Study of the NWC Electron Belts observed onboard DEMETER Satellite

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For 2nd DEMETER workshop, 10-12 OCT 2011

Outline

- Physical Motivation - previous works
- NWC electrons

  -- Statistical analysis of the NWC electron fluxes

  -- Spatial distribution of NWC electron belts

  -- Variation of energy spectrum along with L shell

  -- Comparison of day/night energy spectra
- Summary and discussion

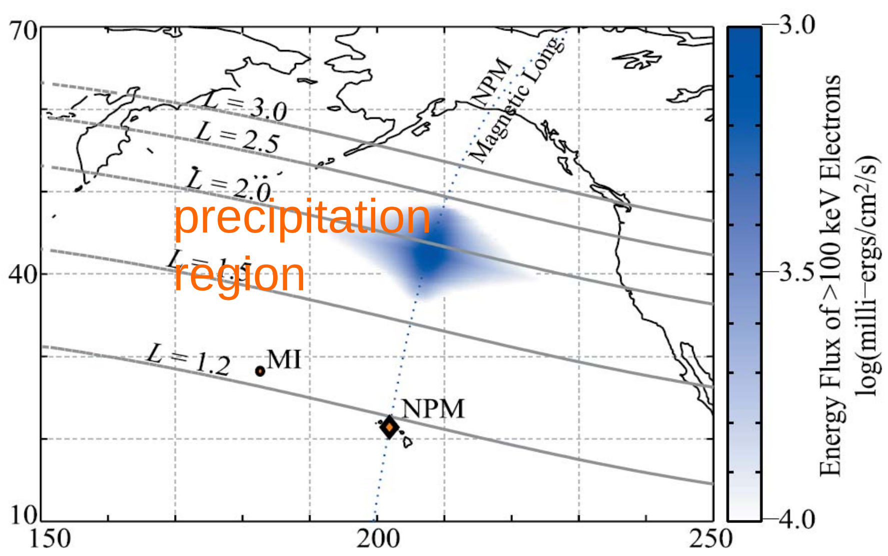
  -- What we know from this analysis

VLF man made electrons precipitations -- Previous works

Midway Island –NPM experiment

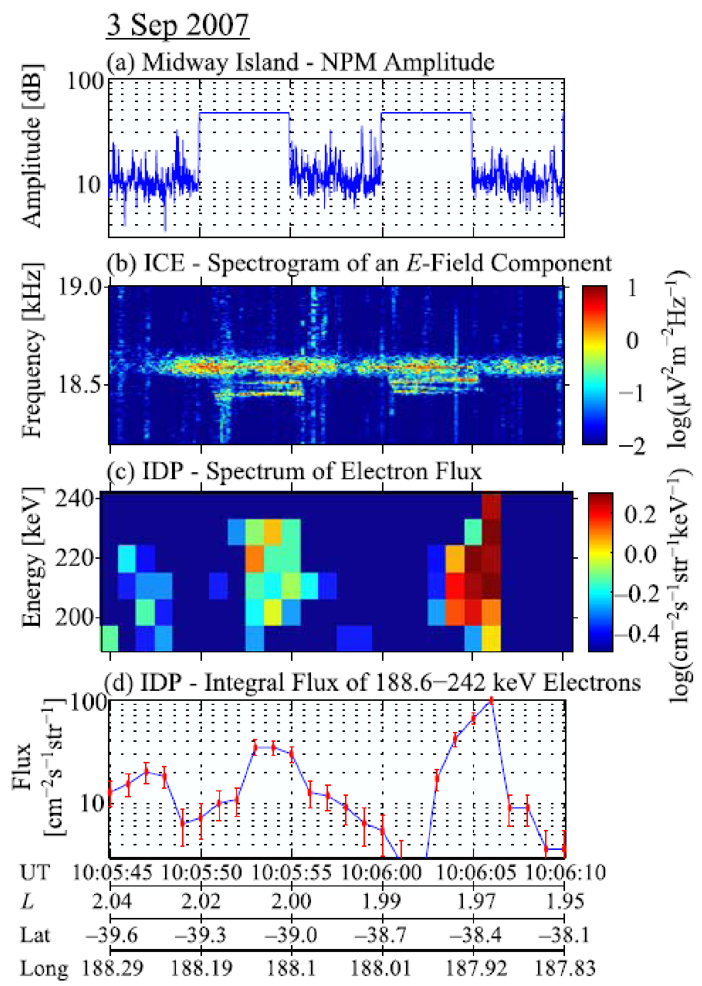
Inan U. S, et al., GeoPhy. Res. Lett., 34, L02106, 2007.

