ELF Whistler Dependence on a Sunlit Ionosphere

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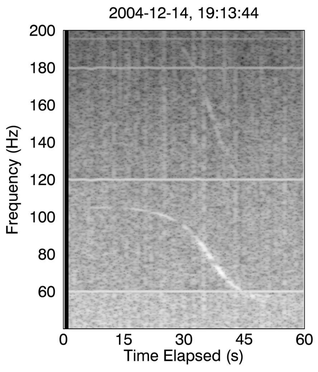
Abstract

Whistler-like spectral features in the extremely low frequency (ELF) range have been observed at the South Pole Station. Analysis of the first full year of data reveal a correlation between the occurrence of ELF whistlers and the solar zenith angle (SZA). ELF whistlers stop appearing for the duration of the polar winter, when the SZA increases to greater than 80°. Previous studies at lower geographic latitudes all observed a noon-time peak in the occurrence rate, which led to speculation of source mechanisms in the dayside magnetosphere. The extended polar winter allows for a separation of "dayside" and "sunlit" conditions. The absence of ELF whistlers in the polar winter implies that ELF whistler explicitly depend on local ionospheric conditions.

1. Introduction

ELF whistlers are narrow-band dispersive spectral features in the lower ELF range (1-250 Hz) that descend monotonically in frequency, typically over timescales on the order of a minute. Observations were first reported at auroral latitudes [Heacock, 1974], and have since been reported at mid-latitudes [Sentman and Ehring, 1994], low latitudes [Wang et al, 2005], and polar latitudes [Kim et al, 2006].



Sample power spectrum of ELF whistler from 14 December, 2014. Data is from E-W axis relative to the local magnetic field.

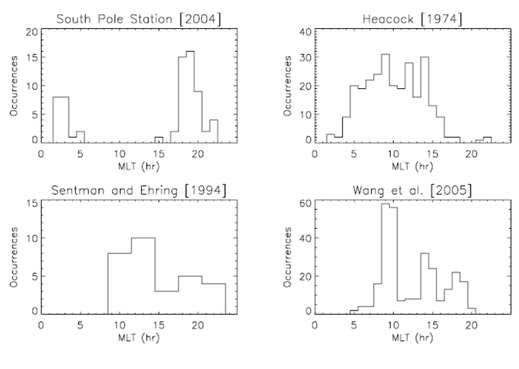


Figure from Kim et al. [2006] compares ELF whistler events as a function of MLT. All sub-polar locations all follow a diurnal pattern with a daytime peak occurrence

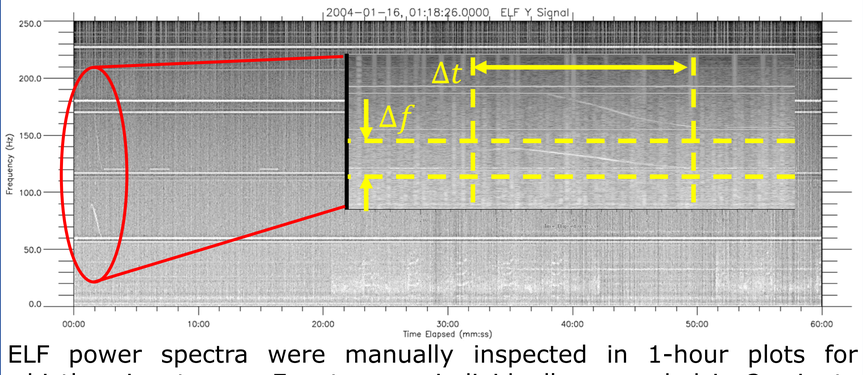
Wang et al [2011] demonstrated that ELF whistlers are most likely right-hand polarized ion cyclotron waves. However, there is still no established physical basis for why these signatures tend to appear only on the dayside.

The work in this poster examines the first full year of data taken at the geographic south pole and reveals behavior that appears to tie the occurrence of ELF whistlers to a sunlit ionosphere.

