Ionospheric sporadic layers (Es) in middle latitudes

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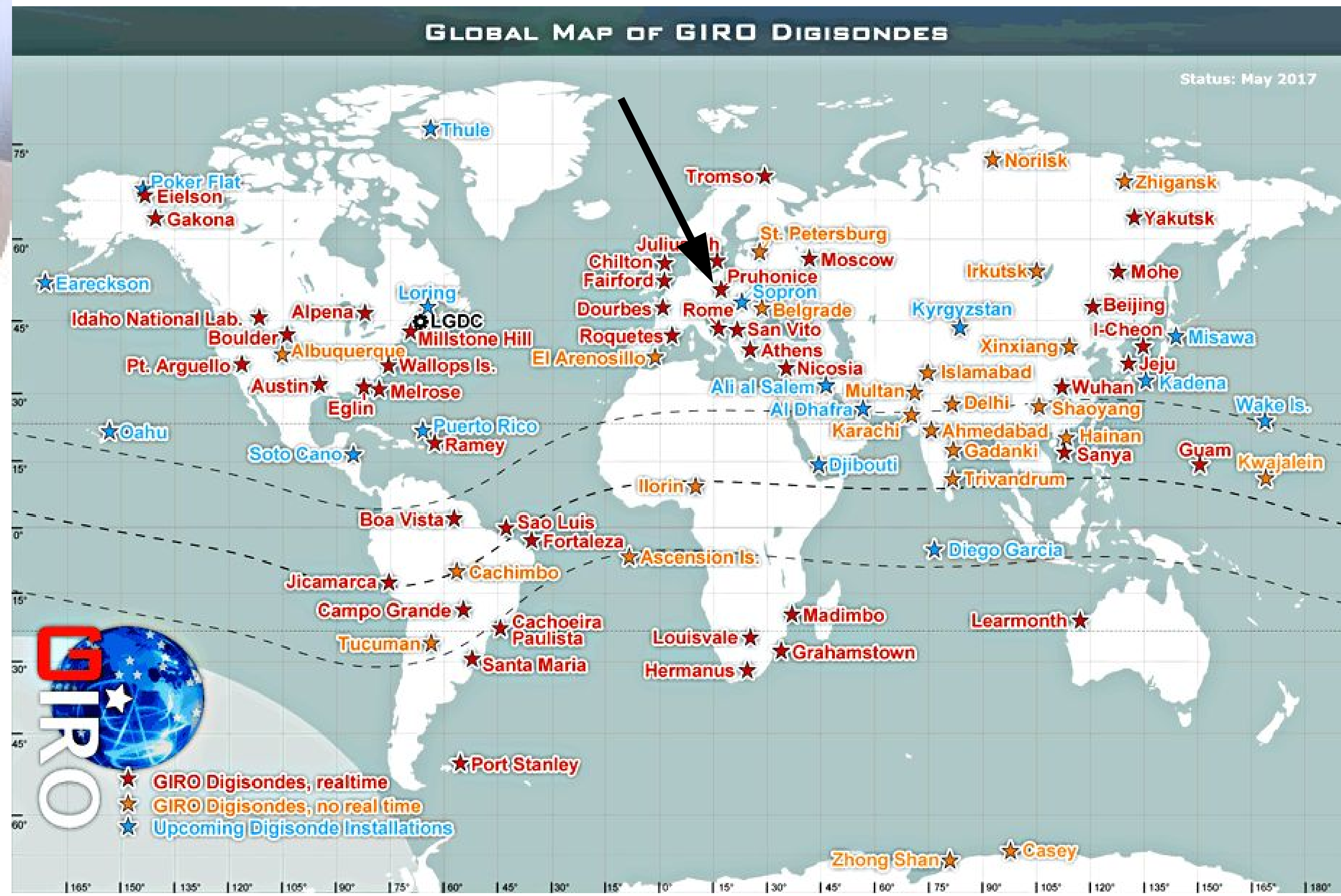
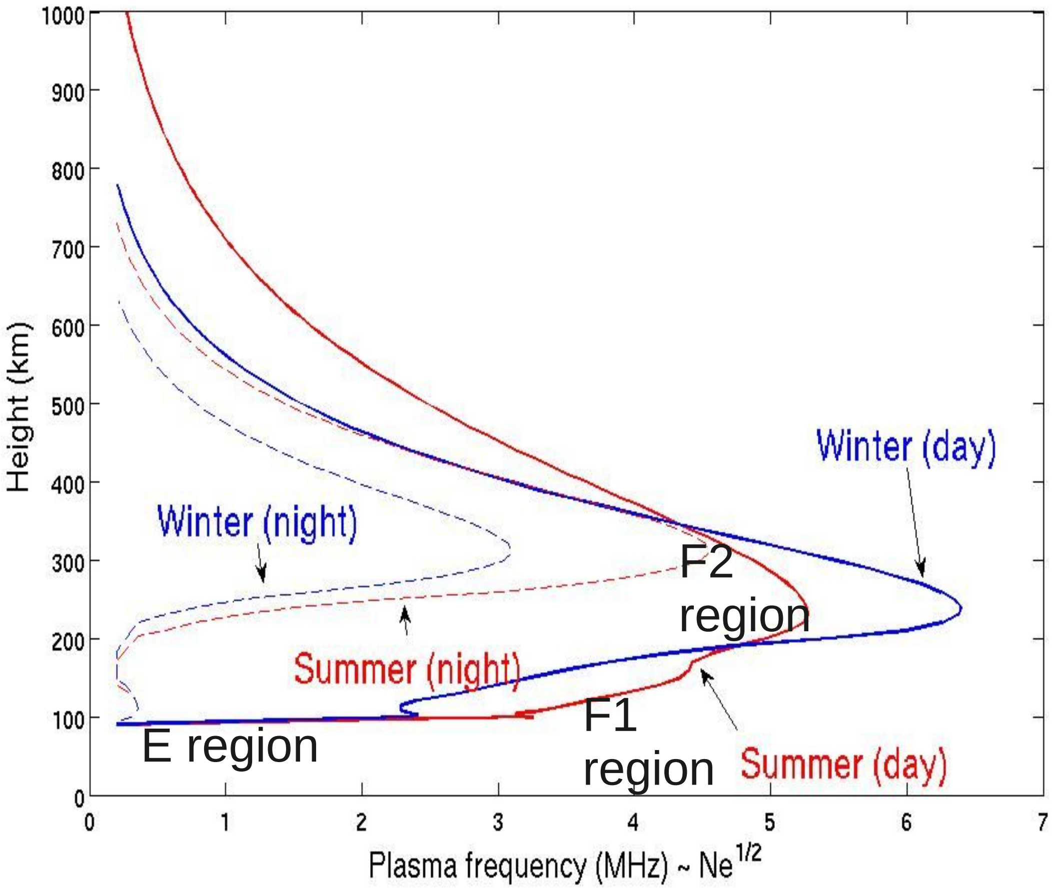
50°N, 15°E, near Prague, Czech Republic
Ionospheric observation since 1957 (hourly basis)
2004-2010 DPS-4, upgraded to DPS-4D in 2010



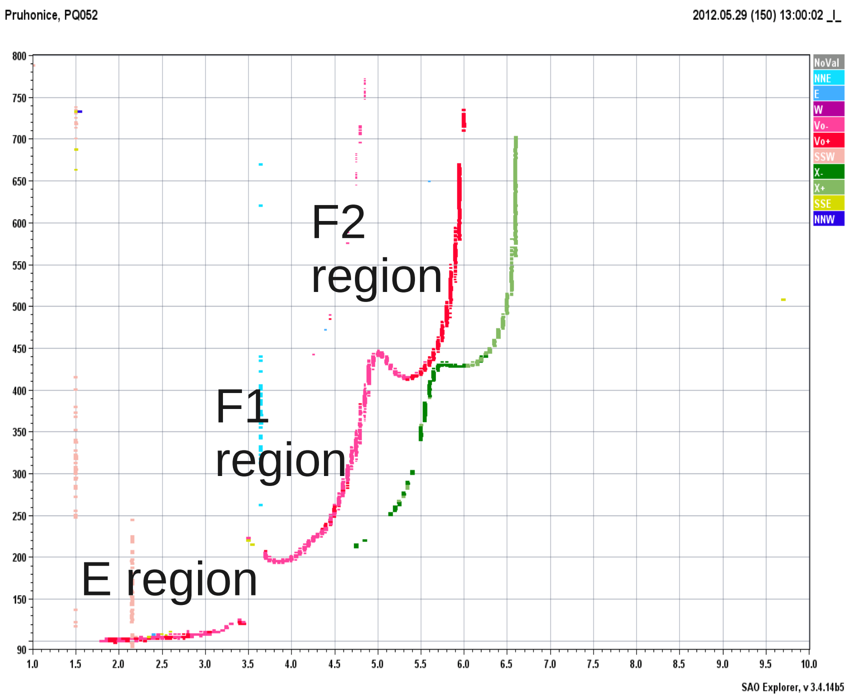
Low transmission power
Doppler measurement
O vs. X mode
Detection of direction
Oblique sounding

Morphology and radio sounding

Electron density profile



Ionogram

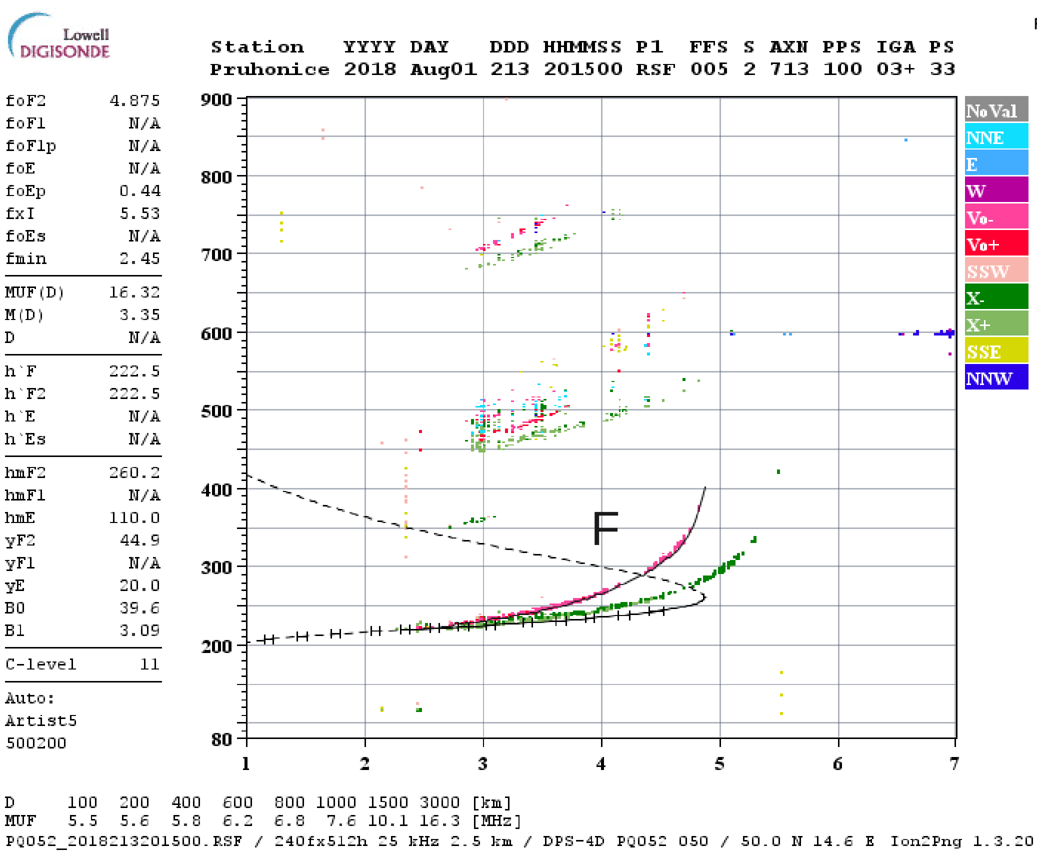


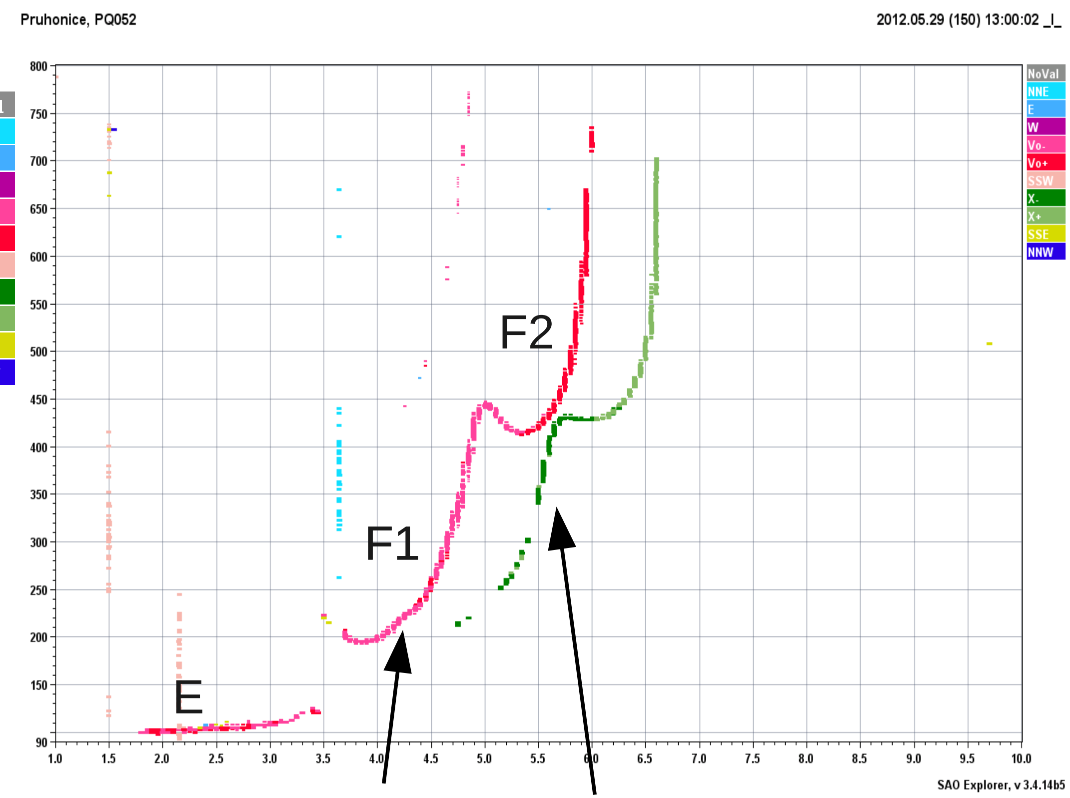
Information up to maximum of electron concentration

Regular ionograms

Night (F layer)

Day (E, F, or E, F1, F2)

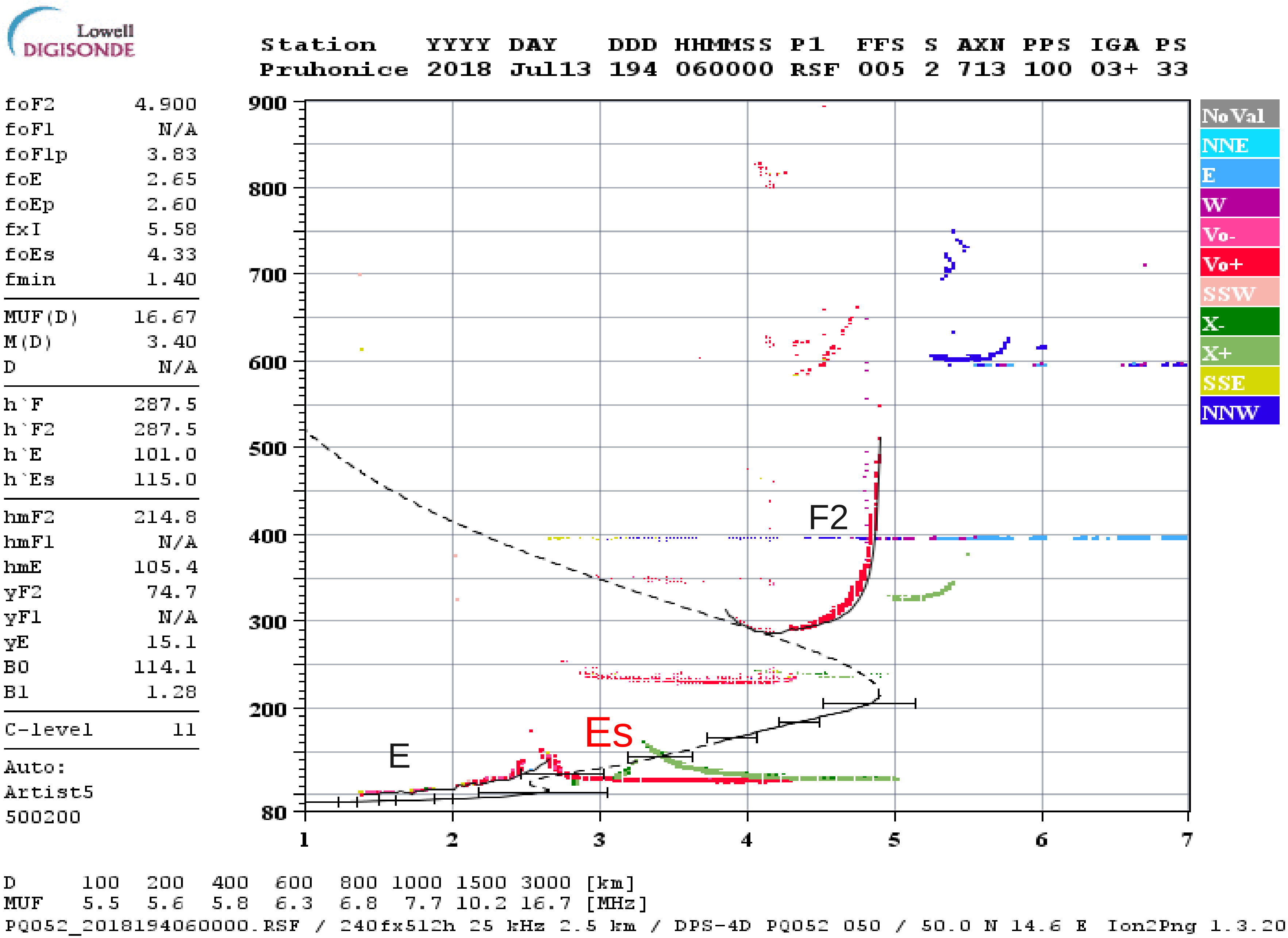




Ordinary reflections (O-mode)