Graf K. L, et al., J. Geophys. Res., 114, A07205, 2009

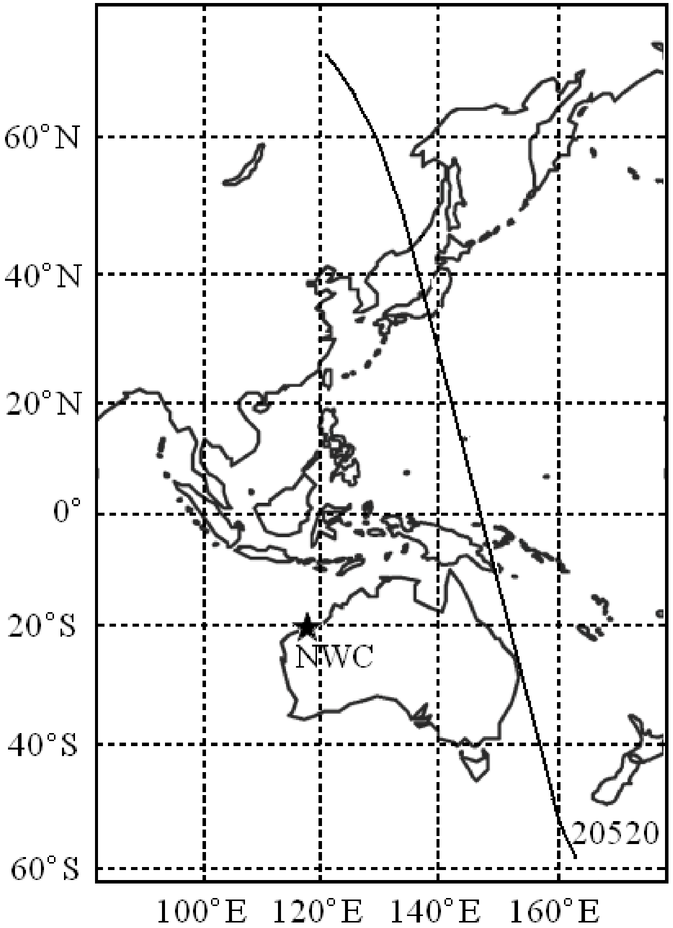


The majority of the transmissions were keyed in a 5-sec ON/5-sec OFF format.

If both one-burst and two-burst events are counted, the detection rate is still only 13.9%.



NWC Transmitter station



- 21.8° S，114.5° E
- 19.8 kHz， Δf ~300Hz
- Emission power：1 MW
- Demeter project: L~1.42 (tbc)

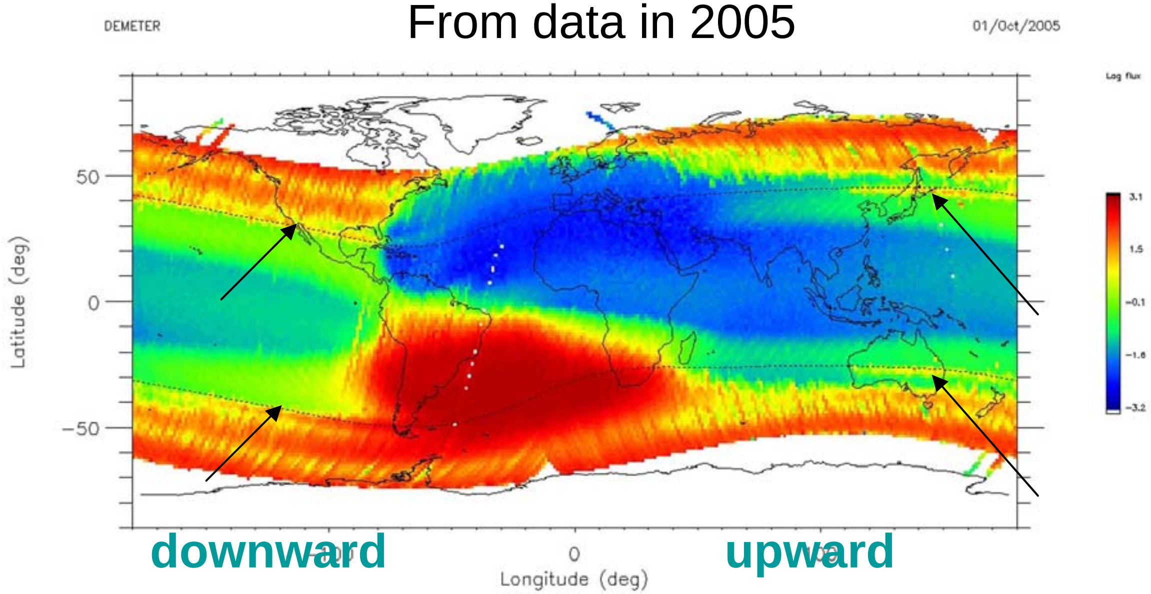
Why it is so motivative:

- Good location,
- Narrow band width
- Big power
- Good example to study -- wave-particle interactions
- Ducted propagation

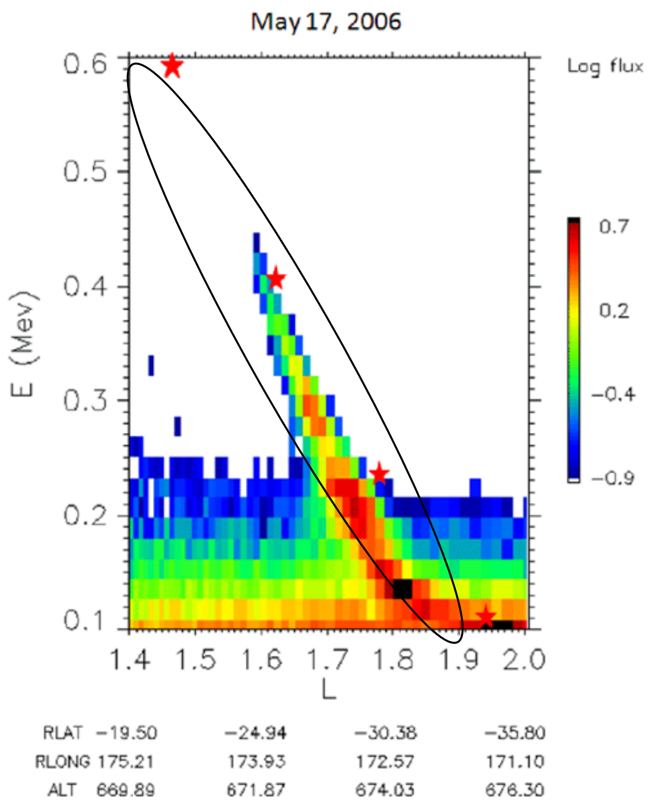
Previous work

electron precipitation due to NWC VLF transmitter

From data in 2005



downward upward



Wisp structure

Sauvaud J.-A., R. Maggiolo, et al., Geophys. Res. Lett., 35, L09101, 2008.
Rory J. Gamble, Craig J. Rodger, Mark A. Clilverd et al., 2008

Our work

An independent analysis to make systematic analysis about:

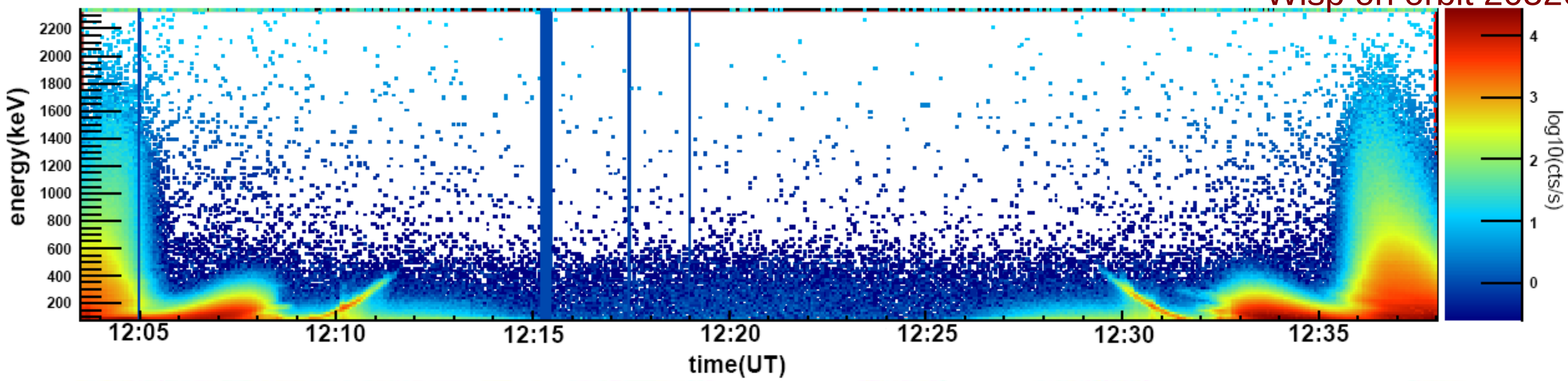
- NWC electrons spatial distribution
- Energy spectra of electrons in drift lose cone – wisp – NWC electron belts.