Objectives

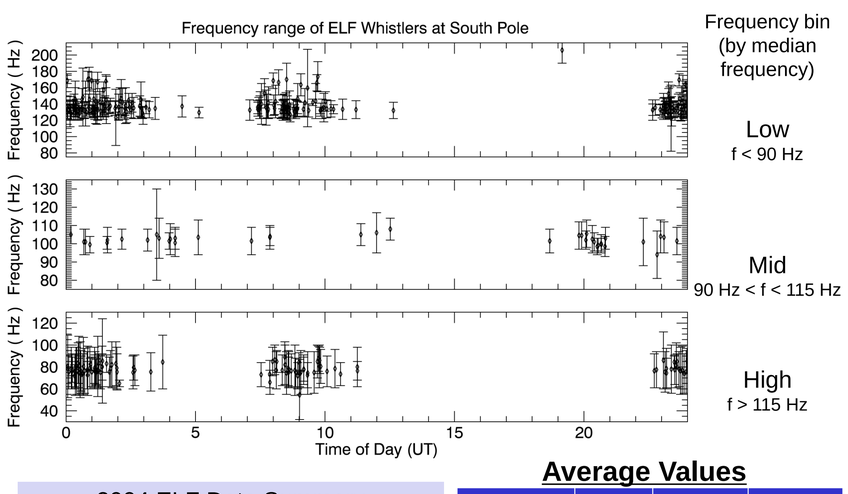
- Demonstrate connection between occurrence of ELF whistlers at the geographic south pole and a sunlit ionosphere
- Determine correlation between solar flux levels and the occurrence rate of ELF whistlers
- Examine ionosphere conditions during detection of ELF whistlers

2. Methodology



ELF power spectra were manually inspected in 1-hour plots for whistler signatures. Events were individually expanded in 2 minute spectra to determine Δf and Δt.

3. 2004 ELF Whistler Statistics



Frequency bin (by median frequency)

Low
f < 90 Hz

Mid
90 Hz < f < 115 Hz

High
f > 115 Hz

2004 ELF Data Summary

Data available: 94%

X Axis: 67% (37% in summer)
Y Axis: 94% (95% in summer)

ELF Whistler Events

identified: 342

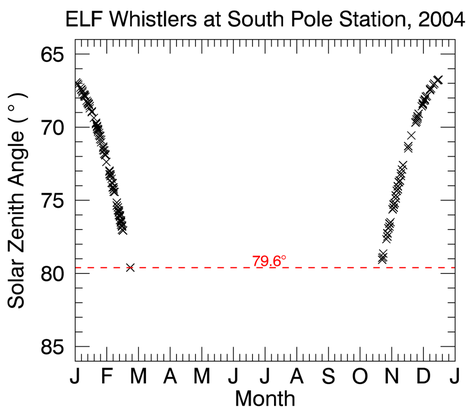
X Axis: 50% Y Axis: 100%

Average Values

Freq.	Low	Mid	High
Δt (s)	37	28	29
Min Δt	7	7	5
Max Δt	73	46	76
Δf (Hz)	32	15	25
High f	94	110	151
Low f	62	95	126
Δf/Δt	0.88	0.53	0.84

Caveat: An apparent drift in system time is corrected using 6 hour offset it 2nd half of year. Time offset is verified by technician records at SP station and corroborated by 2010 data set.

4. Initial results

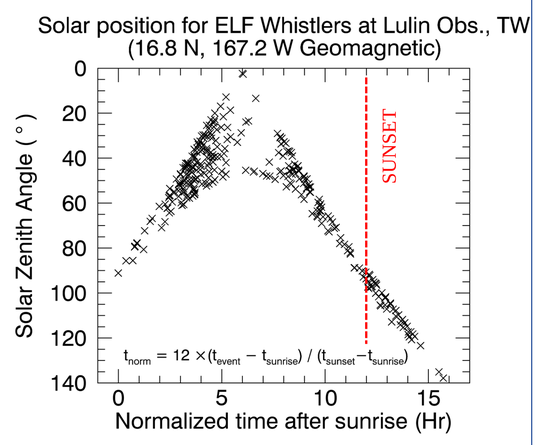


LEFT: Solar zenith angle (SZA) at the time of each ELF whistler detected at south pole station during 2004. Events are plotted as a function of the day of year. ***ZERO*** events occur when SZA > 80°

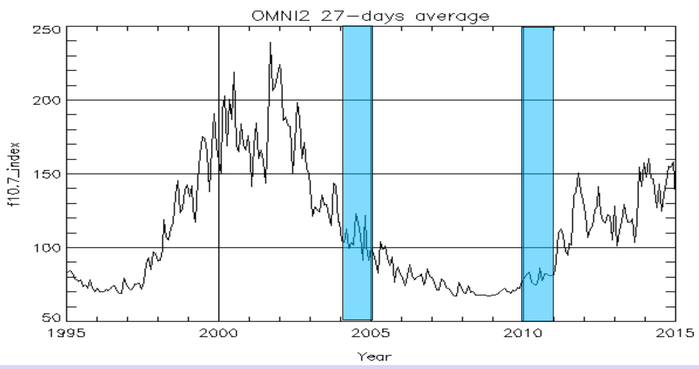
$$\cos\theta_{SZA} = \sin\Phi_{LAT}\sin\Psi_{DEC} - \cos\Phi_{LAT}\cos\Psi_{DEC}\cos\Lambda_{GHA}$$

θ_{SZA} = Solar zenith angle
Φ_{LAT} = Local geographic latitude
Ψ_{DEC} = Solar declination
Λ_{GHA} = Greenwich hour angle

RIGHT: Solar position for 310 ELF whistlers detected at Lulin Observatory, Taiwan from 2003-08-23 to 2004-07-12. Whistlers only appear after local sunrise each day (SZA < 90°) but persist after sunset.