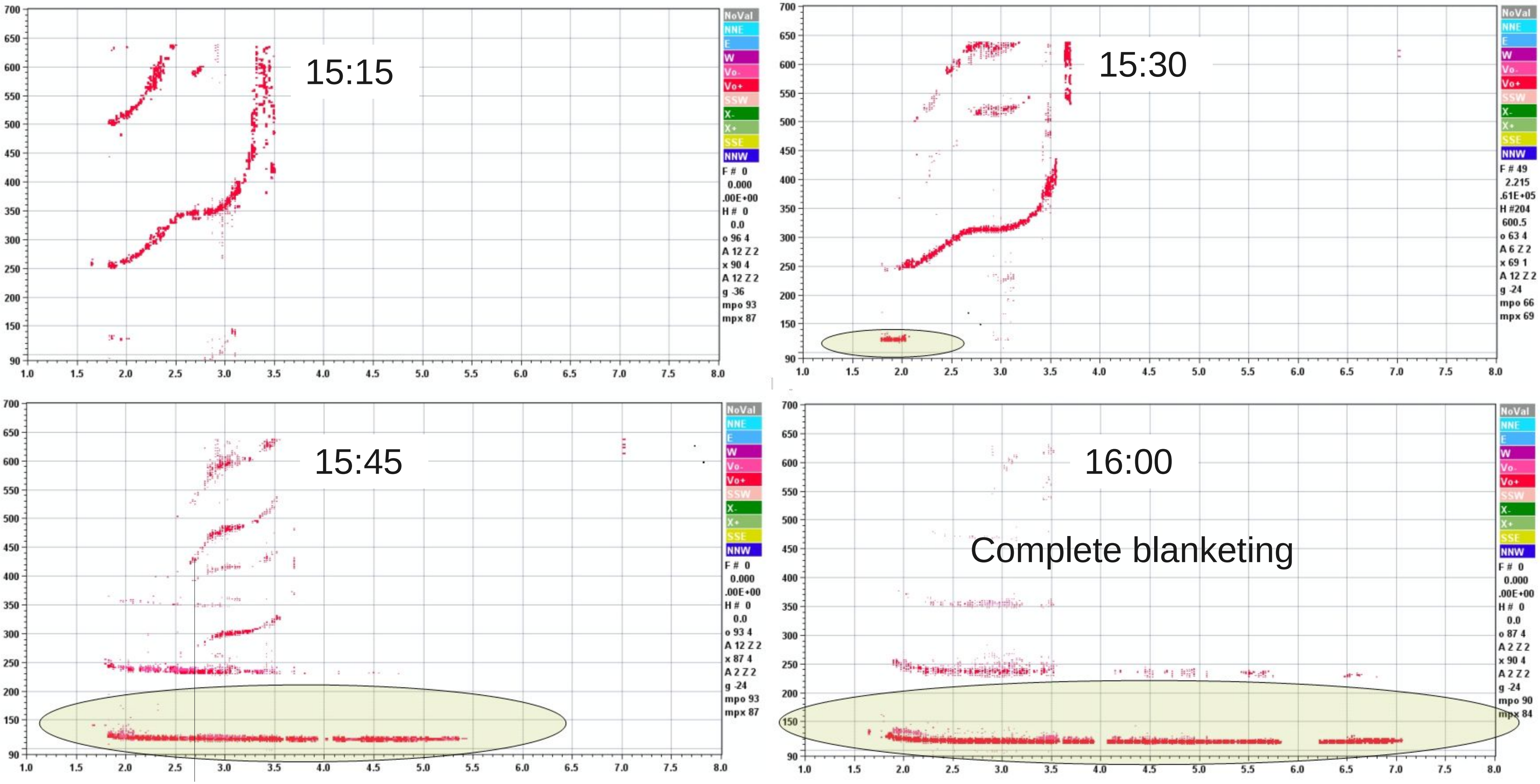
Extraordinary reflections (X-mode)

Es presence



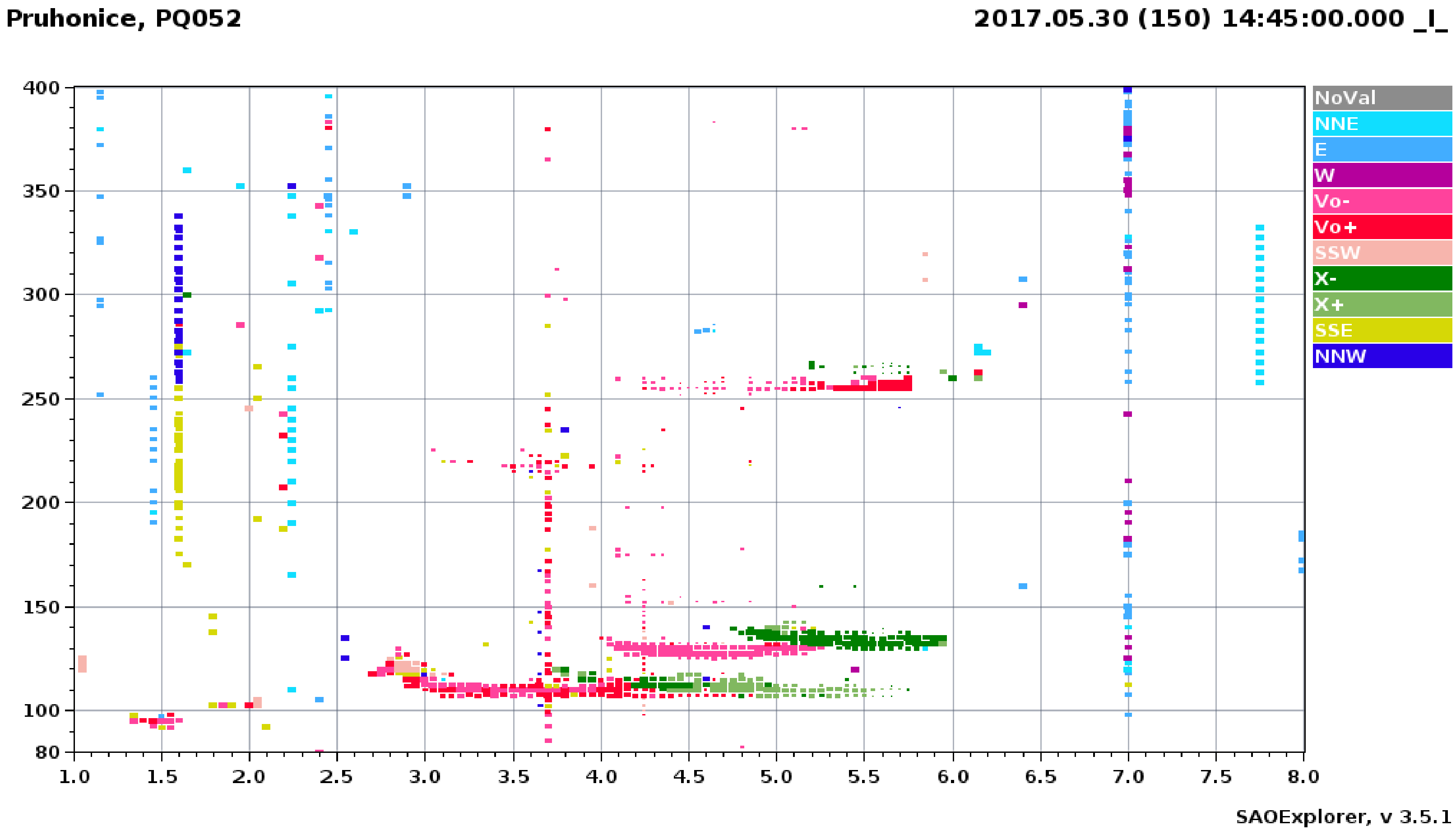
Lowell DIGISONDE
Station YYYY DAY DDD HHMMSS P1 FFS S AXN PPS IGA PS
Pruhonice 2018 Jul13 194 060000 RSF 005 2 713 100 03+ 33
foF2 4.900
foF1 N/A
foF1p 3.83
foE 2.65
foEp 2.60
fxI 5.58
foEs 4.33
fmin 1.40
MUF(D) 16.67
M(D) 3.40
D N/A
h`F 287.5
h`F2 287.5
h`E 101.0
h`Es 115.0
hmF2 214.8
hmF1 N/A
hmE 105.4
yF2 74.7
yF1 N/A
yE 15.1
B0 114.1
B1 1.28
C-level 11
Auto:
Artist5
500200
900
800
700
600
500
400
300
200
80
1
2
3
4
5
6
7
F2
Es
E
No Val
NNE
E
W
Vo-
Vo+
SSW
X-
X+
SSE
NNW
D 100 200 400 600 800 1000 1500 3000 [km]
MUF 5.5 5.6 5.8 6.3 6.8 7.7 10.2 16.7 [MHz]
PQ052_2018194060000.RSF / 240fx512h 25 kHz 2.5 km / DPS-4D PQ052 050 / 50.0 N 14.6 E Ion2Png 1.3.20

Es development



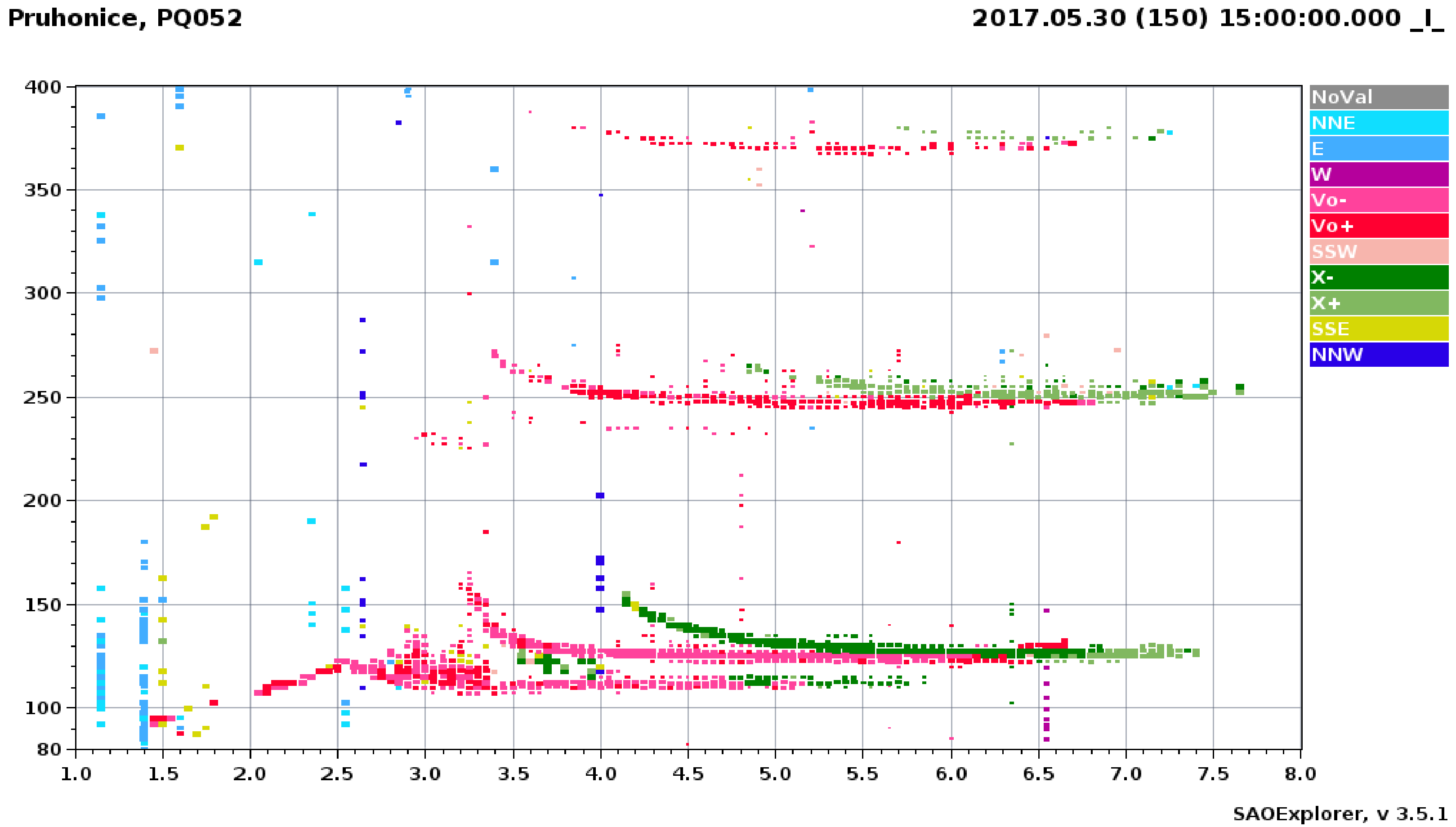
Blanketing frequency fbEs

Multiple layers (May 2017)

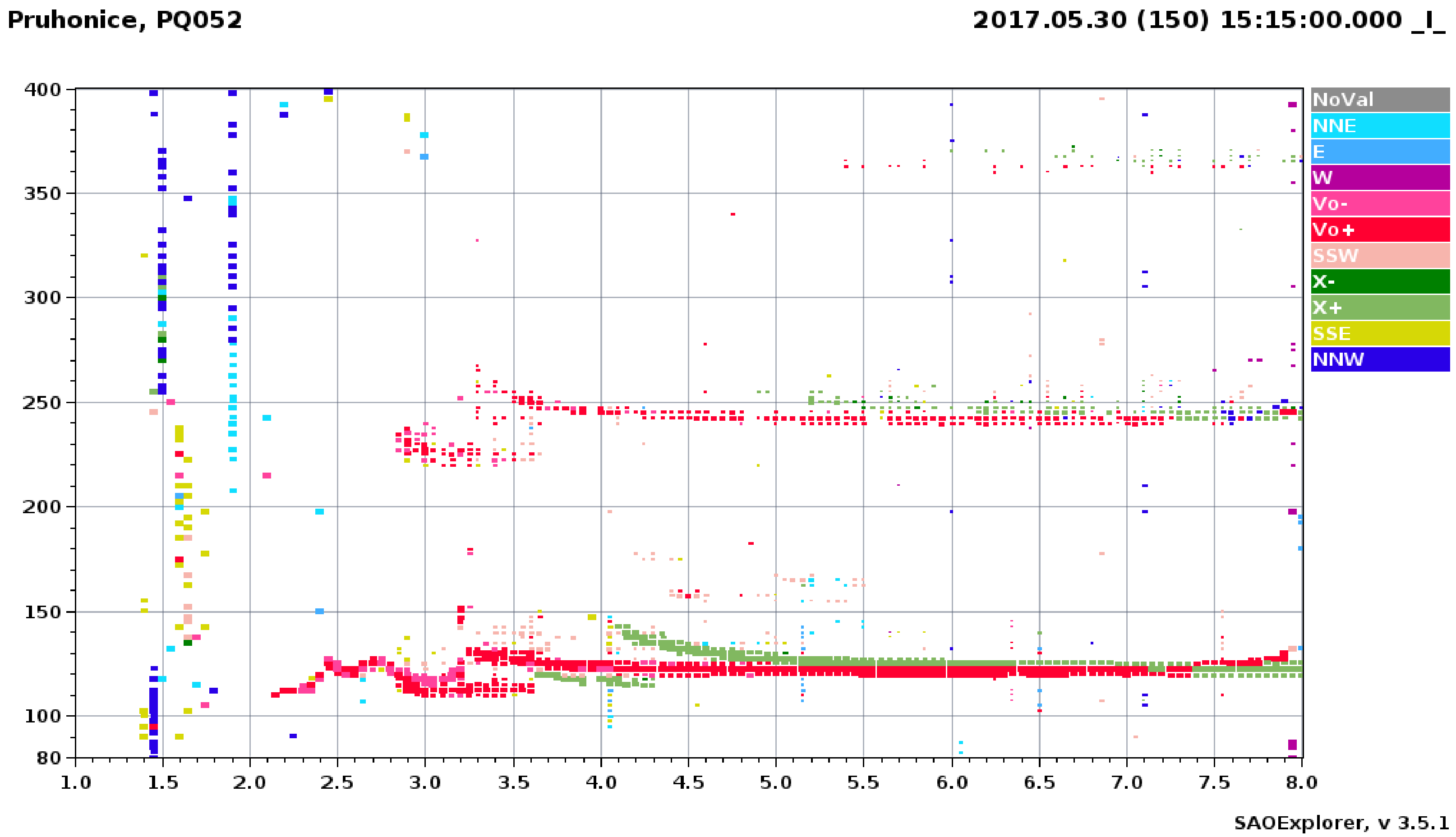


Oblique reflections vs. real multiple layers

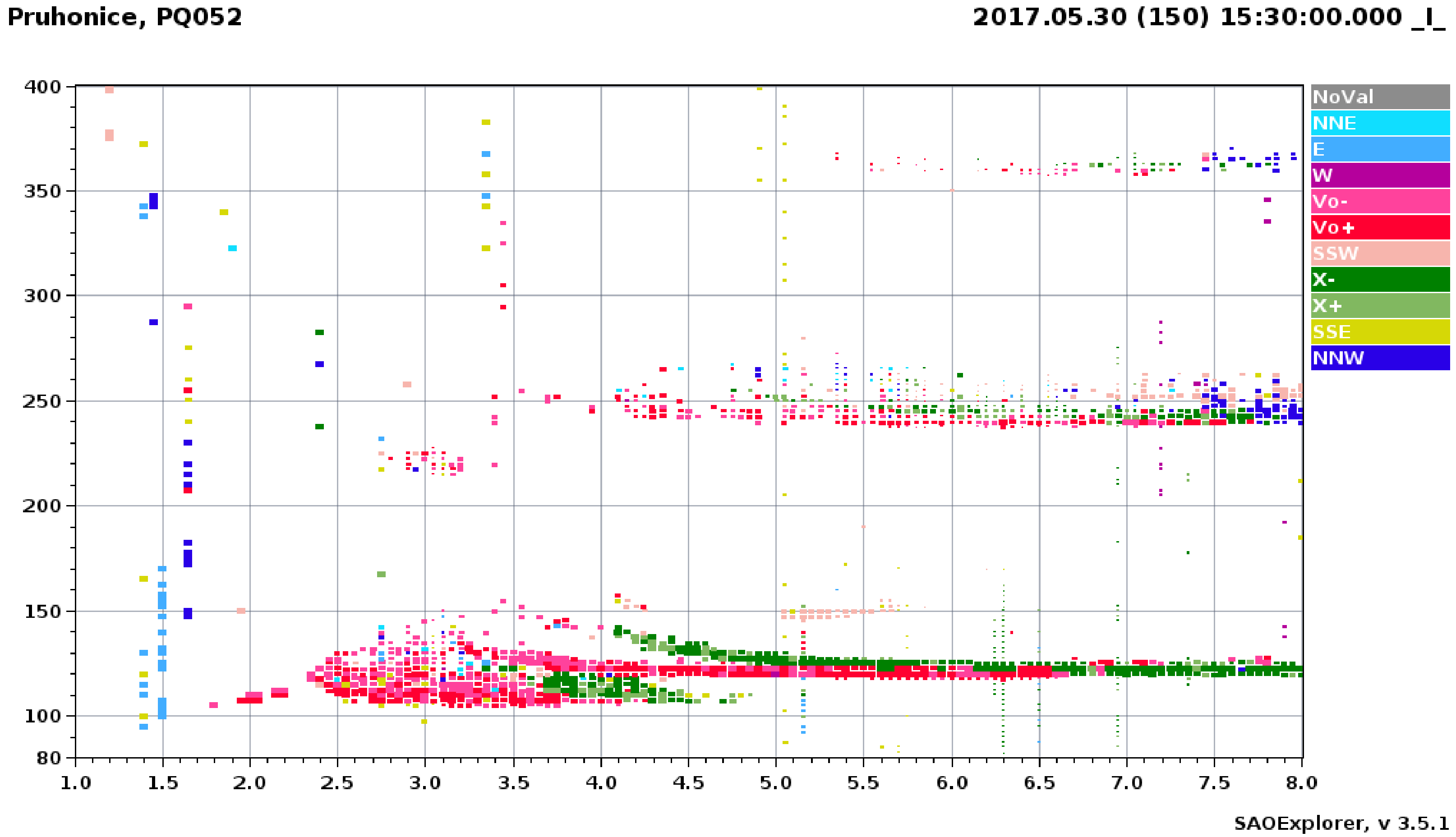
Multiple layers (May 2017)



