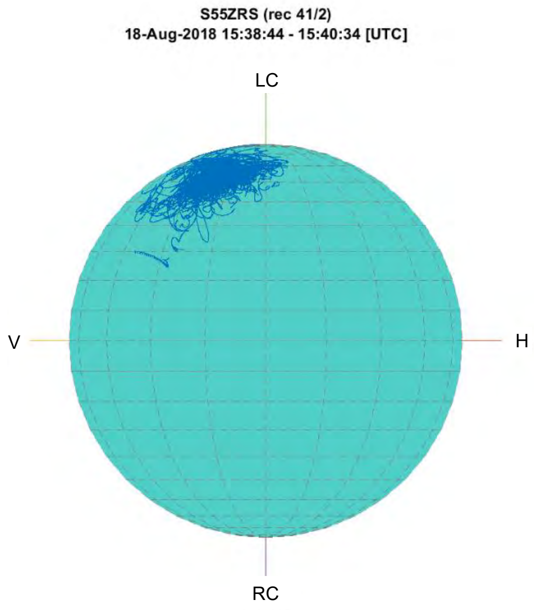


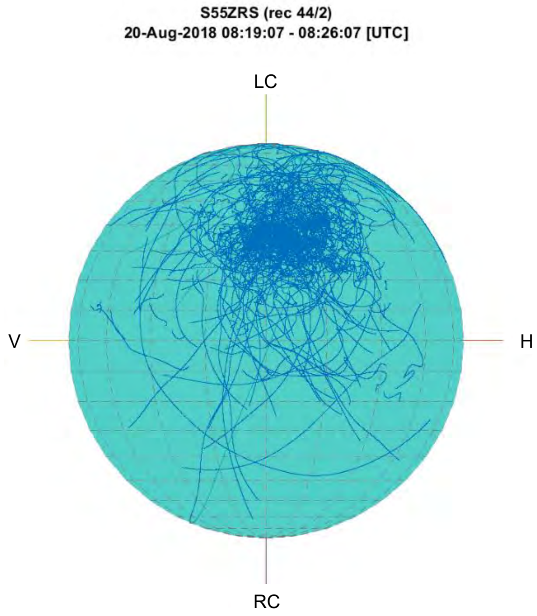
Poincaré Sphere – Slovenia on four different days

As before, there seems to be a 'home' polarization state, plus periodic disturbances