5. Comparison to F10.7 solar flux index

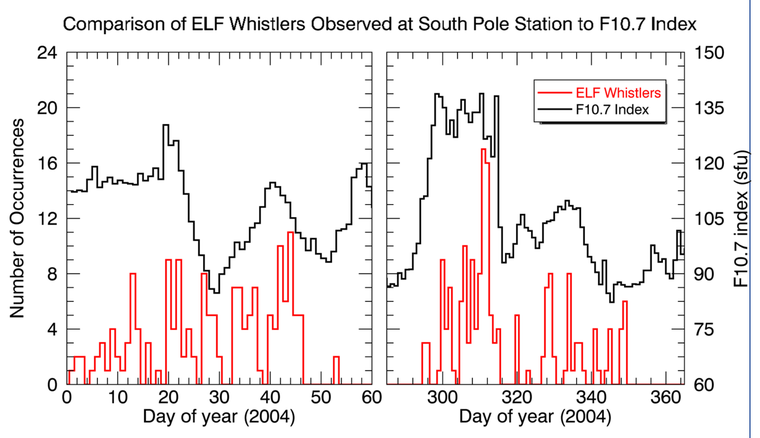


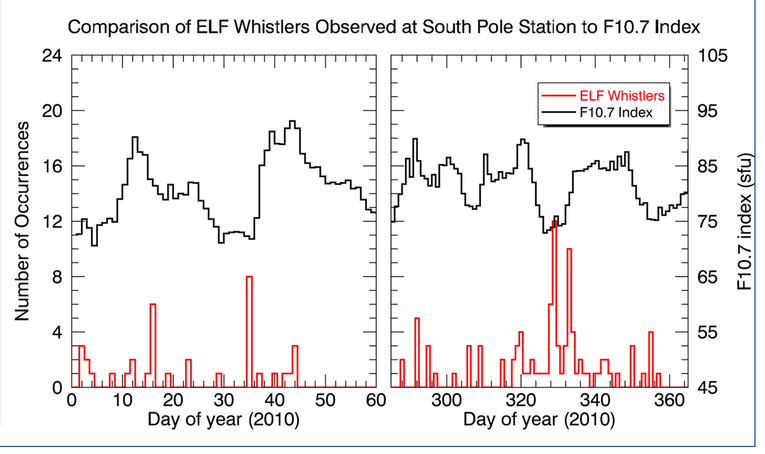
ABOVE: F10.7 solar flux index is used as a proxy for solar activity. Blue boxed areas highlight the point in the solar cycles where index values are used to compare with ELF whistler database.

RIGHT: F10.7 daily values are compared to daily occurrence rate of ELF whistlers at South Pole Station during 2004 and 2010, summarized in table:

Year	Days	Correlation	F10.7 Ave	# Whistlers/Day
2004	1-53	0.32	107.1	3.11
2004	285-365	-0.20	104.6	2.16
2010	1-53	-0.05	80.5	0.68
2010	285-365	-0.02	81.7	1.21

On a daily time scale, there is basically *no correlation* between solar flux levels and ELF whistlers. On a yearly time scale, ELF whistlers occur *less frequently* at times of *lower F10.7 flux levels*.