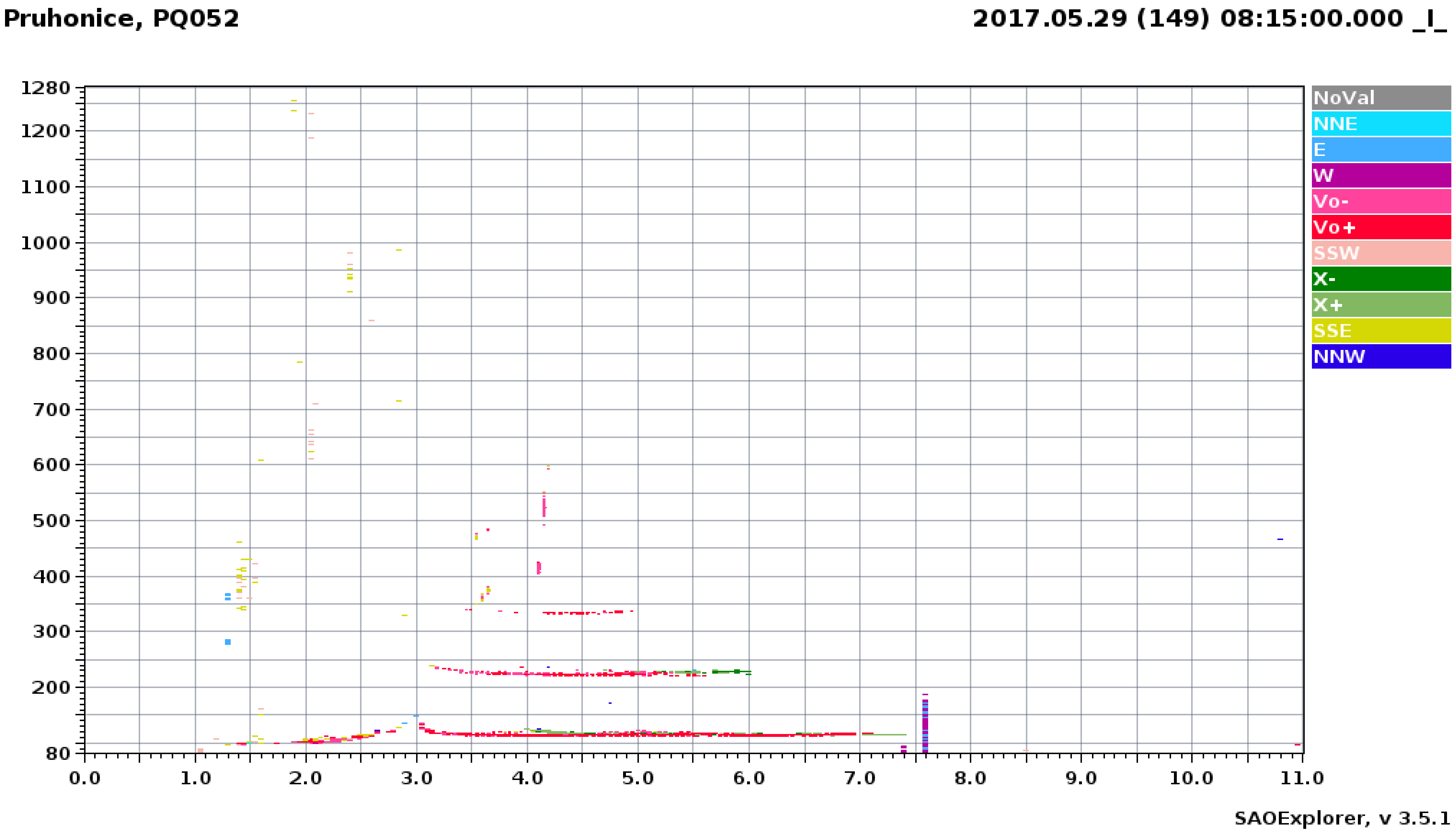
Multiple layers (May 2017)



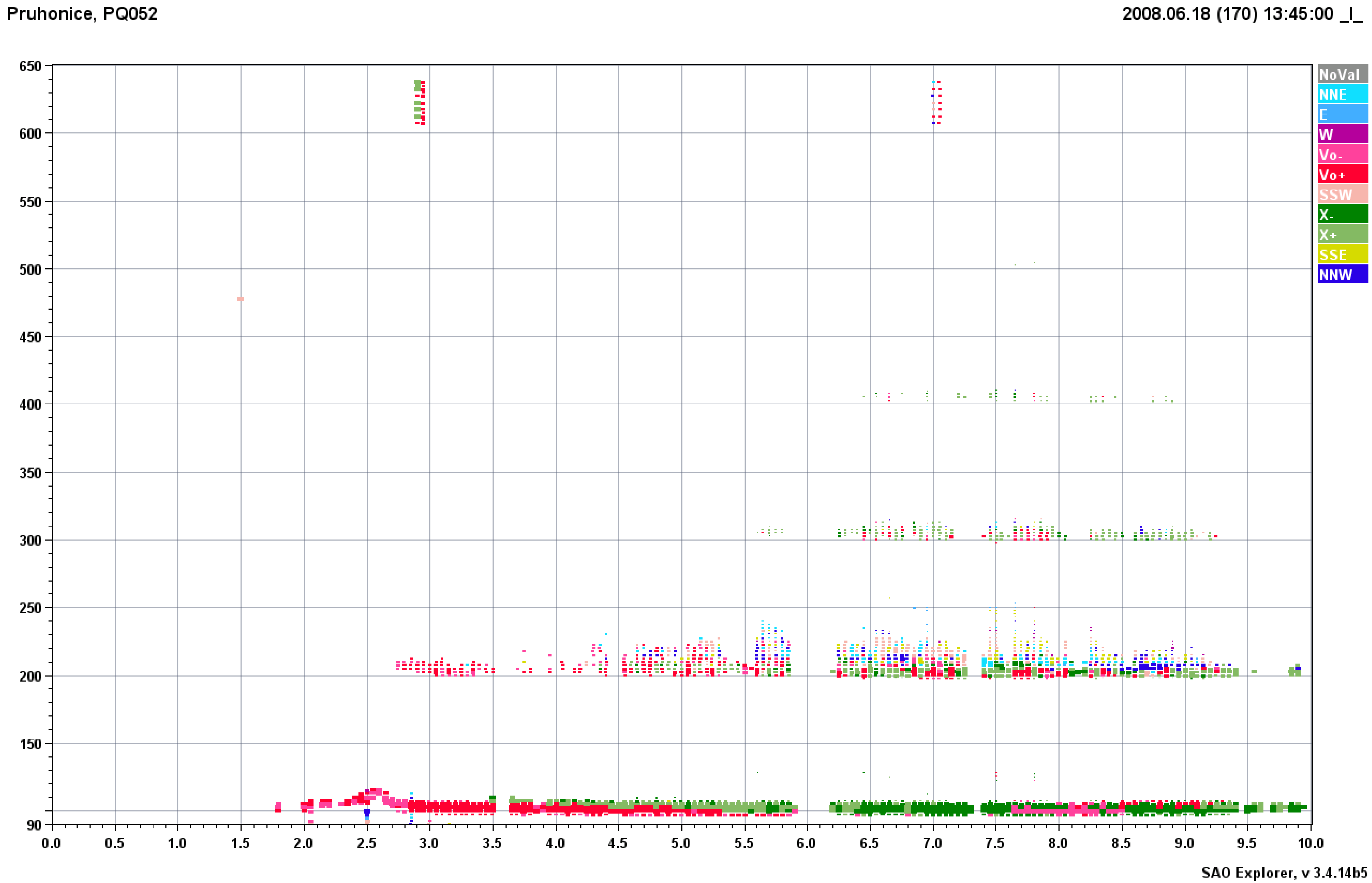
Multiple layers (May 2017)



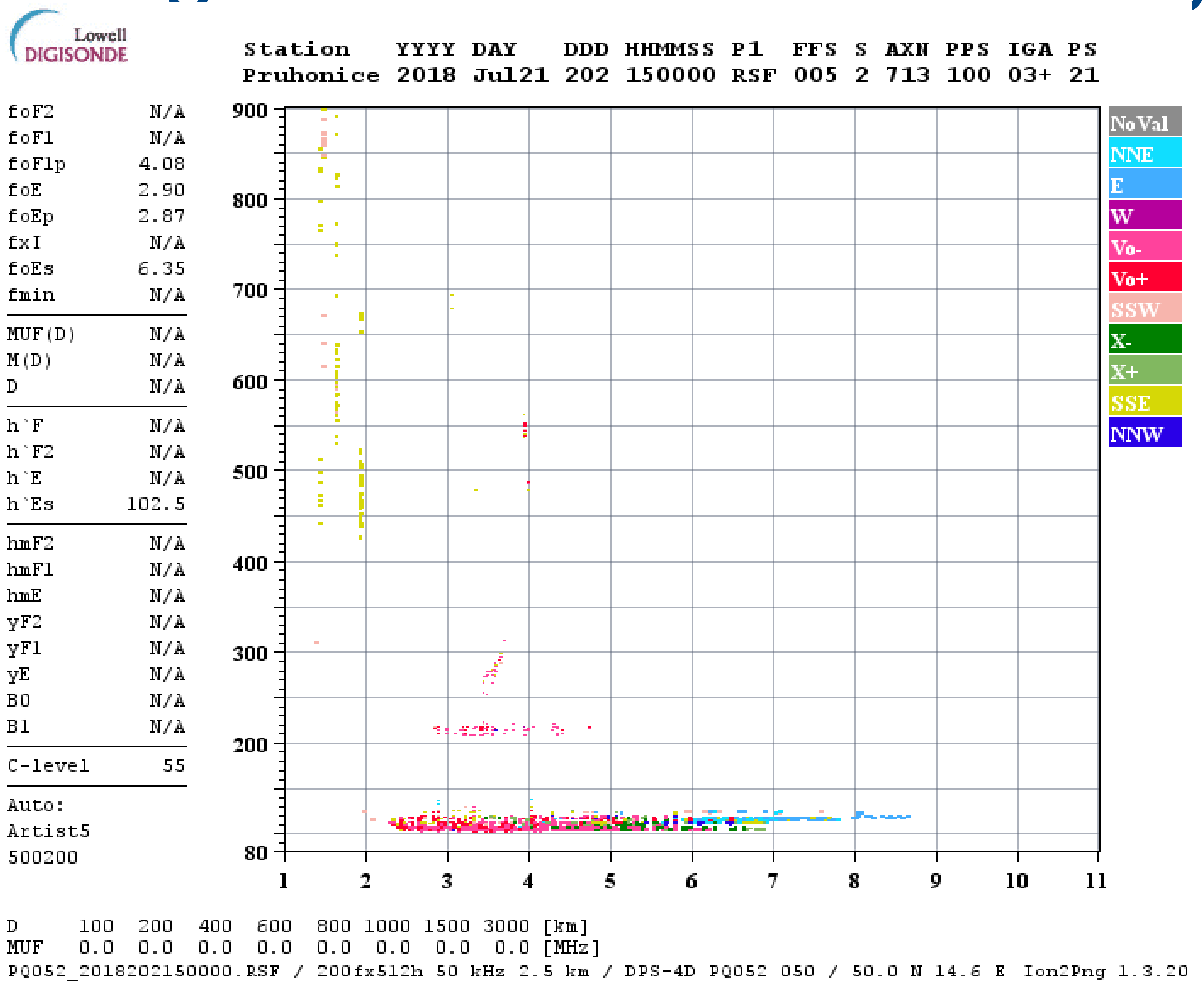
Complete blanketing - Průhonice



Complete blanketing - Průhonice



High foEs values in history



High historical values of foEs—Reality or artefact?
Laštovička et al., JASTP, 74, 2012.

Es formation – Wind shear theory

$$m_i \nu_i (\boldsymbol{v_i} - \boldsymbol{U_n}) - e\boldsymbol{v_i} \times \boldsymbol{B} = 0$$

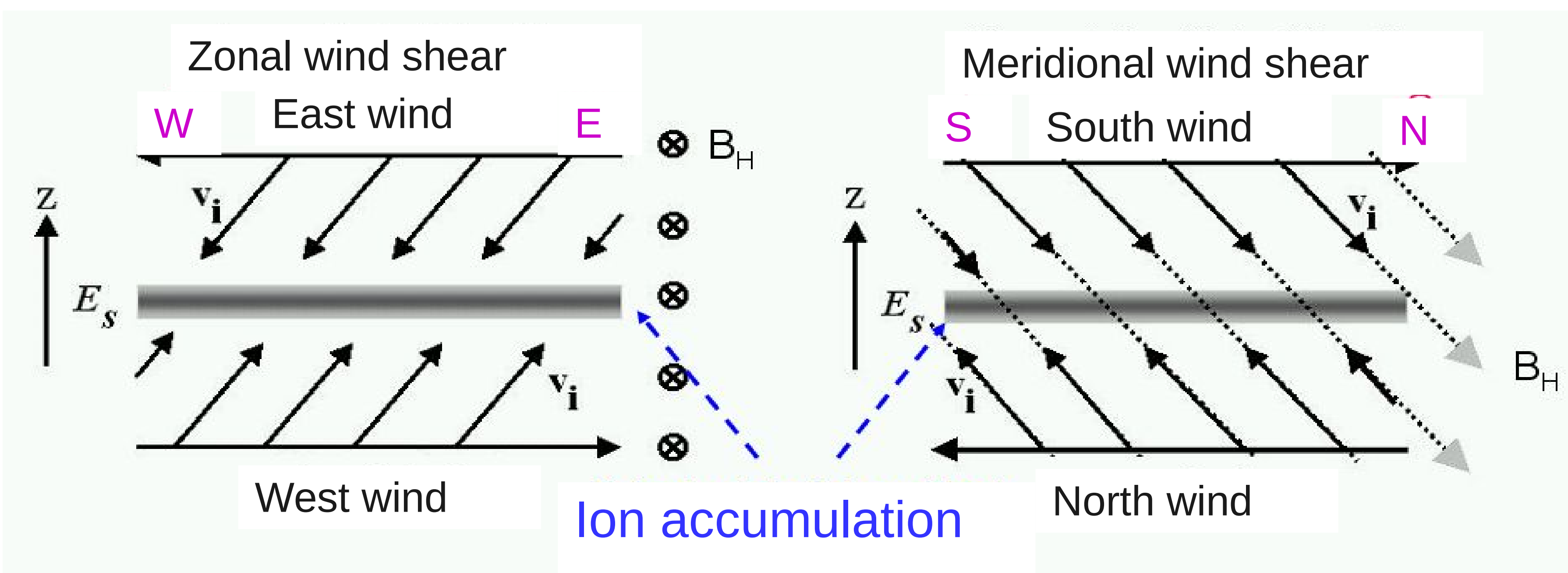
mass

Collision frequency I-N

Ion velocity

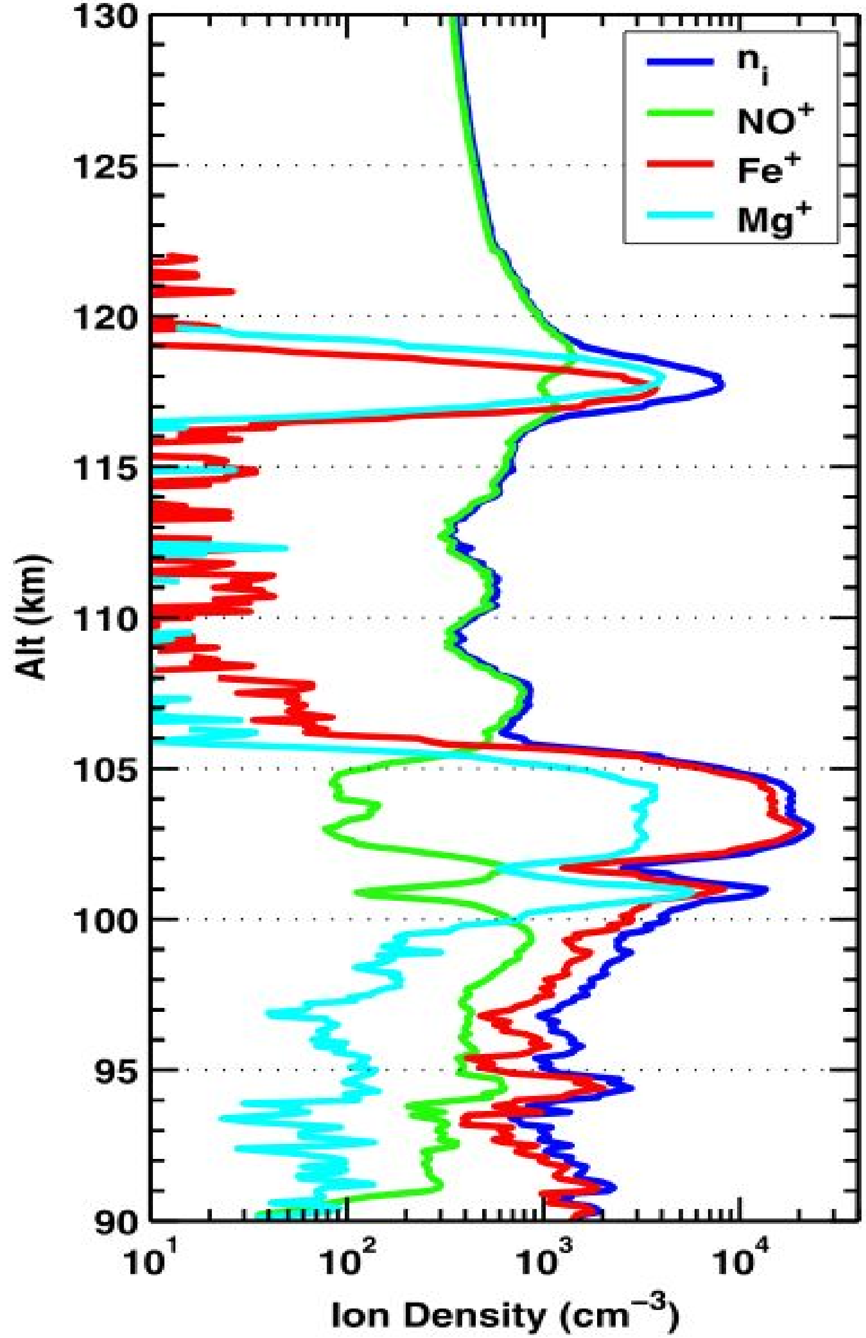
Neutral wind velocity

Degree of ionization very low → neutral atmosphere effects



Whitehead, 1961; Axford, 1963

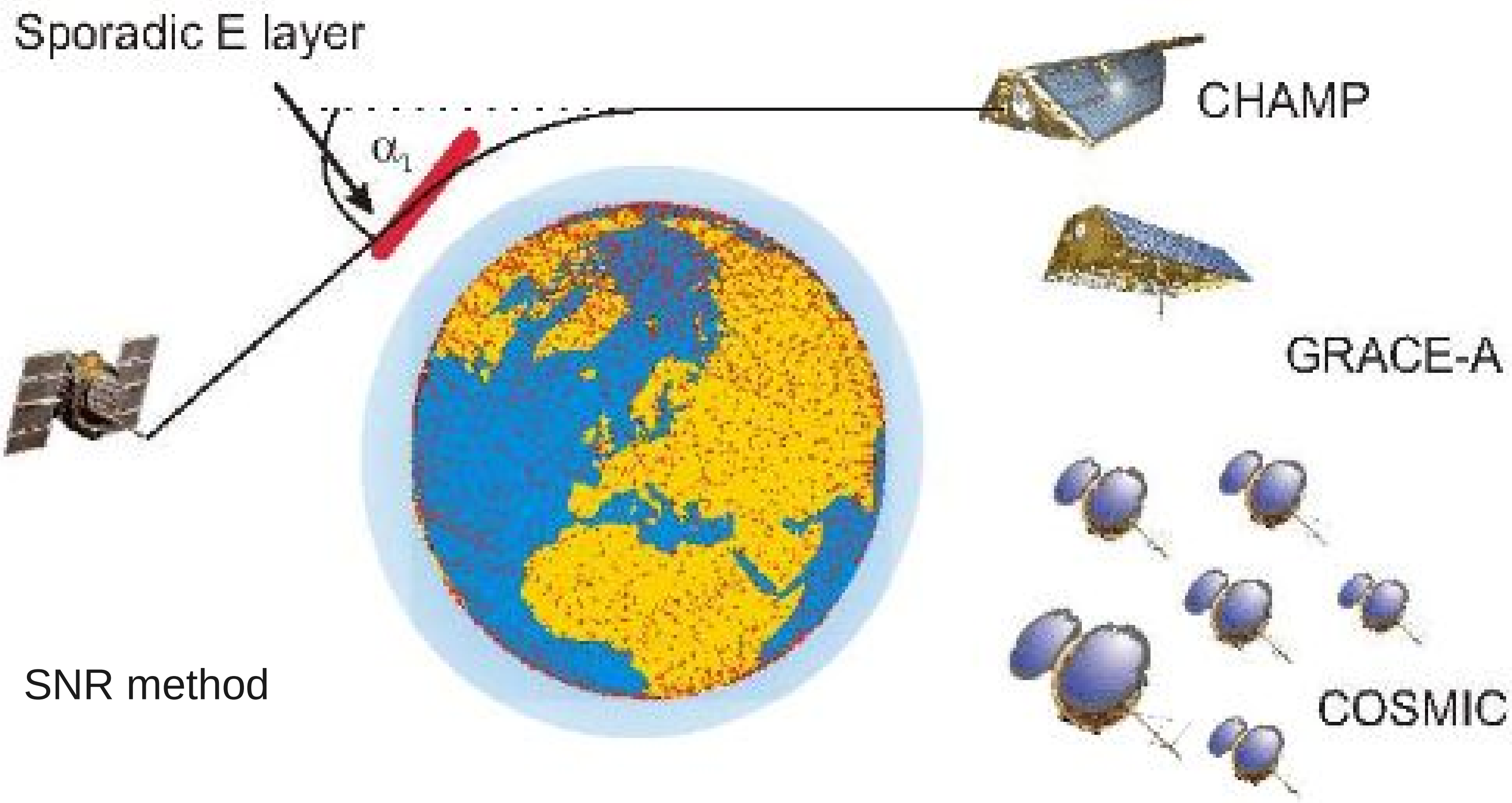
Chemical composition



Roddy et al., 2004

Low electron density
Extremaly low ionization degree (10^{-6}) → Es driven by neutral atmosphere