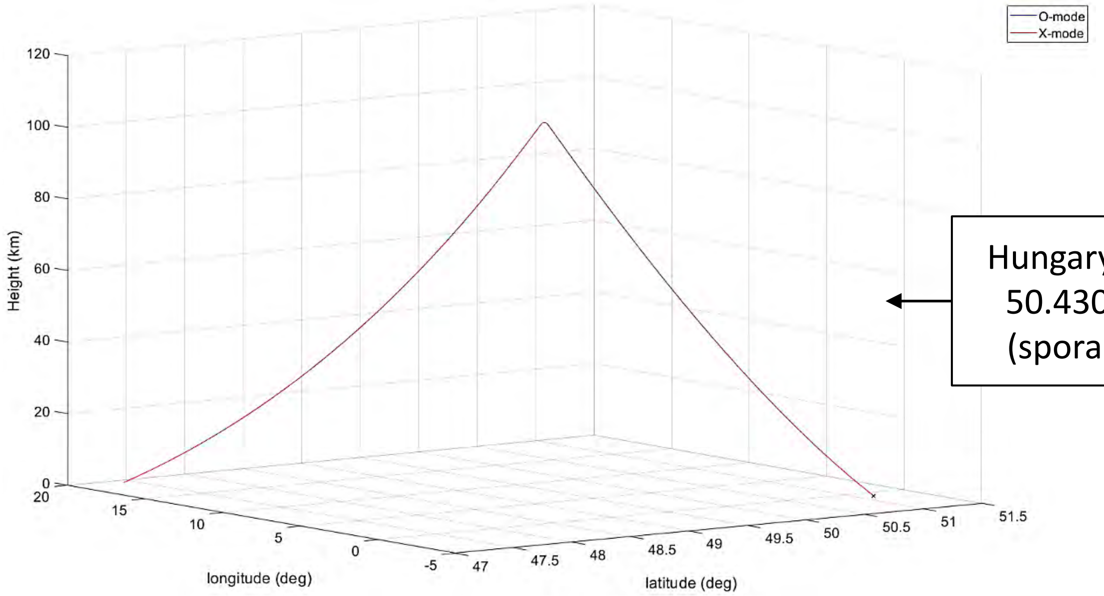




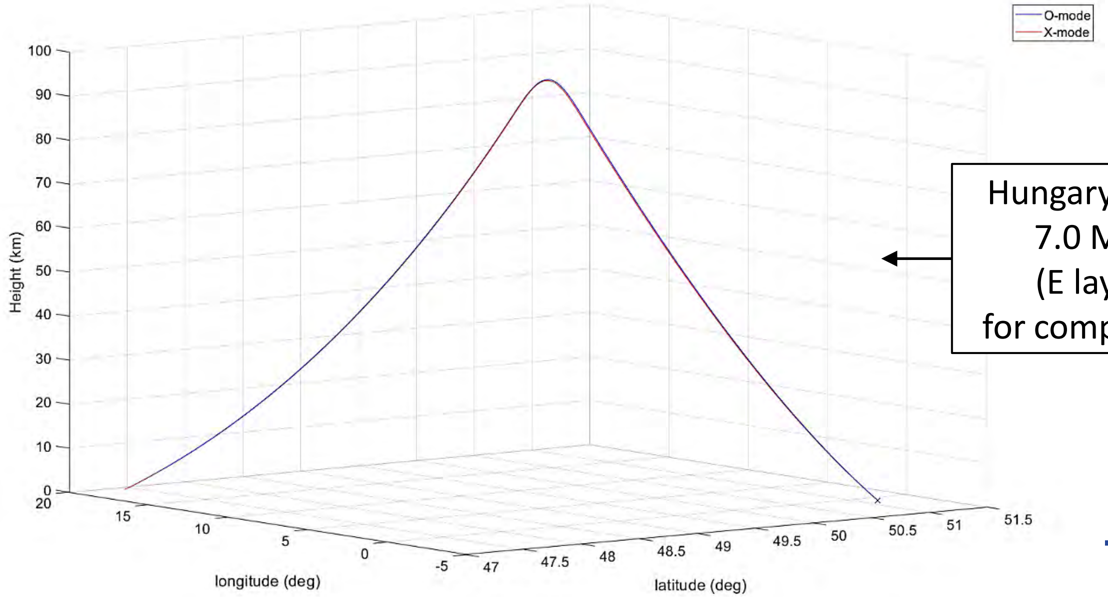


NB spheres rotated so display is 'front to back' v/s Hungary

3-D raytrace modelling (PHaRLAP): numerical solution of Appleton equation

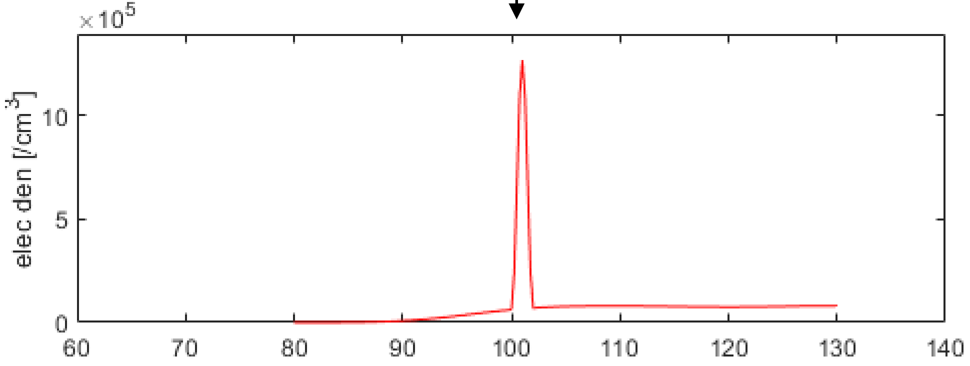


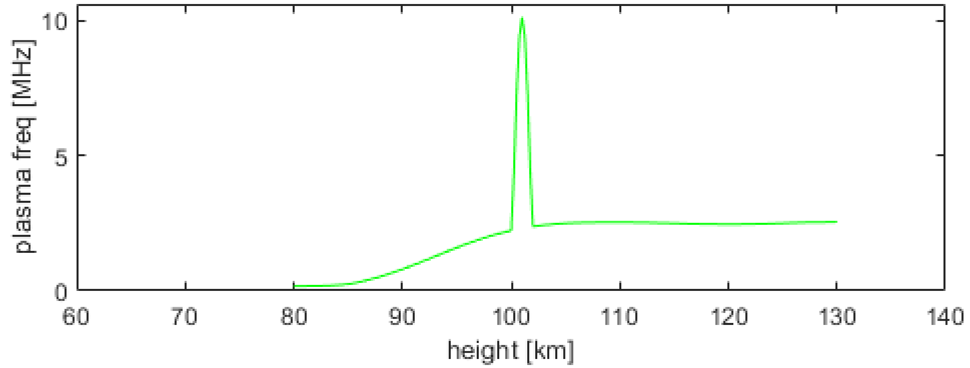
Hungary to UK
50.430 MHz
(sporadic-E)