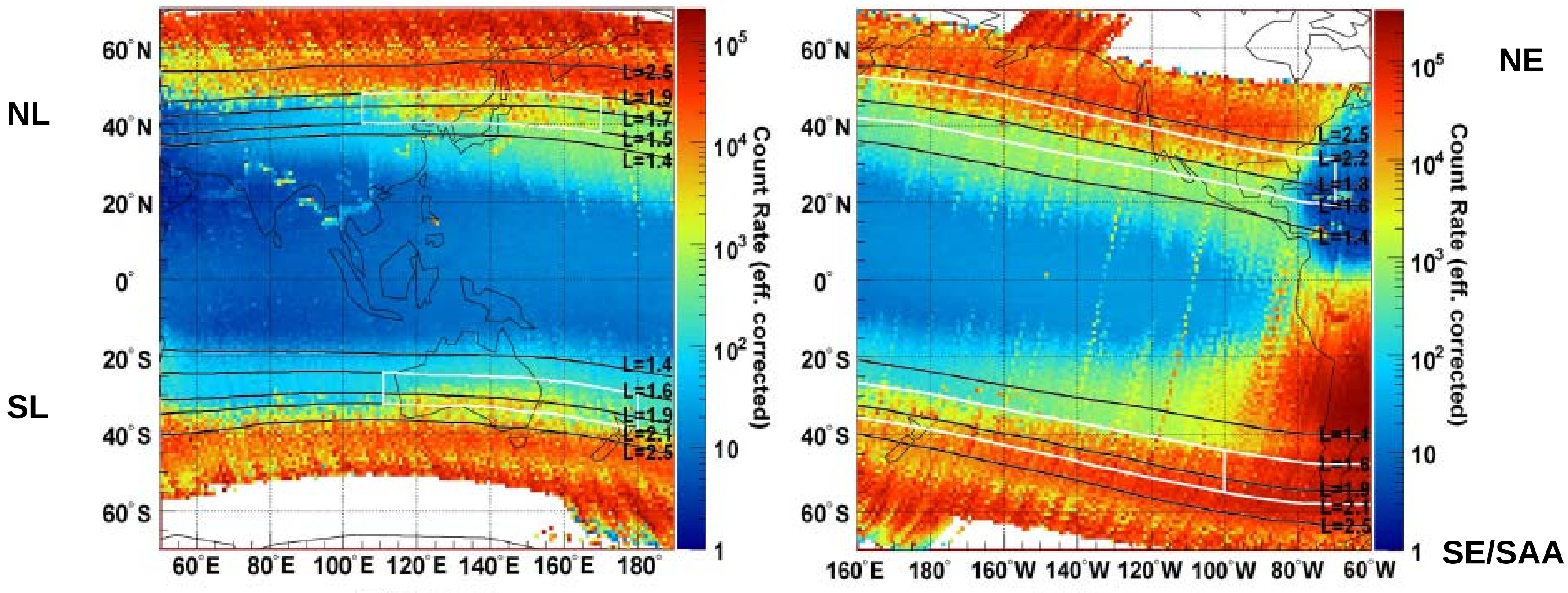
– statistically dynamic property of NWC electrons

(arXiv:1012.1439V2, in modification)