Ionosonde vs. radio occultation

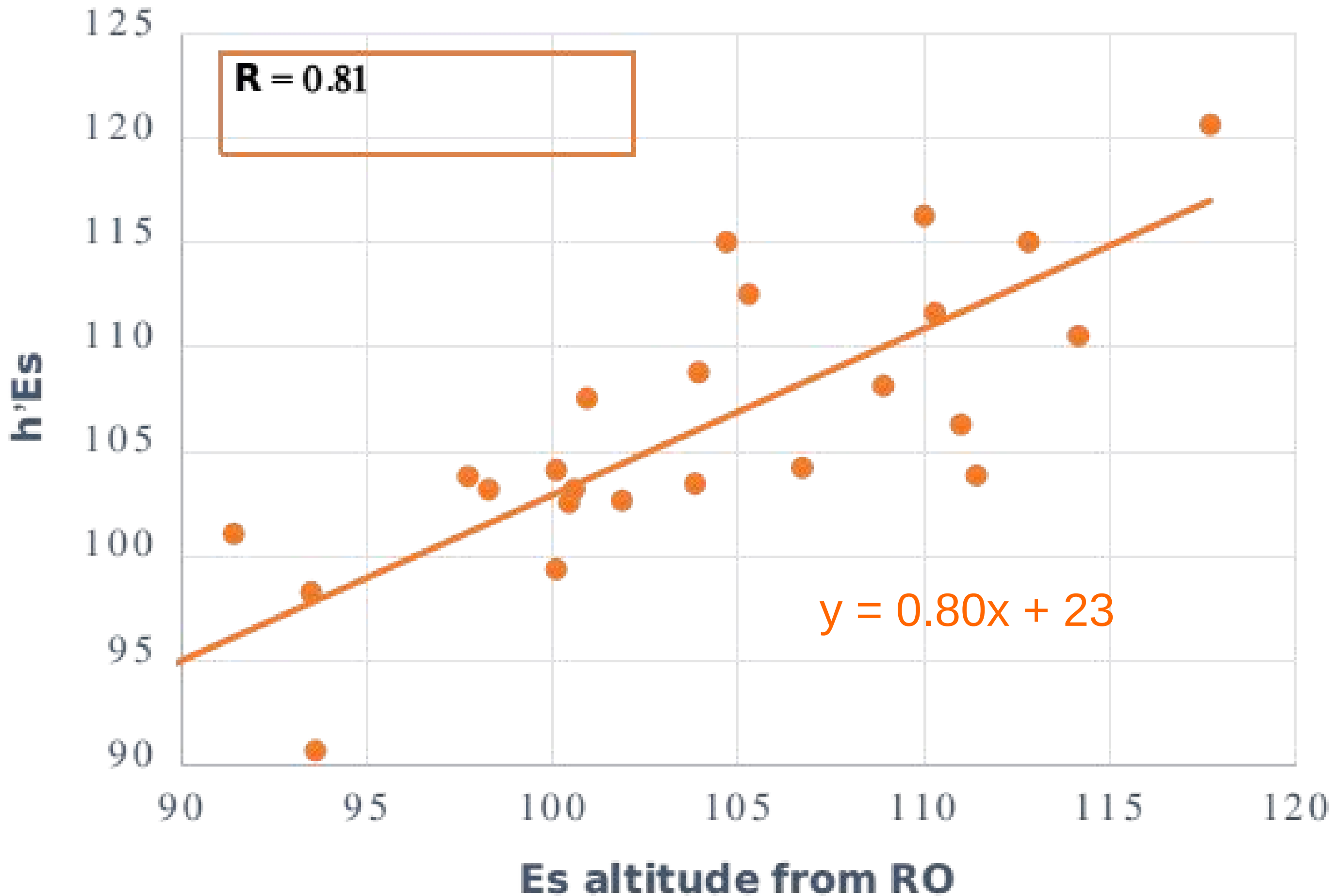


SNR method

Arras, 2010

Ionosonde vs. radio occultation (h'Es)

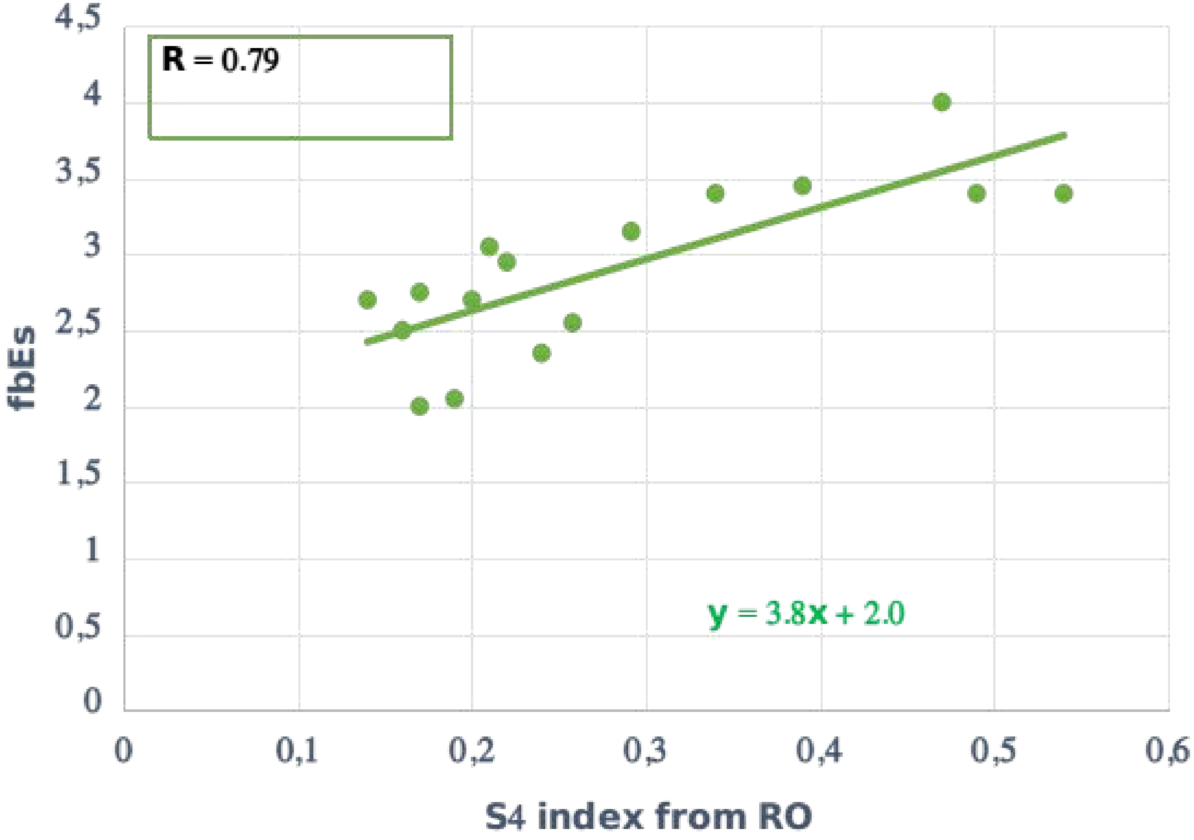
Comparison of ionosonde sporadic E parameters (Pruhonice) with coinciding radio occultation measurements 2009/2010, N=29



Arras et al., 7th Vertical coupling workshop, 2018

Ionosonde vs. radio occultation (fbEs)

Comparison of ionosonde sporadic E parameters (Pruhonice) with coinciding radio occultation measurements 2009/2010, N=29

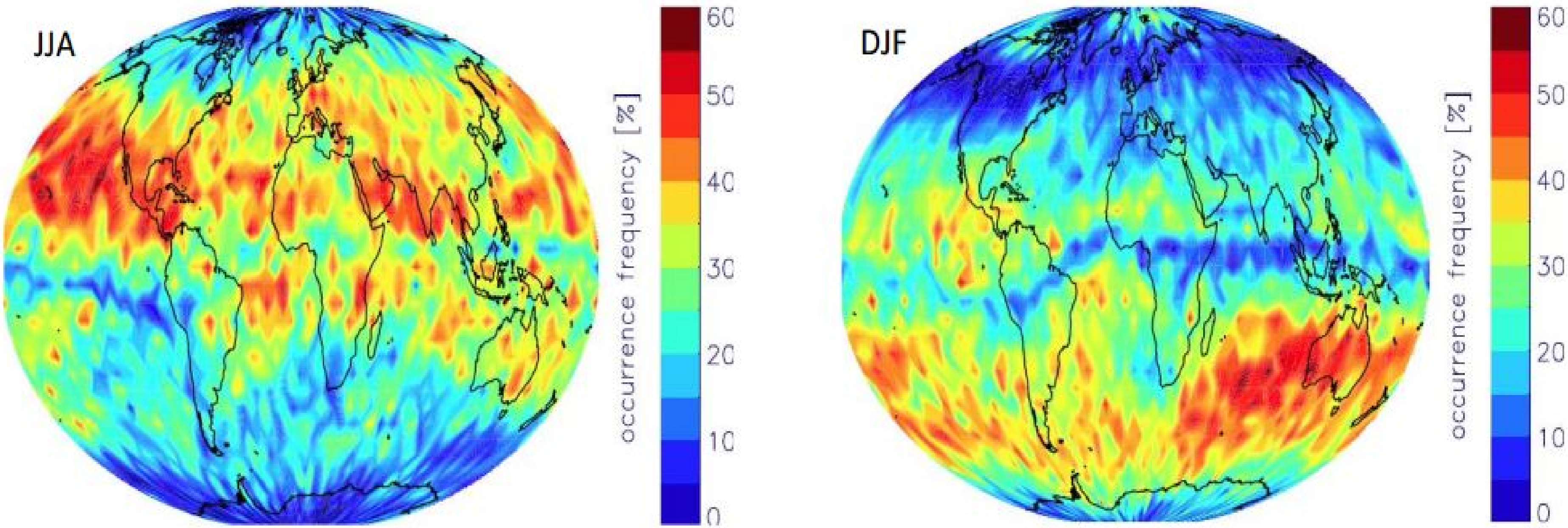


Arras et al., 7th Vertical coupling workshop, 2018

Statistical distribution of Es

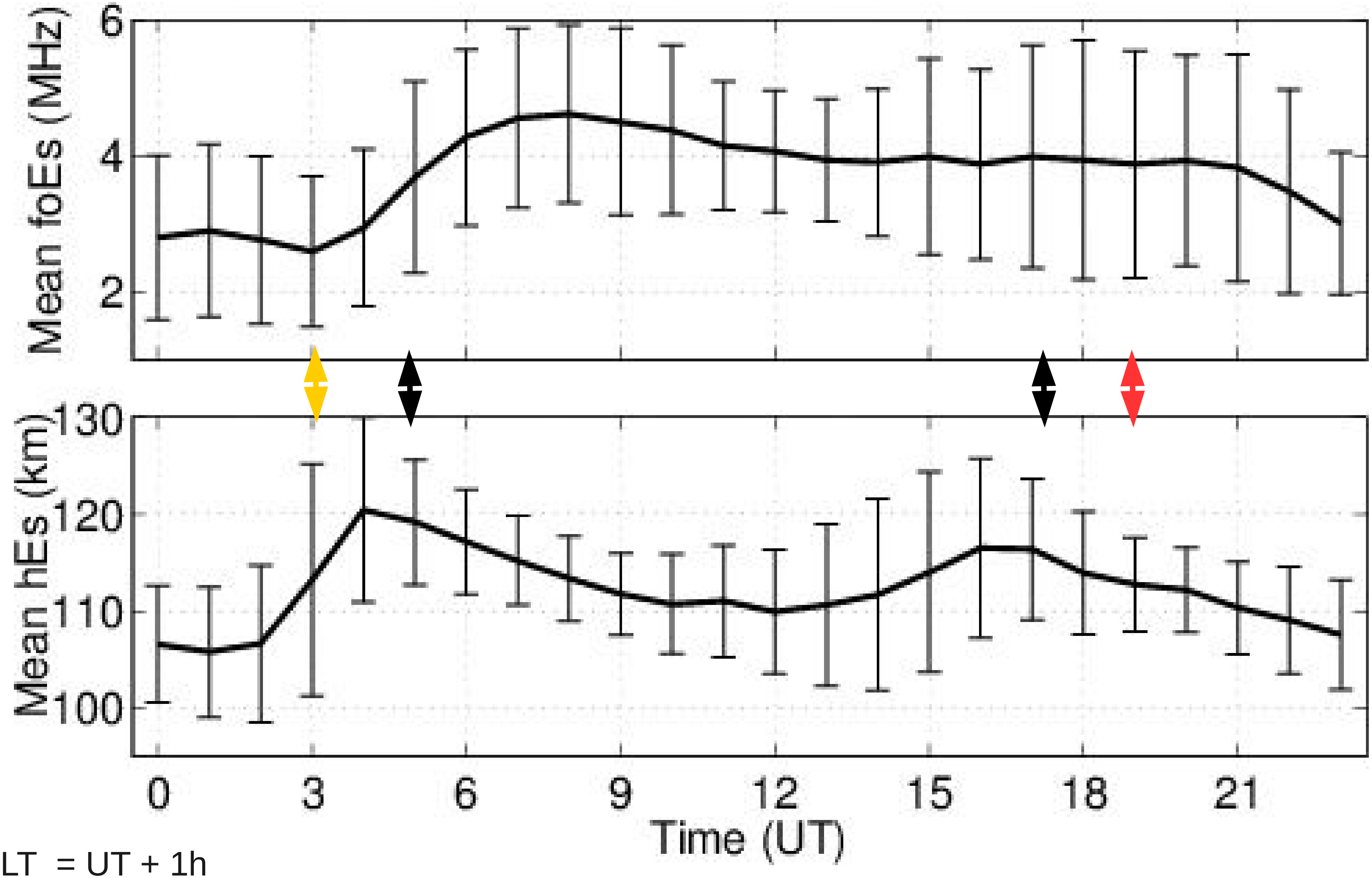
Mid-latitudes
Local summer

2013



Arras et al., 2018

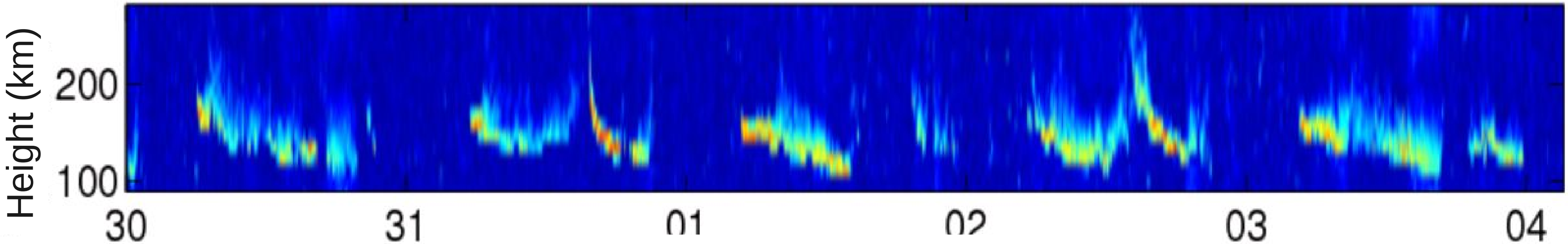
Diurnal course of foEs and h'Es (May – September 2009)