Hungary to UK
7.0 MHz
(E layer)
for comparison

Raised-cosine simulation of
Es layer, 2 km thickness assumed
in this presentation





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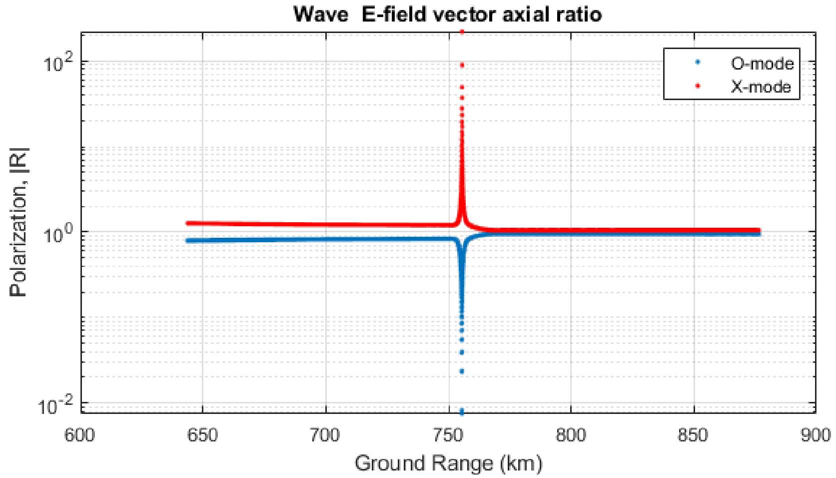
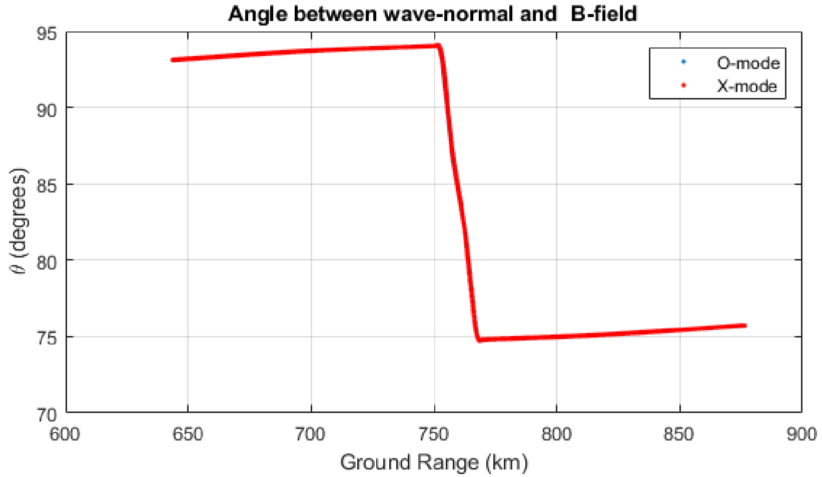
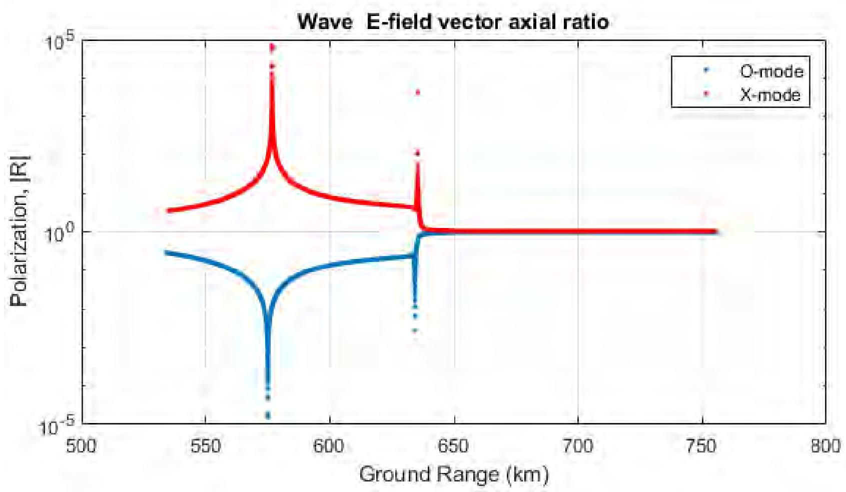
3-D raytrace modelling (PHaRLAP): polarization