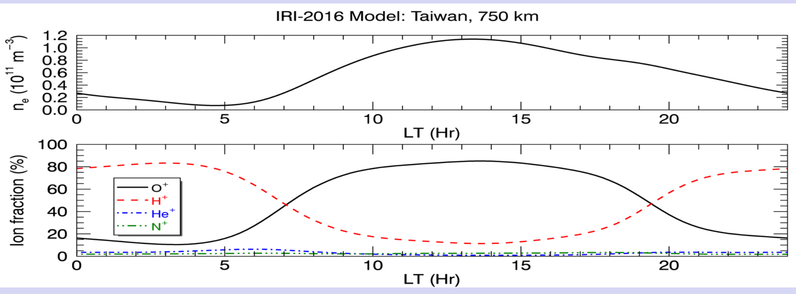




6. Comparison with IRI

IRI 2016 Model Inputs

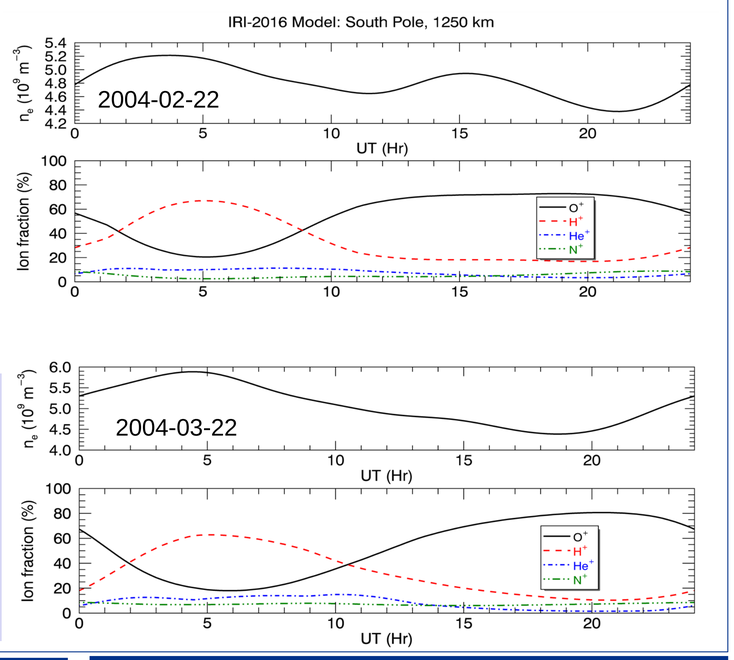
RIGHT: 90.0° S, 0.0° Geographic, 1250 km (2004-02-22, 2004-03-22)
BELOW: 23.5° N, 120.9° E Geographic, 750 km (2004-02-22)



Low latitude ionosphere (above) shows similar behavior as Wang et al. [2011] Figure 3. The dominant species during the day is O^+ at altitudes above the F-peak.

The ionosphere at the South Pole (right) experiences a similar transition in dominant ion species that is observed at higher altitudes.

- Peaks in occurrence of ELF whistlers align with transition times of dominant ion species between H^+ and O^+
- Ion composition transition still occurs after ELF whistlers stop appearing (03/22), which implies that other factors must still be important



7. Bimodal/Diurnal Behavior

Prior ELF whistler observations exhibit a diurnal variation in the occurrence times, which fits with the connection to a sunlit ionosphere. The south pole data also displays a diurnal pattern, but the SZA is nearly constant over the course of a single day. So what changes?

The orientation of the geomagnetic south pole (GMSP, 79.8° S, 108.2° E) relative to the sun changes as it rotates about the geographic pole.

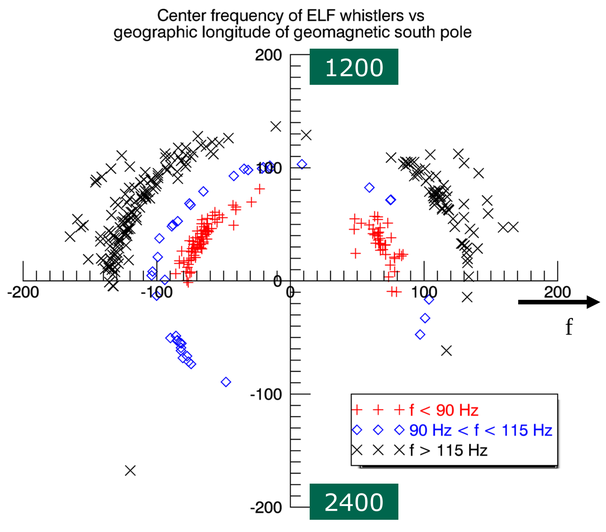
Geomagnetic Pole Location Calculation

$$\theta_{LT} = 2\pi\frac{UT}{24}$$

$$\theta = \theta_{GMSP}\left(\frac{\pi}{180}\right) - \theta_{LT}$$

ELF whistlers primarily observed when GMSP in dawn/dusk sector

Post-noon gap matches result from previous studies (e.g. Wang et al [2005])



ELF whistlers with a mean frequency below 90 Hz or above 115 Hz appear almost exclusively when the geomagnetic south pole is on the dayside

8. Conclusions

- ✓ ELF whistlers are connected to the *effects* of a sunlit ionosphere
- ✓ Higher solar flux levels (as illustrated by F10.7 solar flux index) increase probability of occurrence
- ✓ Trends in ionospheric composition during occurrence of ELF whistlers matches at both low and polar latitudes

Outstanding Questions:

What causes daily change of ion composition at south pole?

Why does diurnal variation of ELF whistlers track the dayside location of geomagnetic south pole?

What is different about events in 100 Hz bin that causes the cluster in the post-midnight sector?

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