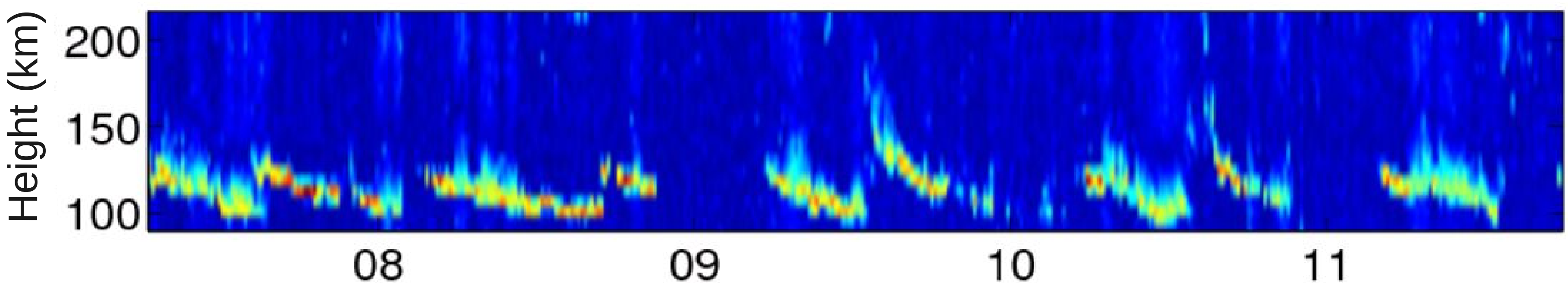
LT = UT + 1h

Periodic behaviour of Es

Pruhonice 3.1-4.0 MHz



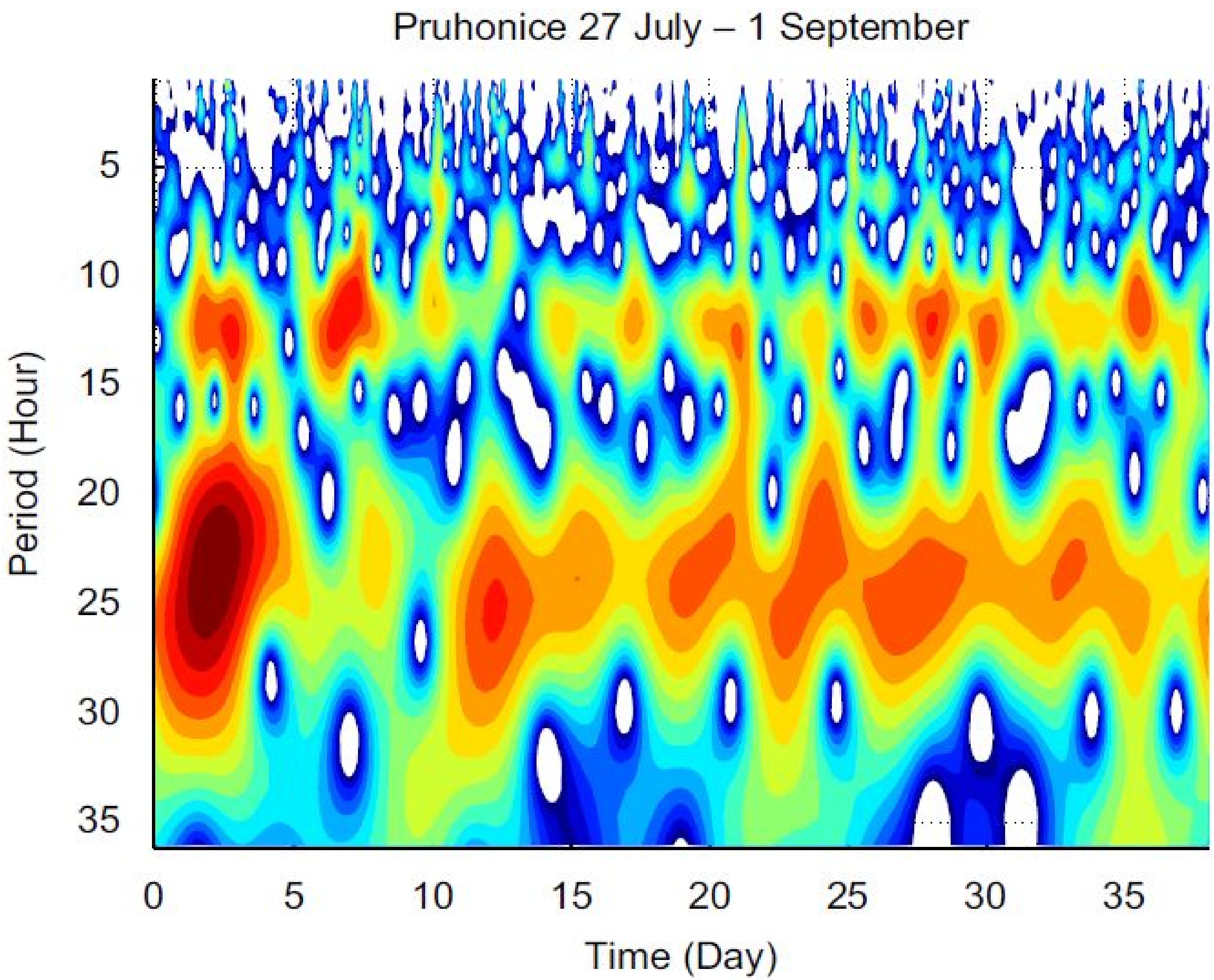
Day (July/August 2004)



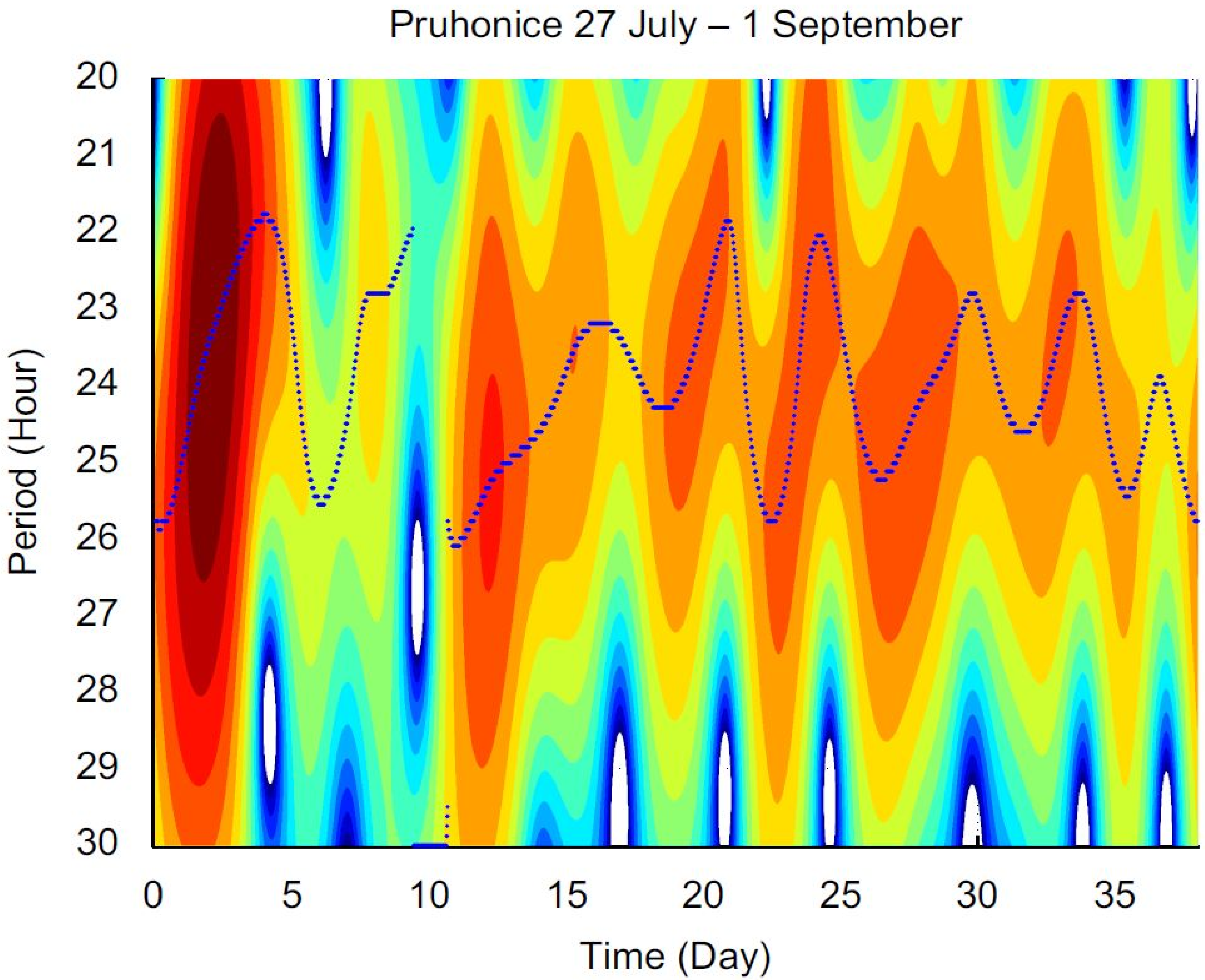
Day (June 2006)

HTI - Haldoupis et al., 2006

Spectral content (hEs)



Modulation of Es data (hEs)



Neutral atmosphere – Es coupling

- Stratosphere and Mesosphere T: 10, 5, 1, 0.1 hPa (32, 37, 48, 65 km, MERRA)
- Zonal and meridional velocities: 82, 85, 88, 91, 94 km (VHF – Collm)

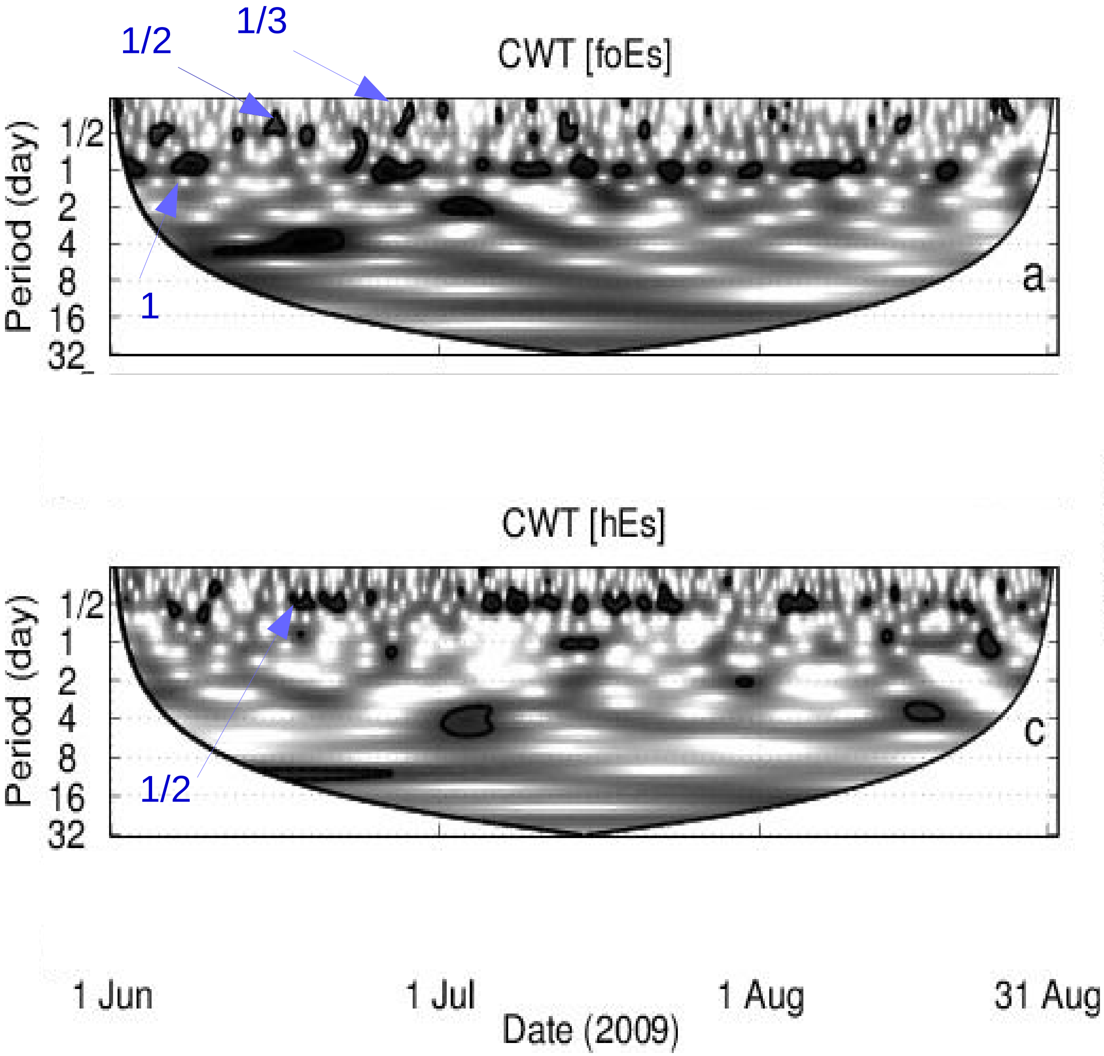
- foEs,hEs

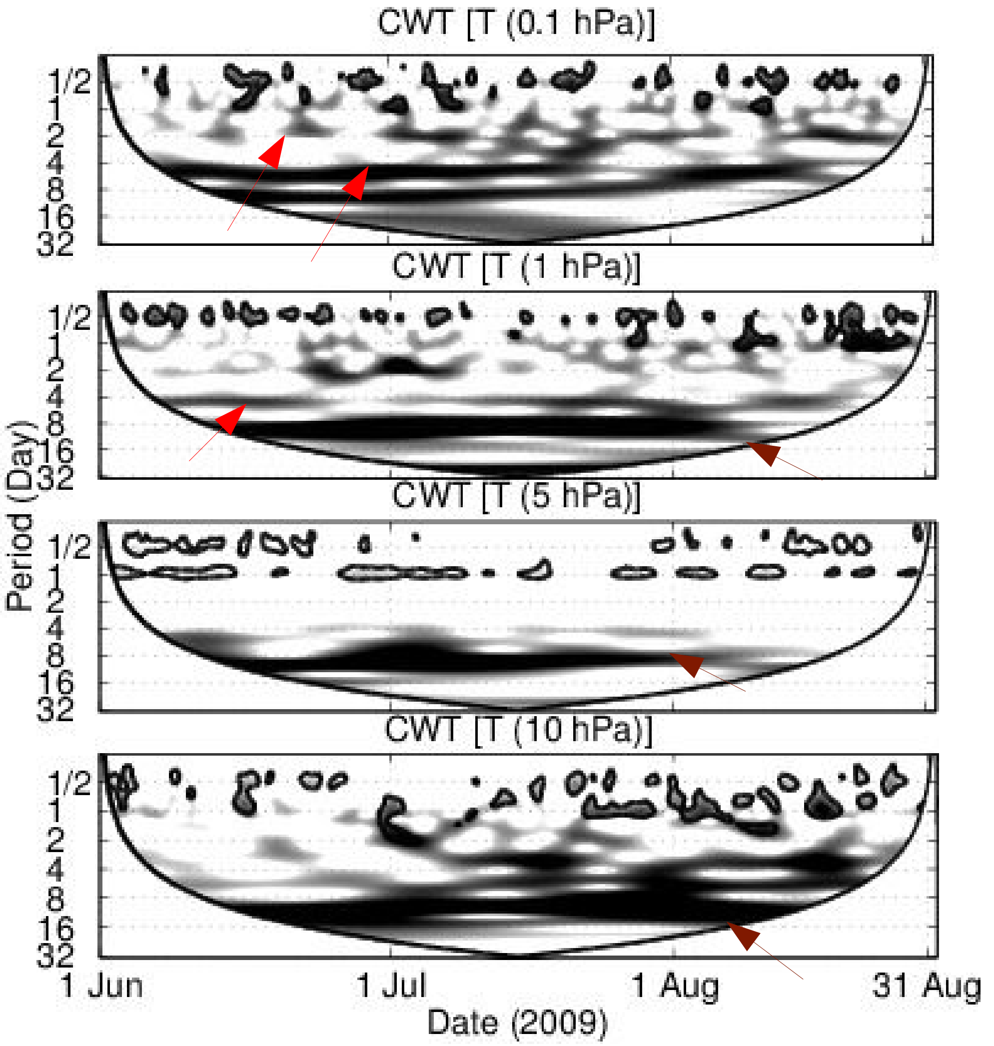
Tide modulation by PW

PW (2, 4-5, 10, 16 days)

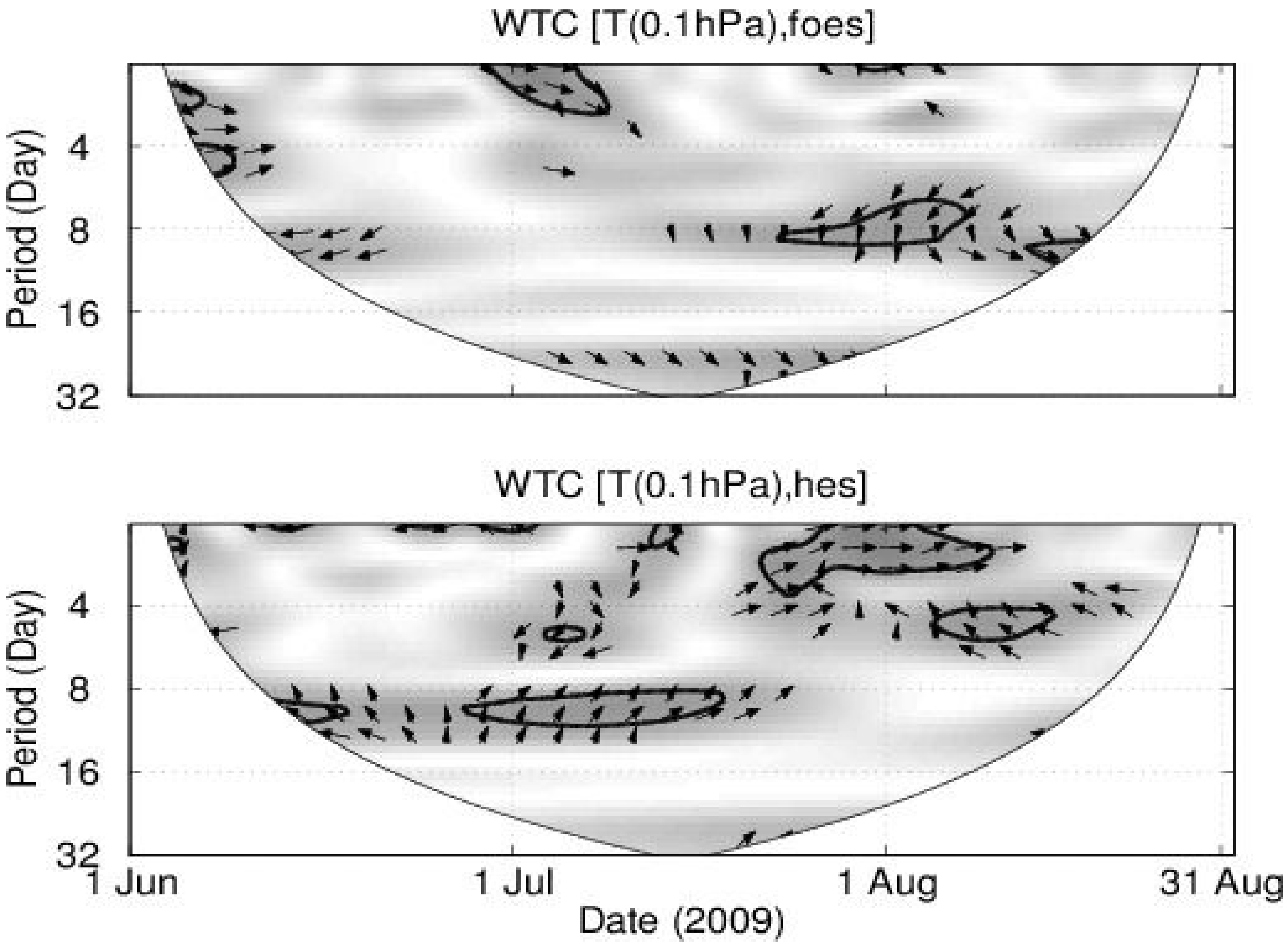
Mosna, Z., Koucka Knizová, P., Potuznikova, K., Coherent structures in the Es layer and neutral middle atmosphere, *Journal of Atmospheric and Solar Terrestrial Physics*, 2015

Spectral characteristics (1)