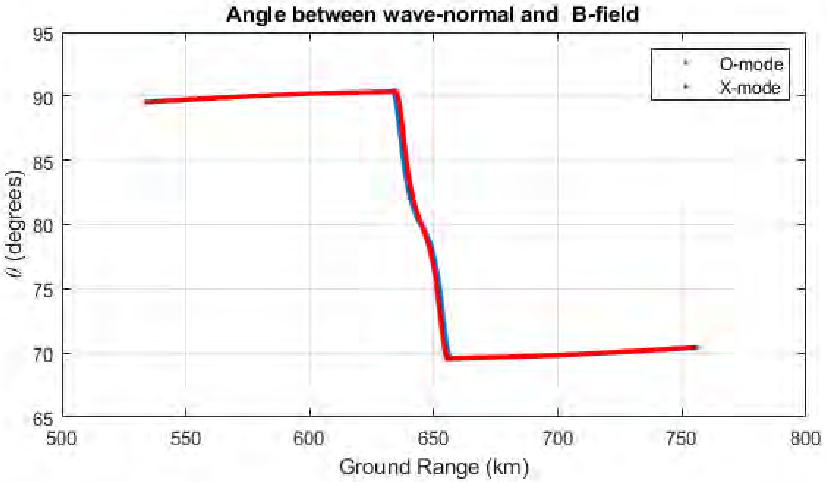
Hungary





Slovenia





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Conclusions so far

- The study gives convincing evidence, across multiple paths and multiple Es events, that single-hop sporadic-E propagation at 50 MHz is mainly magneto-ionic