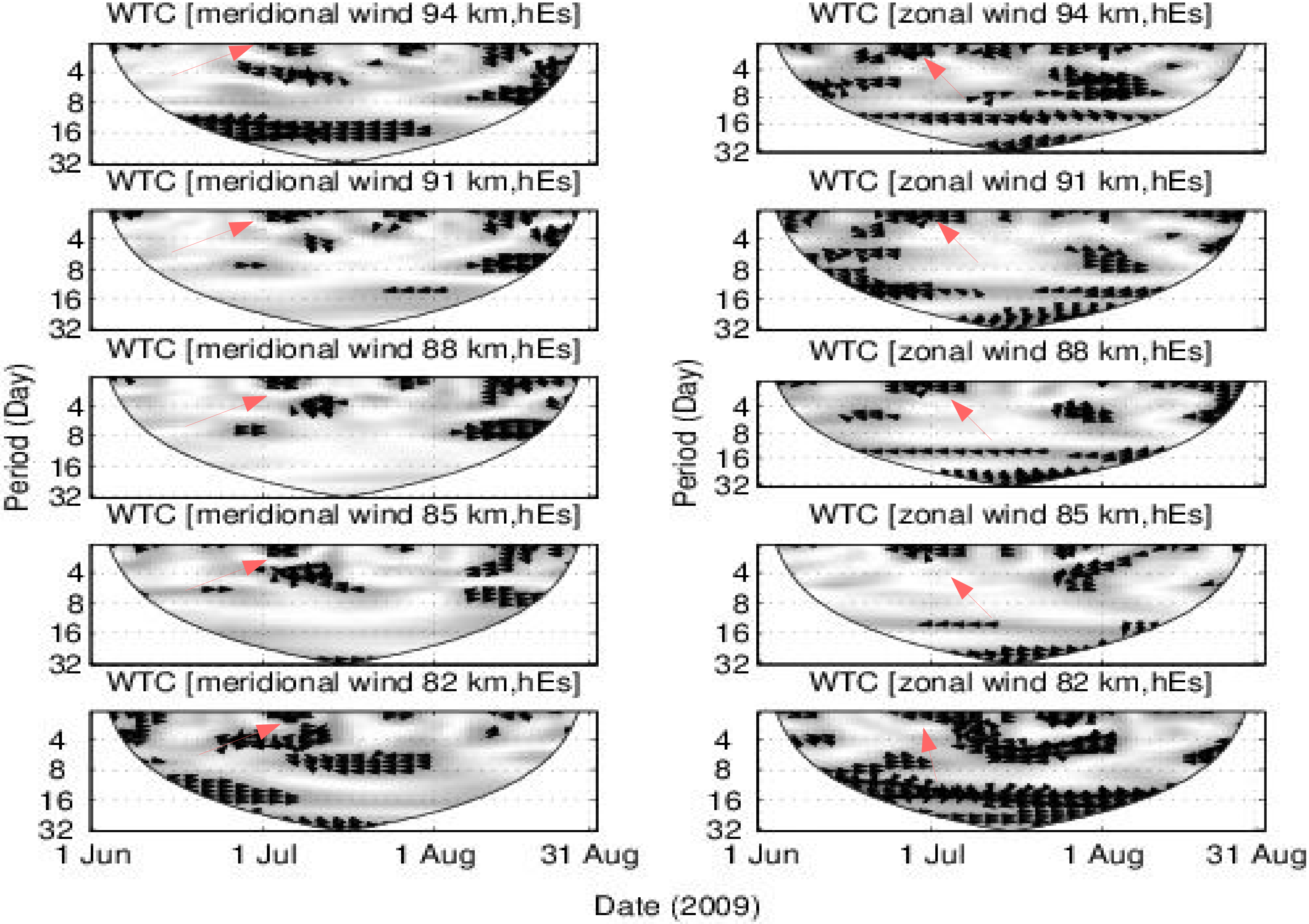




WTC [T, foEs/hEs]



Meridional and zonal wind vs. hEs

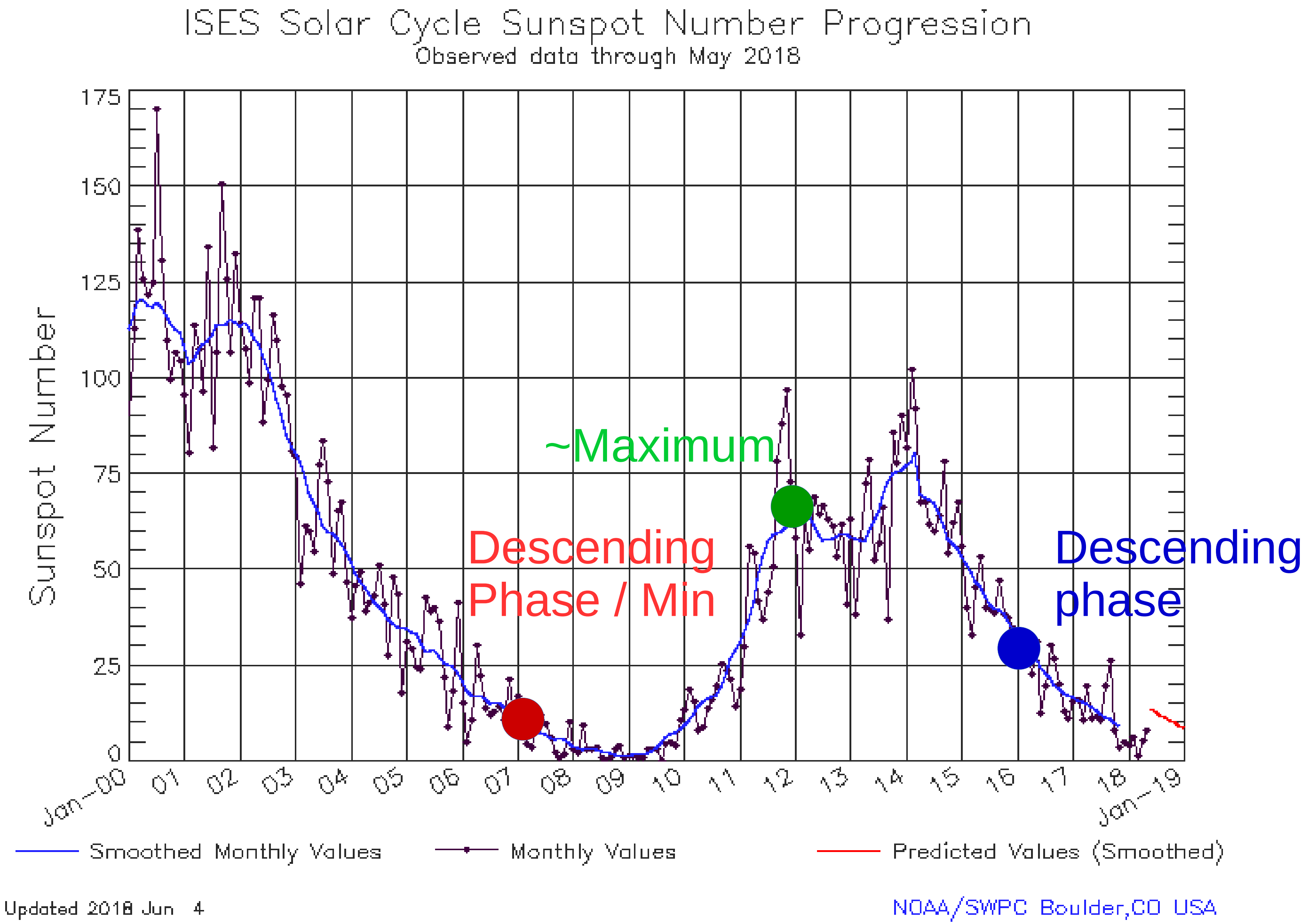


Persistent modes of coherence

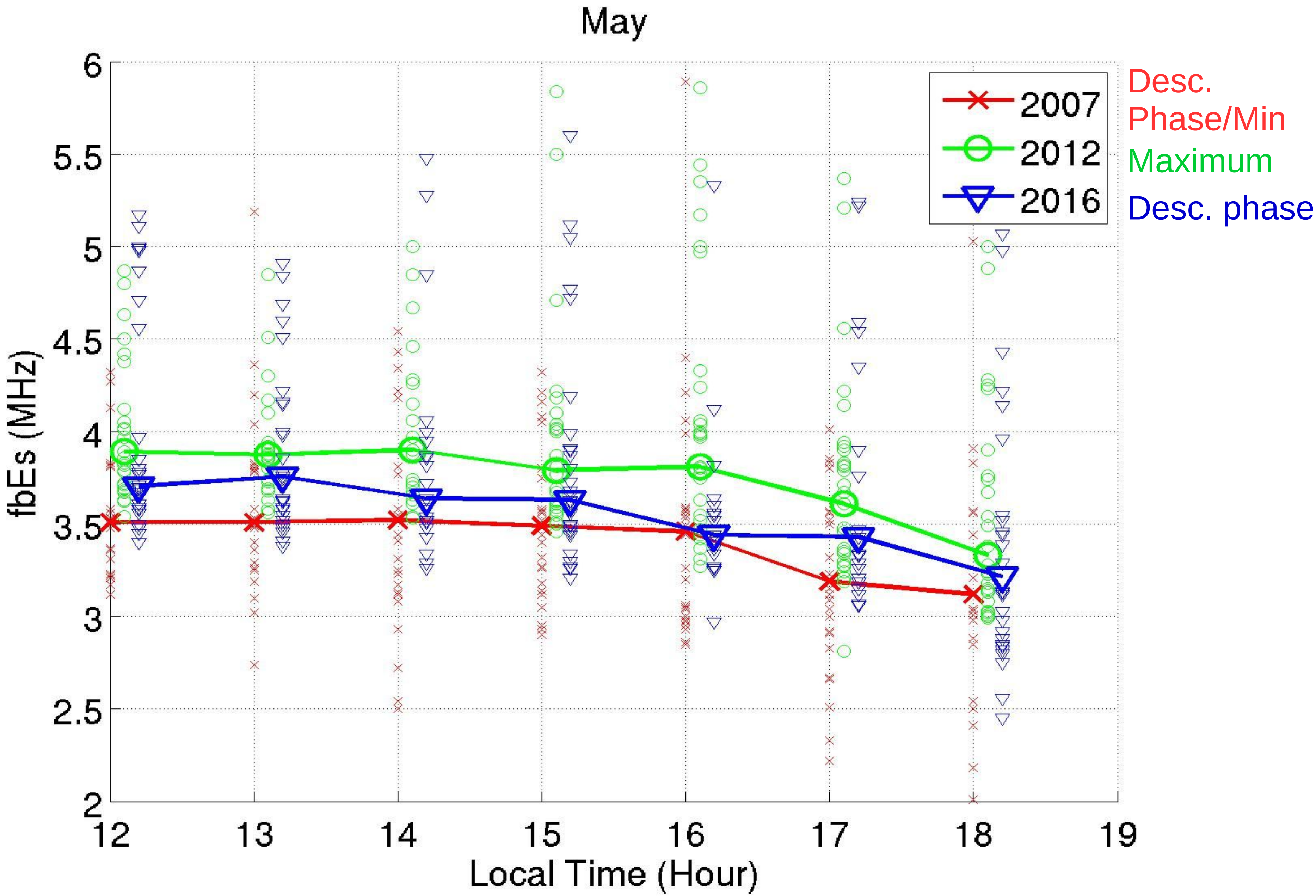
Period	Duration	Data	Level
2	28 June–2 July	[T, foEs]	10–0.1 hPa
		[w, foEs/hEs]	82–85 km
5	12 Jun–28 Jun	[w_m, foEs]	82–94 km
5	12 June–28 June	[w_z, foEs]	88–94 km
		[w_z, hEs]	
5	25 July–5 August	[w_z, foEs]	82–94 km
		[w_z, hEs]	
9	15 July–20 July	[w_m, foEs]	82–94 km
9–10	15 July–15 August	[w_z, foEs]	82–91 km
		[T(0.1 hPa), foEs]	65 km
		[w_z, foEs]	82–94 km
15	15 June–15 August	[w_z, hEs]	82–94 km

Eigen modes of planetary waves

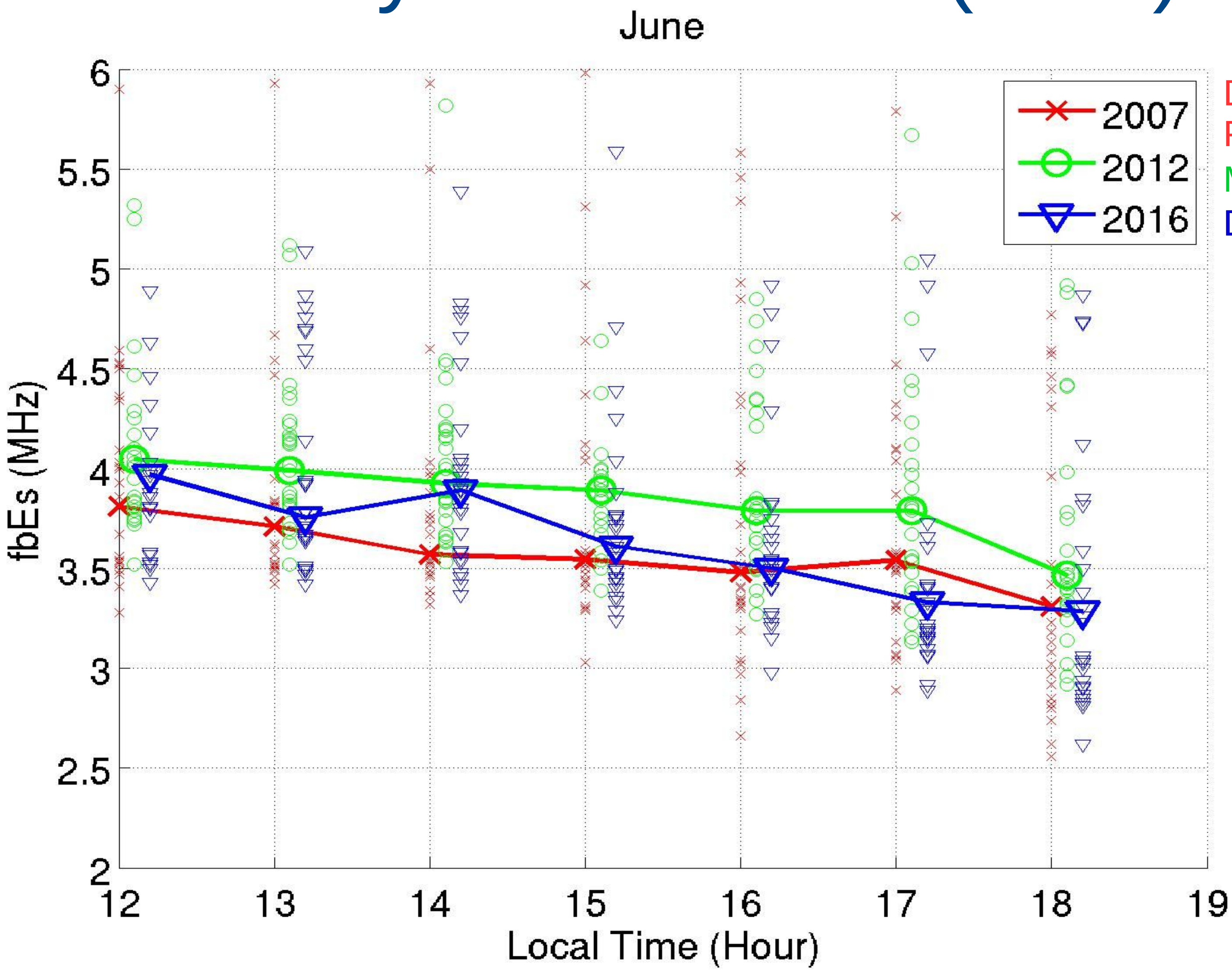
Solar cycle influence



Solar cycle influence (fbEs)

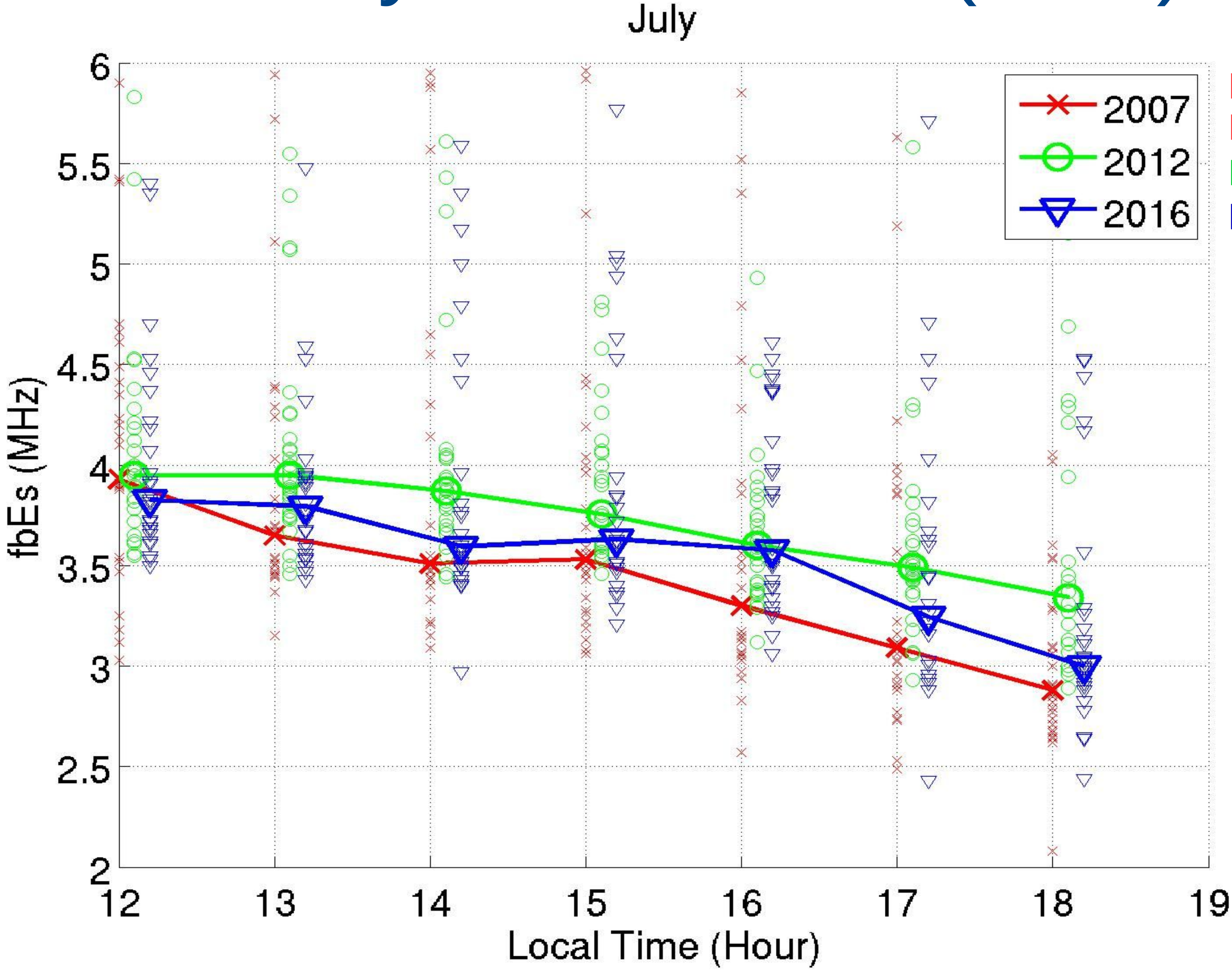


Solar cycle influence (fbEs)



Desc. Phase/Min
Maximum
Desc. phase

Solar cycle influence (fbEs)

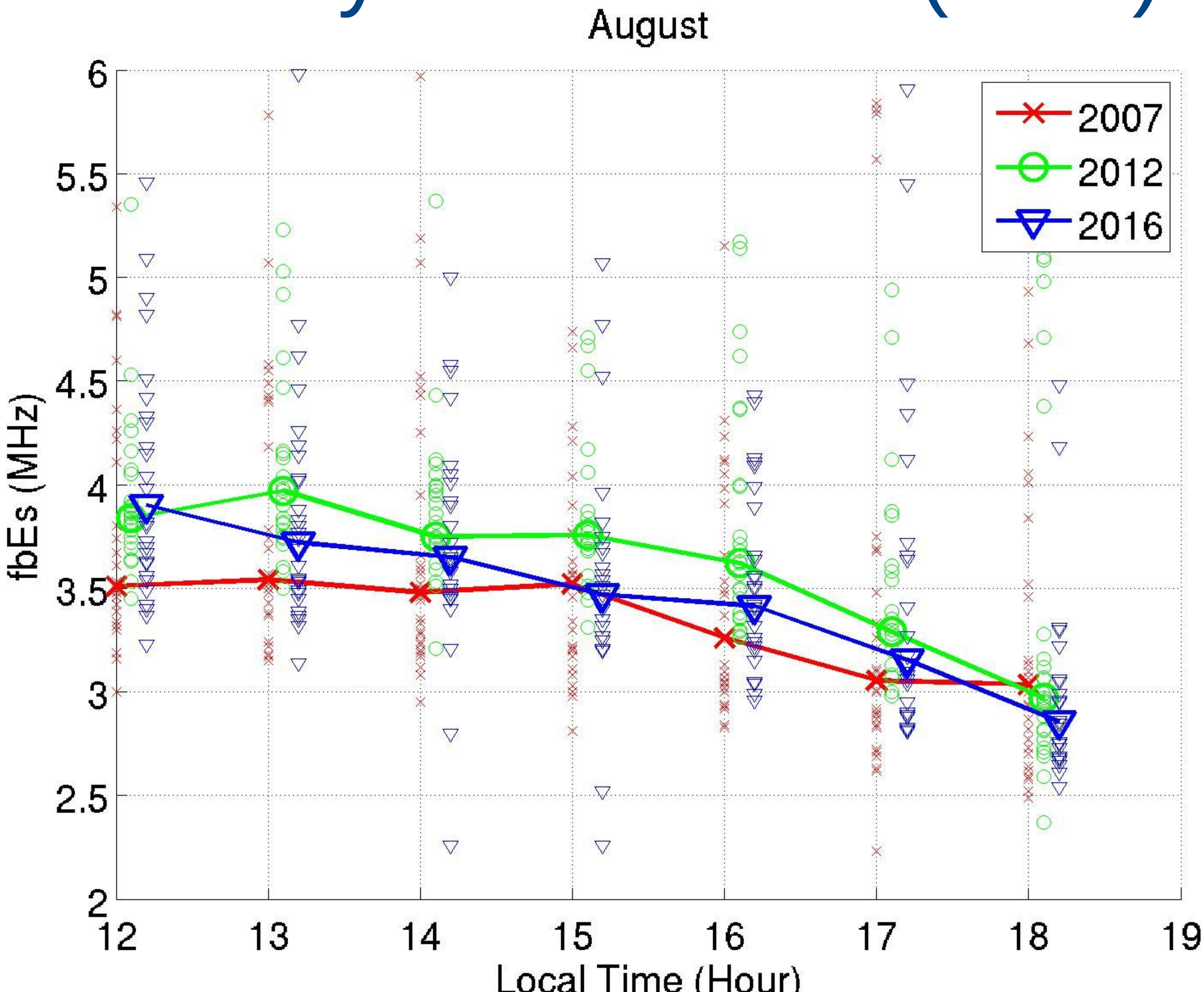


Desc. Phase/Min

Maximum

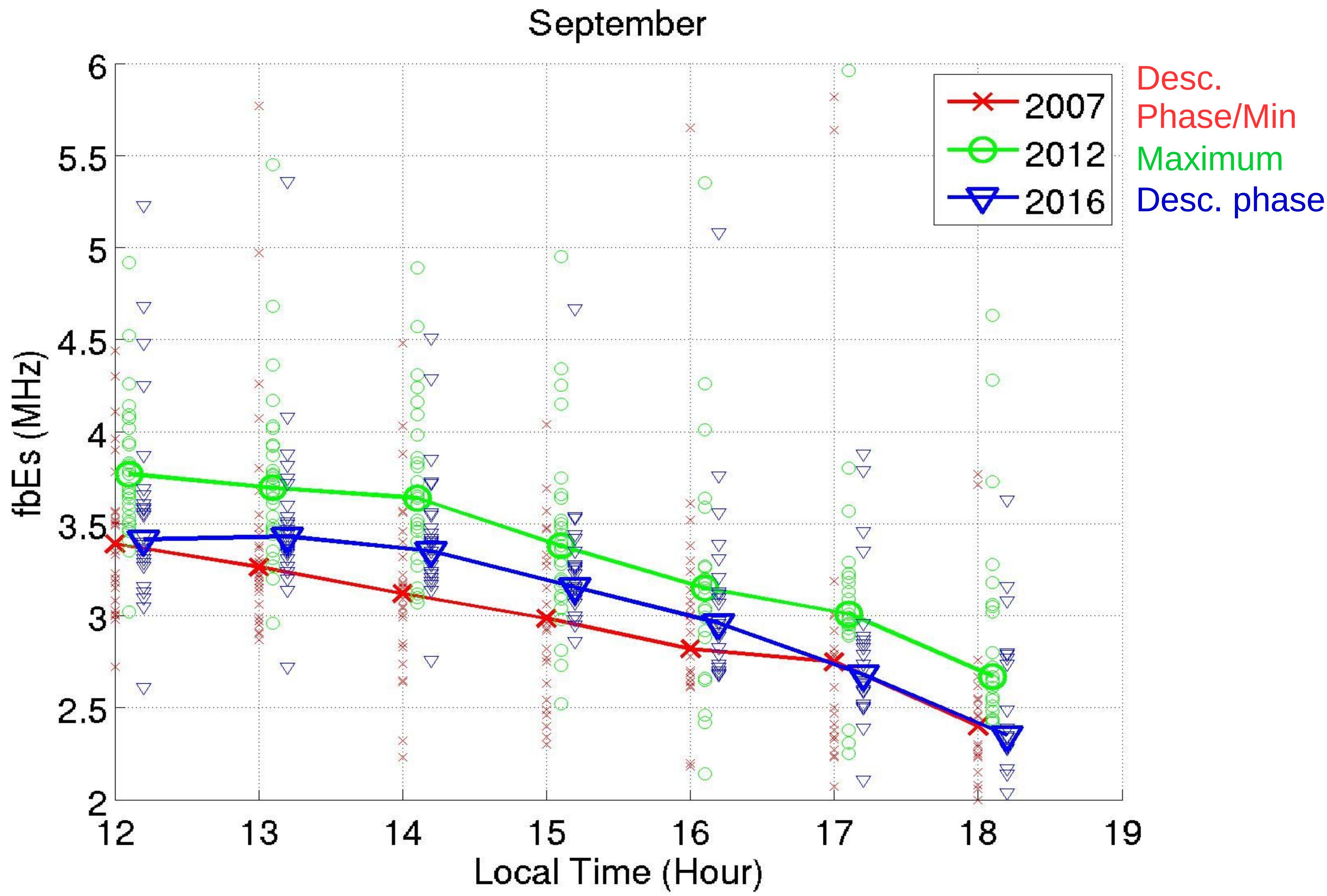
Desc. phase

Solar cycle influence (fbEs)

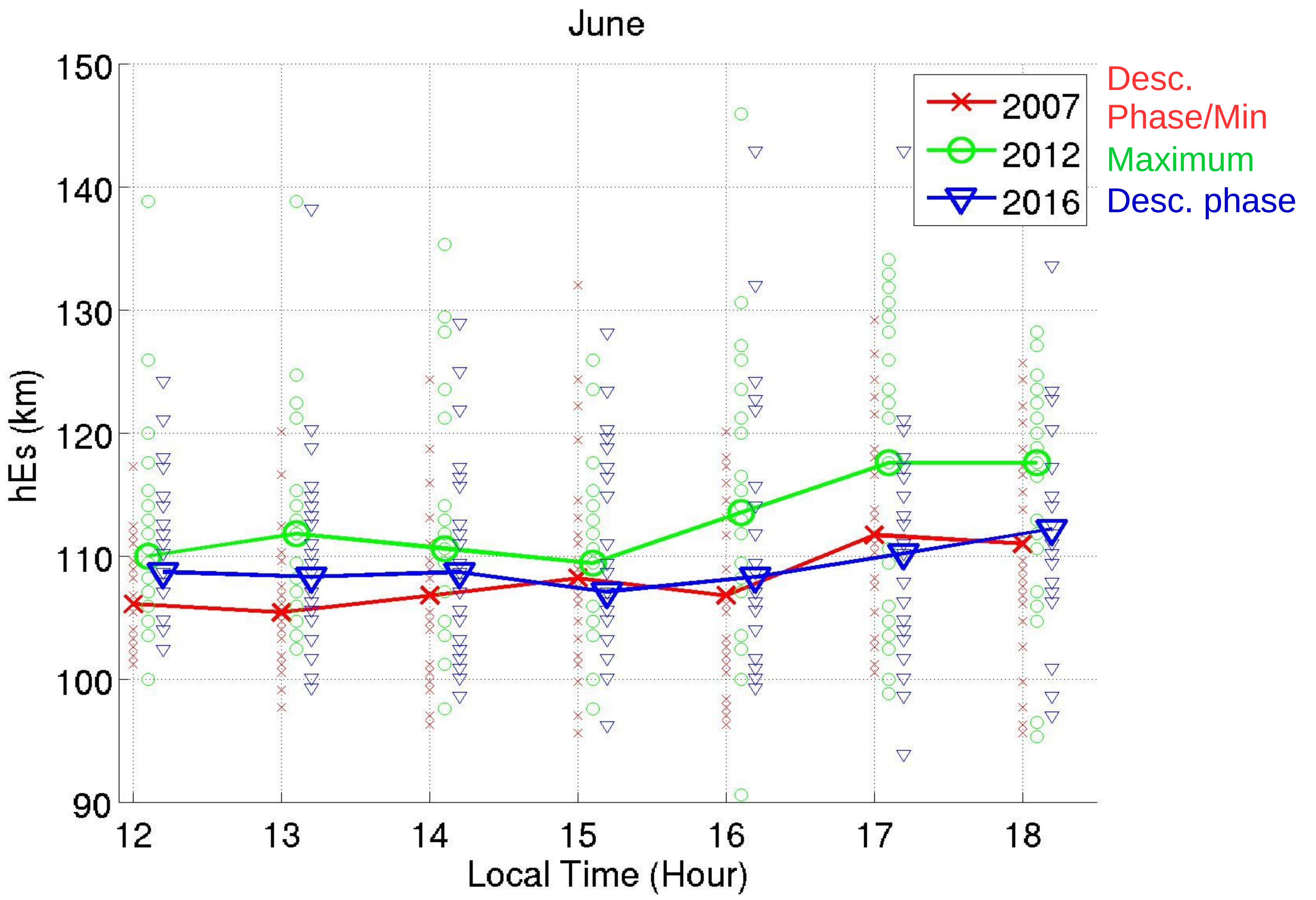


Desc. Phase/Min
Maximum
Desc. phase

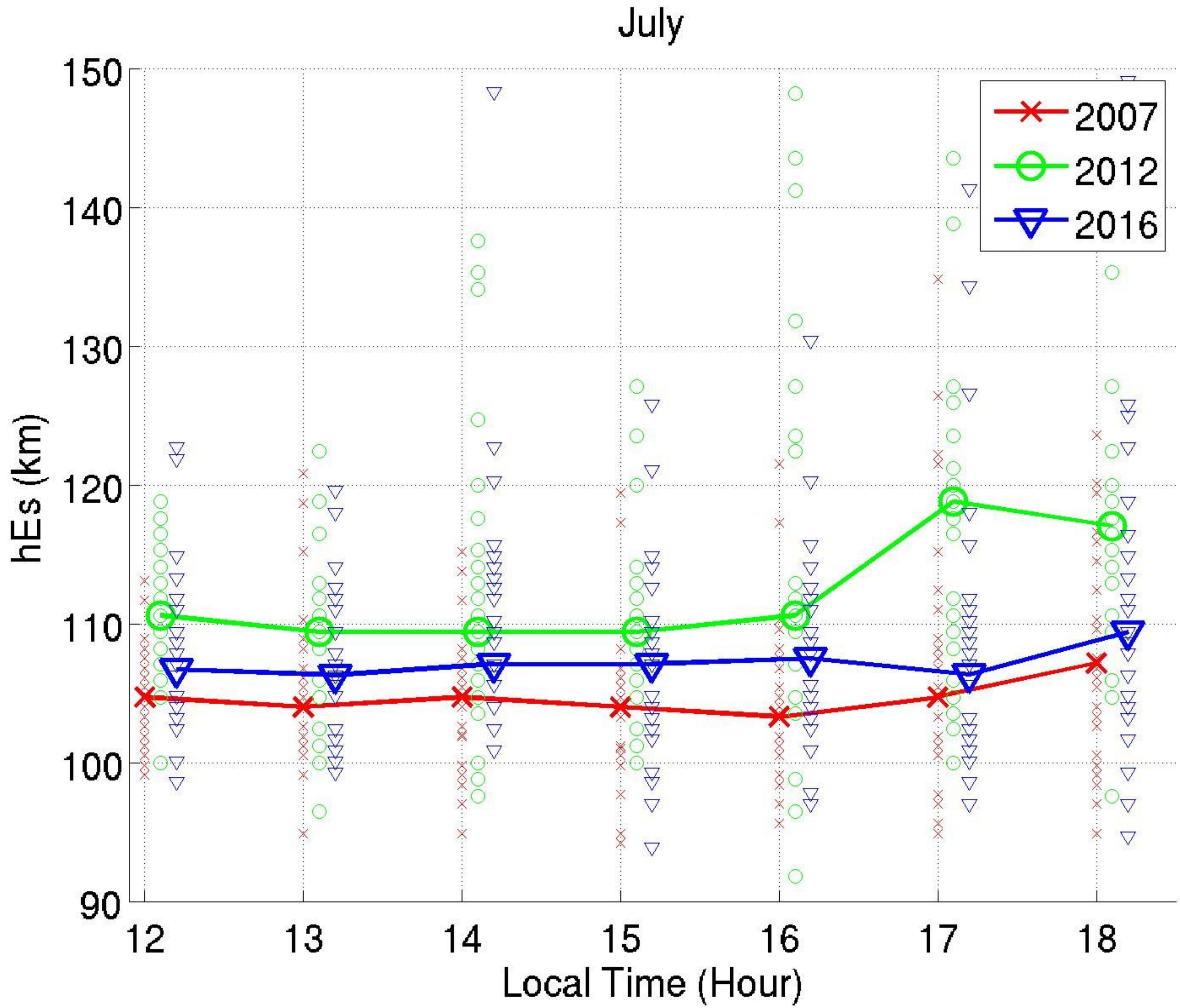
Solar cycle influence (fbEs)



Solar cycle influence (h'Es)



Solar cycle influence (h'Es)

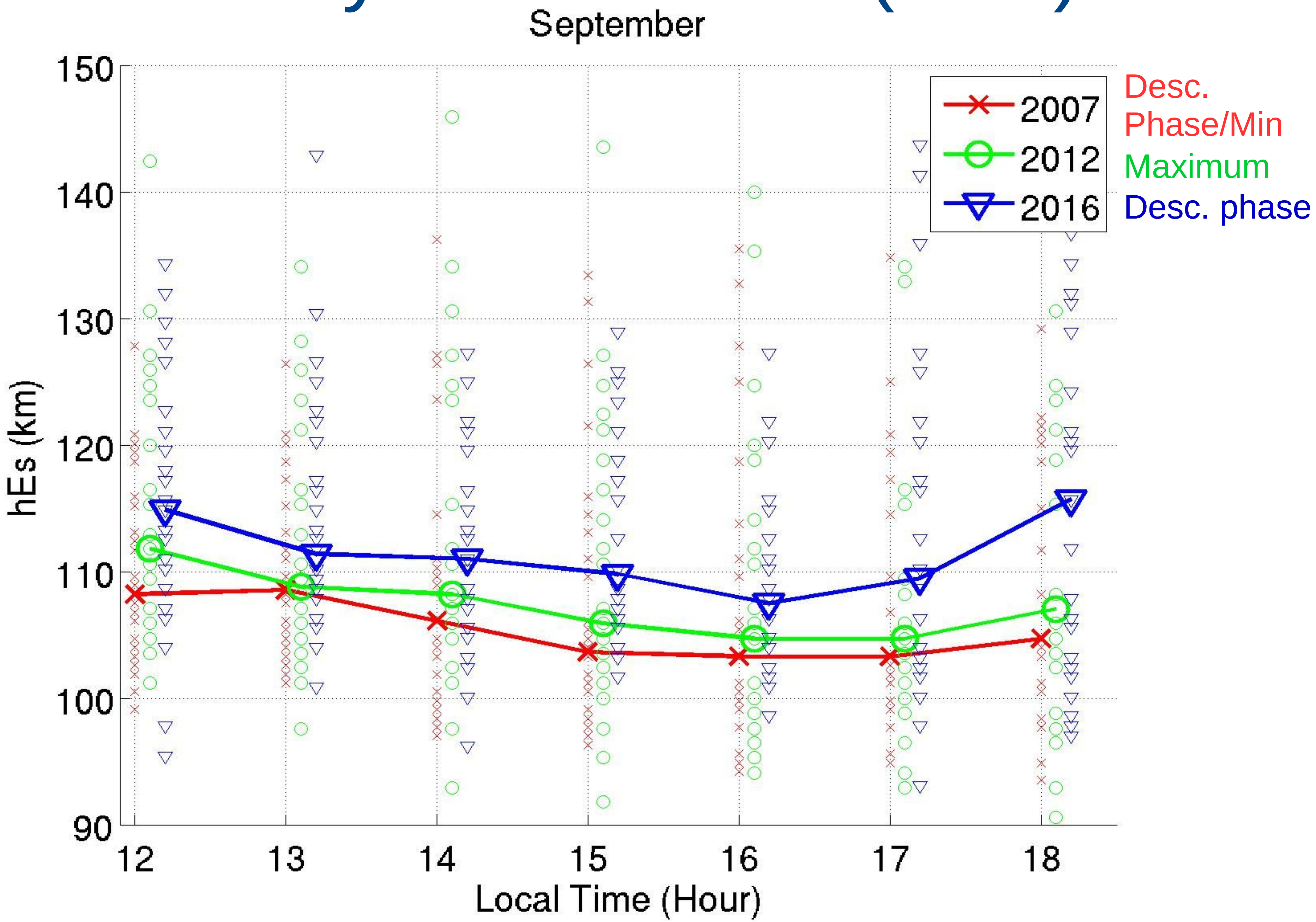


Desc. Phase/Min

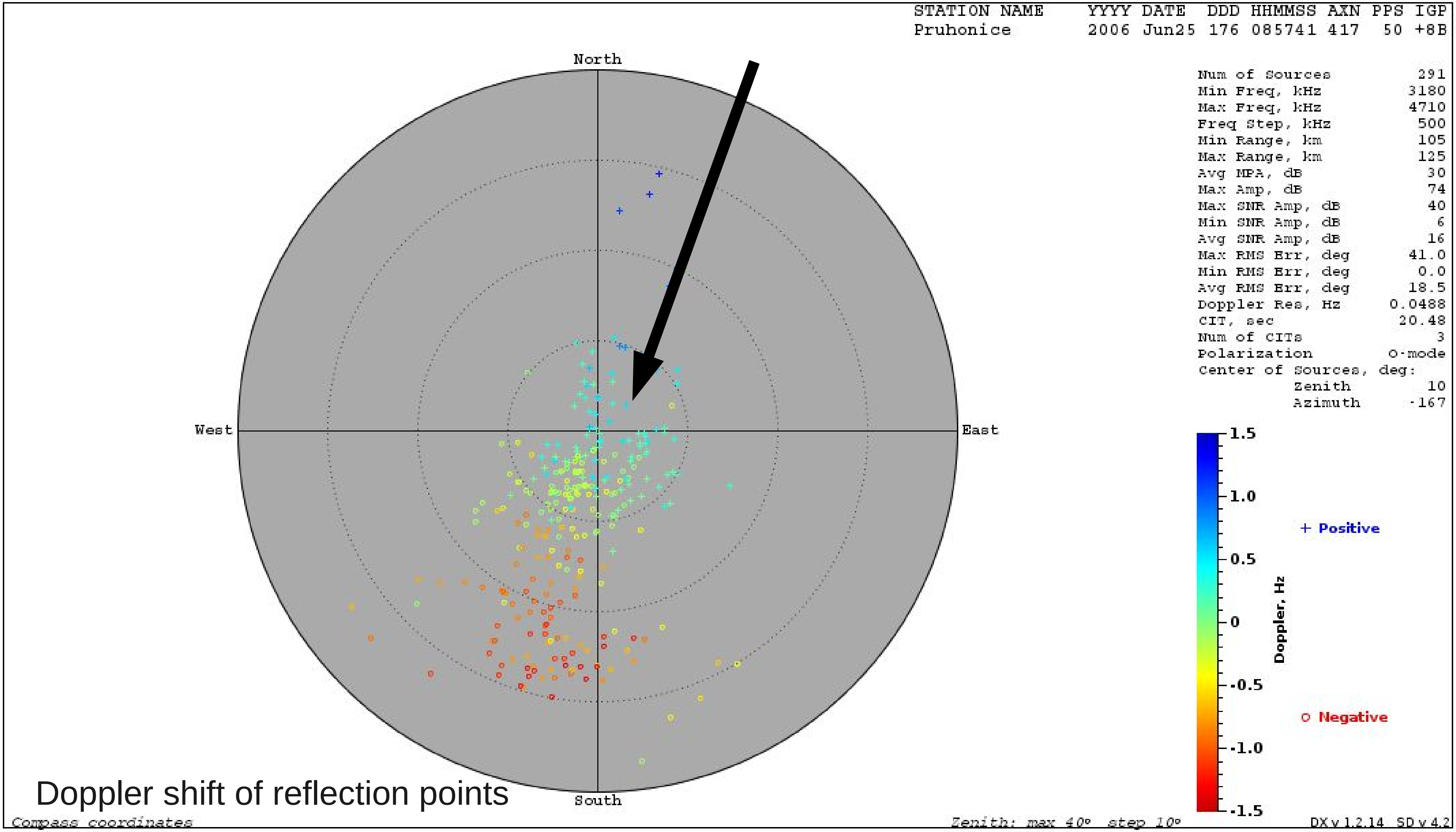
Maximum

Desc. phase

Solar cycle influence (h'Es)