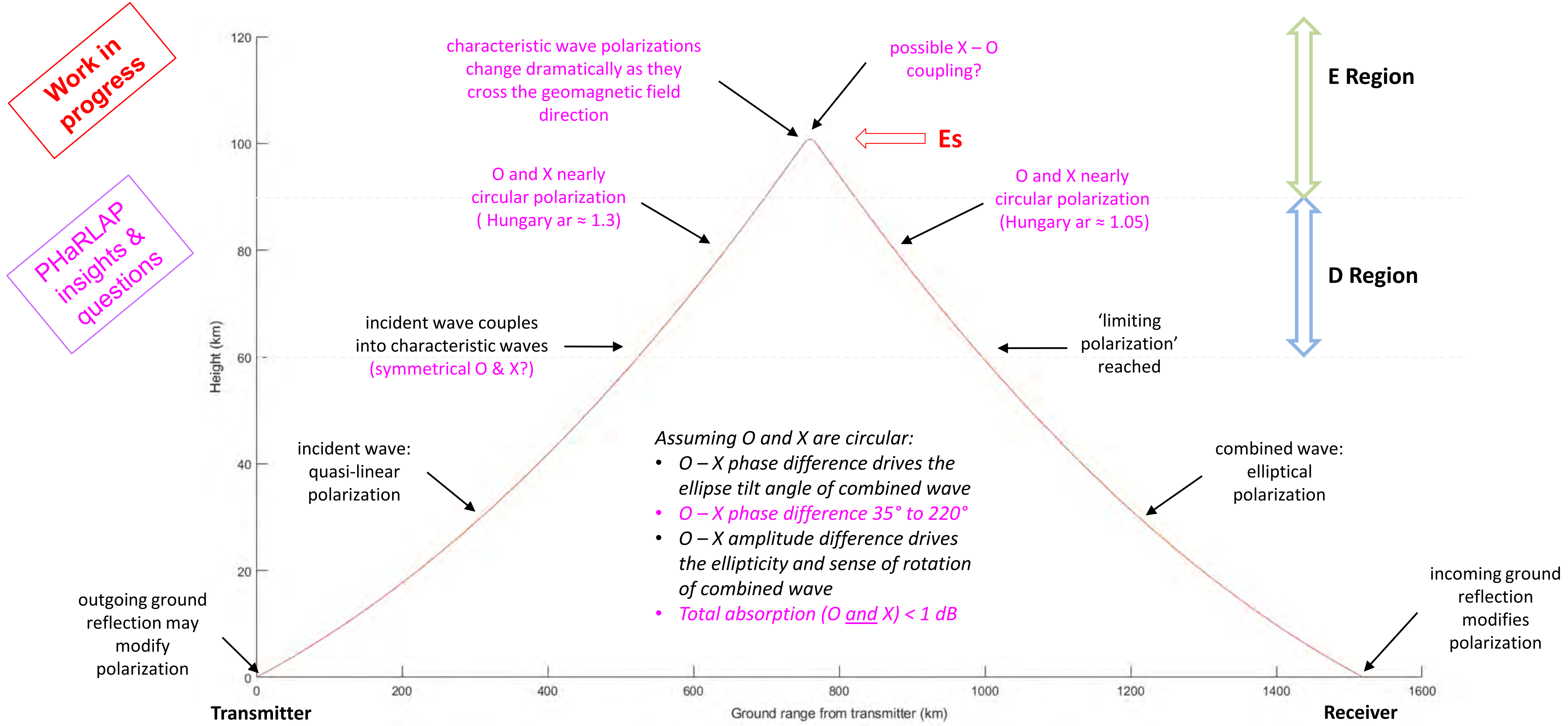
- Initial PHaRLAP ray trace modelling has given results for the 'home' polarization state which are consistent to some extent with the data, but it does not (yet) explain the observed amplitude difference between 'X' and 'O'

- And there are other unanswered questions:

  1. Why are some beacons consistently received with mainly RH elliptical polarization, but others mainly LH?
     - both characteristic waves seem to be present, so it can't just be the 'X' vs 'O' MUF difference
     - is skip distance (hence elevation angle) a factor?
     - geomagnetic field angle must also be important

  2. What are the effects of Es patch shape, size, and motion? Can they explain the observed disturbances from the 'home' polarization state?

3-D raytrace modelling (PHaRLAP): polarization changes over 50 MHz path



Questions?

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