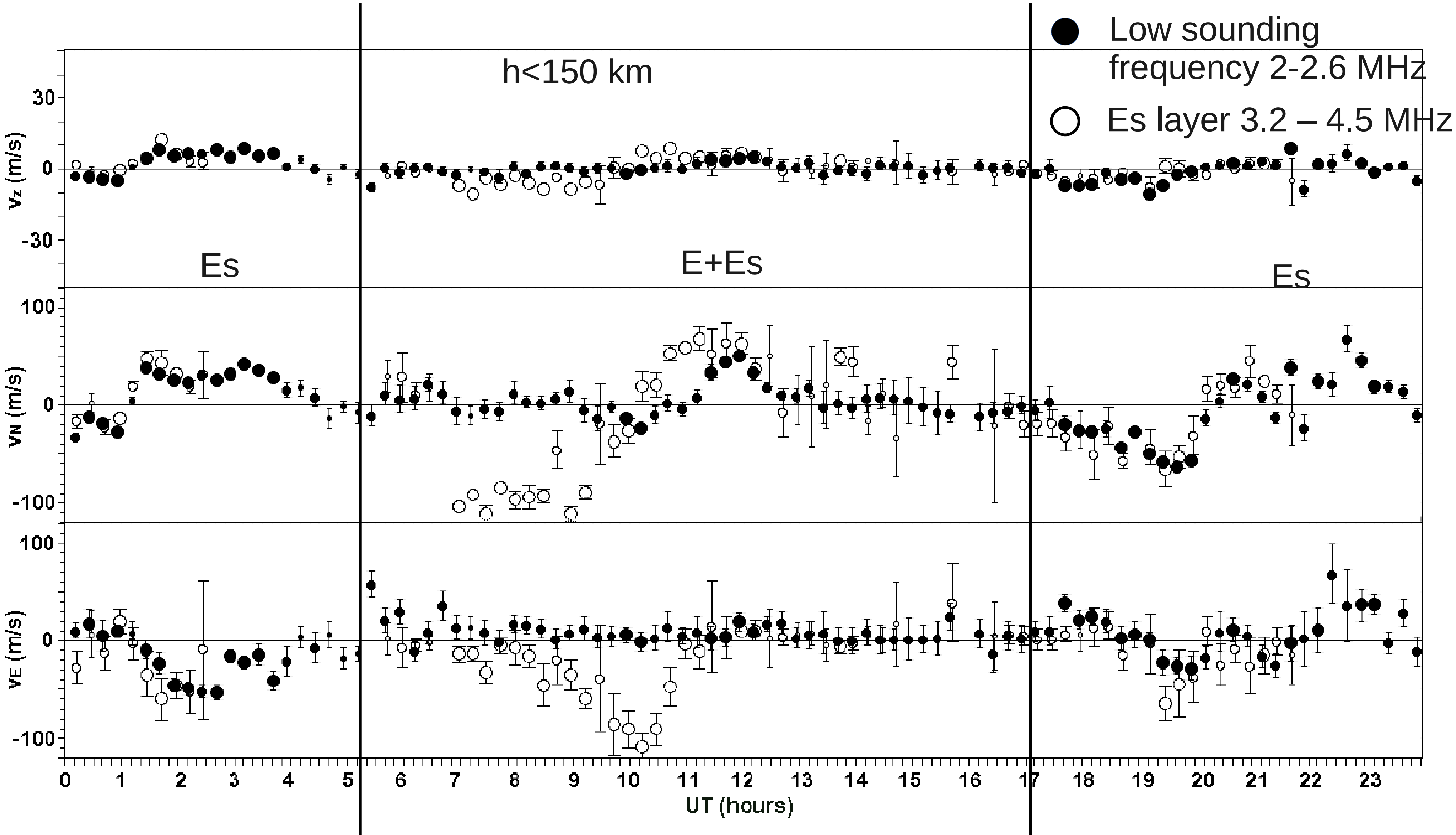


Digisonde Drift Measurement (DDM)



Doppler shift of reflection points

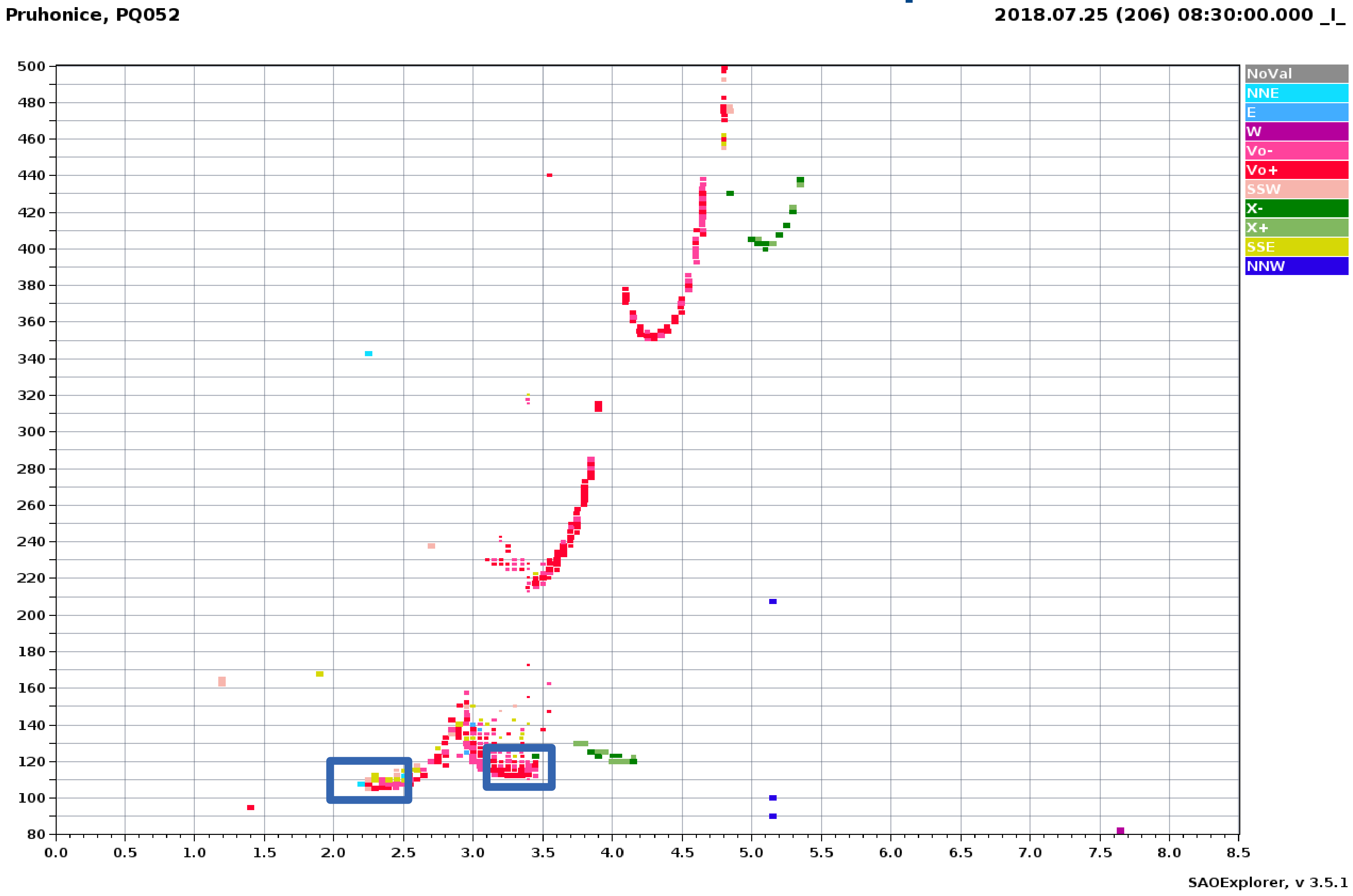
Digisonde Drift Measurement



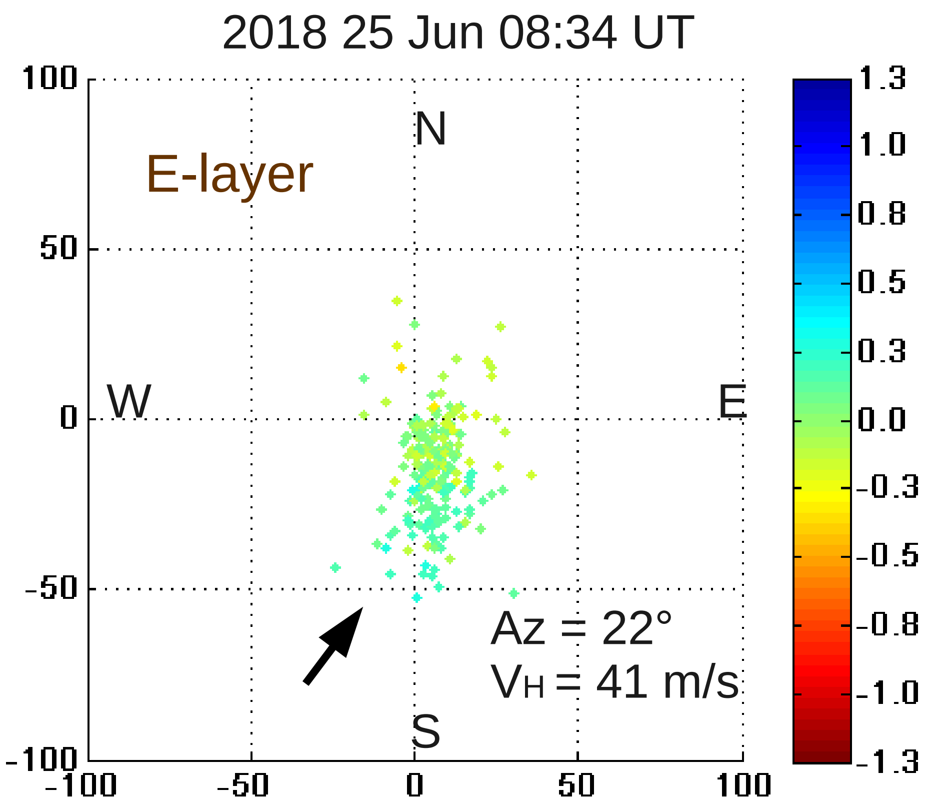
One-day E-region drift velocity components for June 25, 2006 (Kouba et al., 2009)

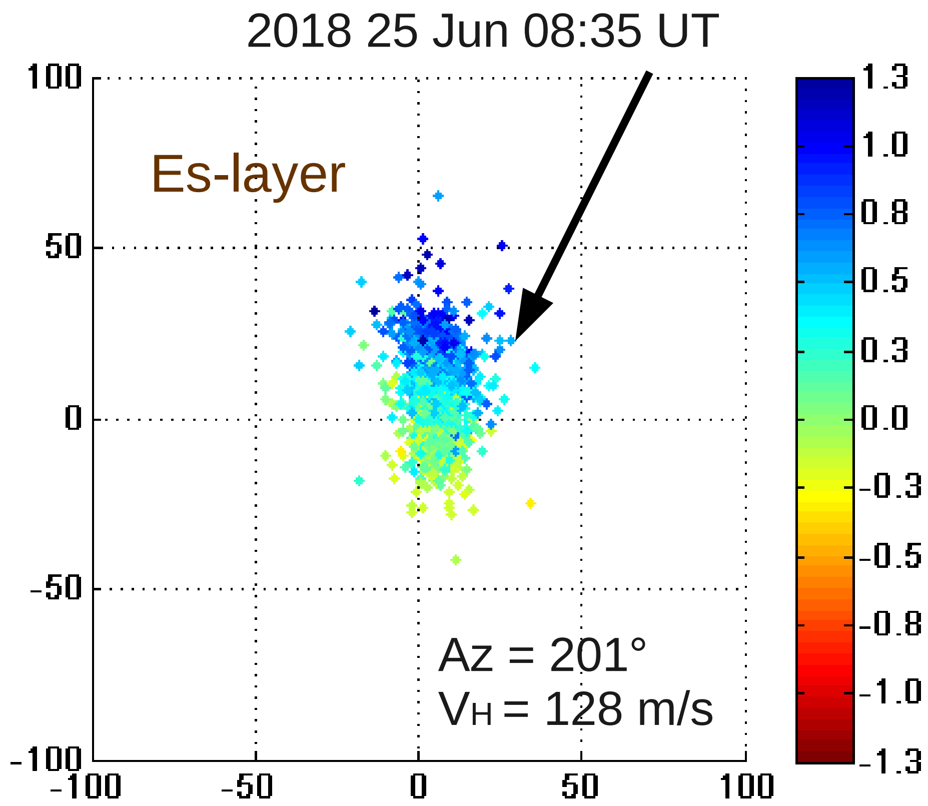
Quiet time (Kp 1)

DDM: E and Es comparison



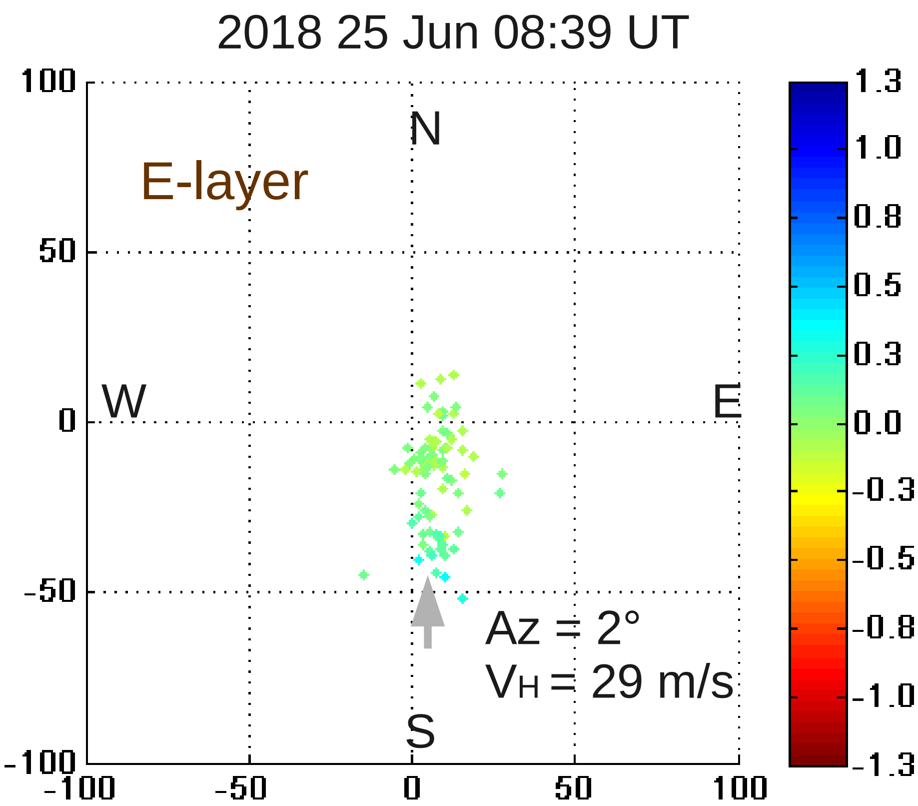
DDM: E and Es comparison (1)

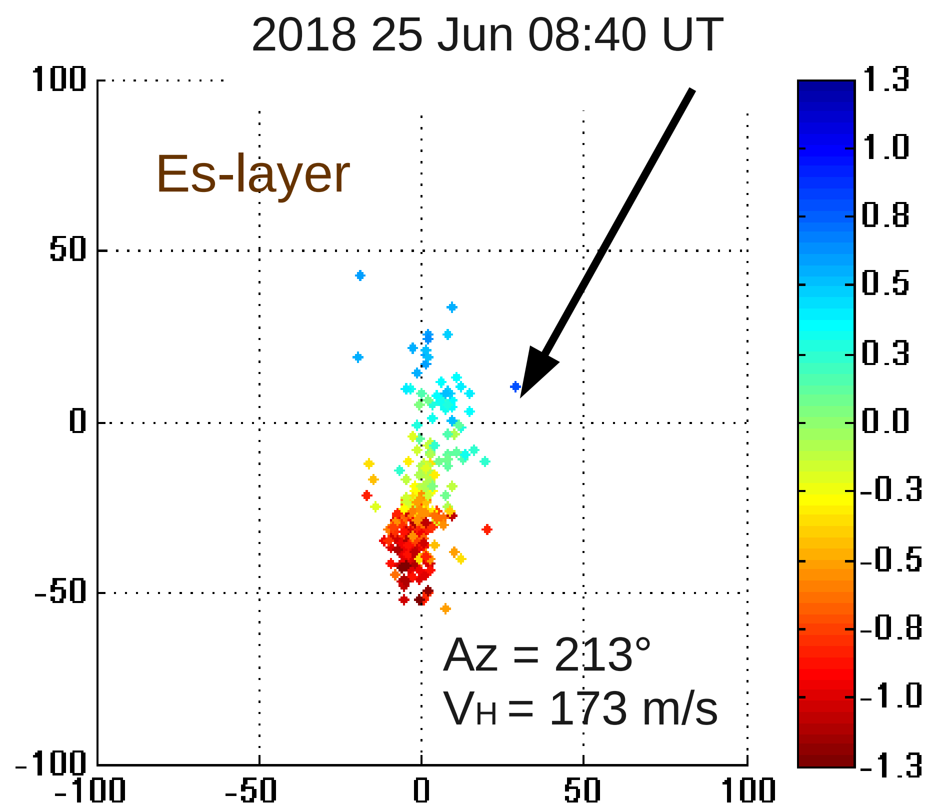




102 - 112 km	Height range	110 - 132 km
2.0 - 2.35 MHz	Frequency range	3.0 - 3.35 MHz

DDM: E and Es comparison (2)





102 - 112 km	Height range	112 - 140 km
2.05 – 2.35 MHz	Frequency range	3.2 - 3.45 MHz

Summary

- Tidal waves dominant in Es formation (foEs 8h, 12h, 24h; hEs 12h)
- Planetary waves influencing Es in range 2-16 days (eigen-modes of planetary waves)
- Good agreement between RO and DPS-4D
- Strong effect of phase of SC in fbEs / less pronounced in h'Es parameter
- Substantially different velocities in E and Es layers detected by DDM

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