Statistical analysis of the NWC electron flux

Wisp on orbit 20520





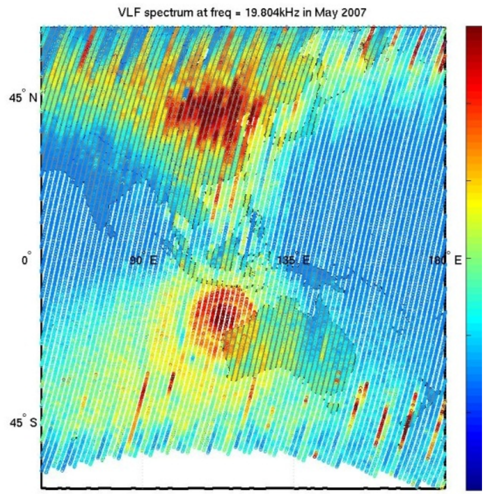
(a) Upward

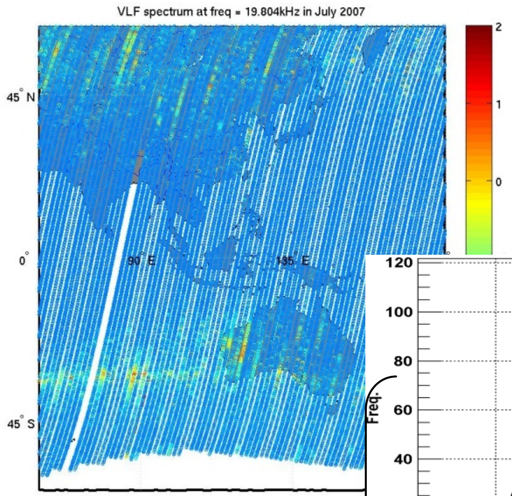
(b) Downward

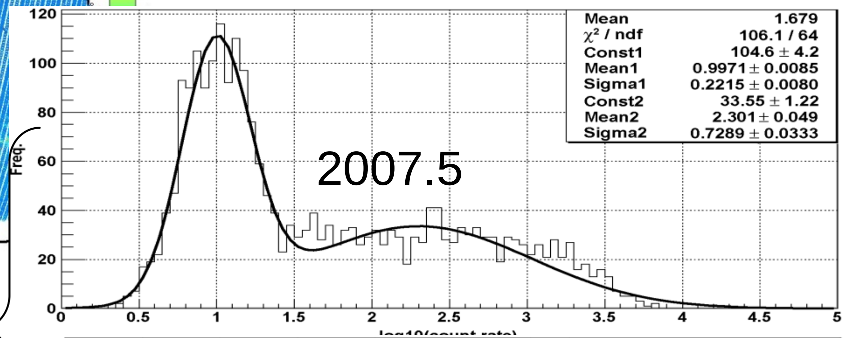
The electron flux distribution with the energy range 108-411keV for observations in 2008.

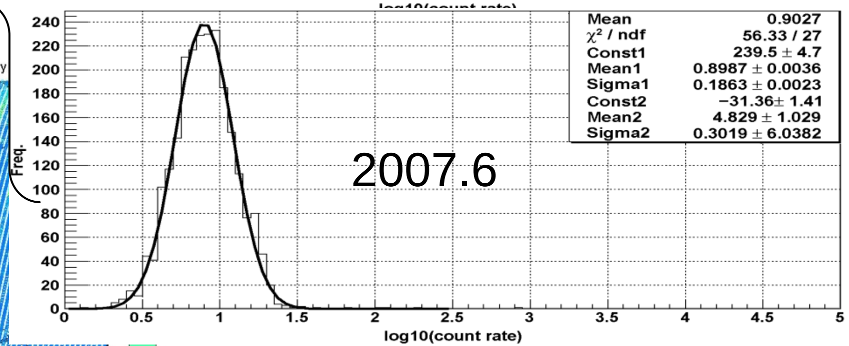
NWC VLF map by DEMETER

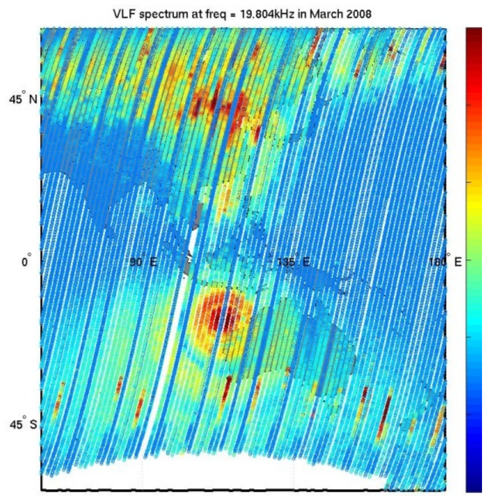
2 components Particles
when NWC was on

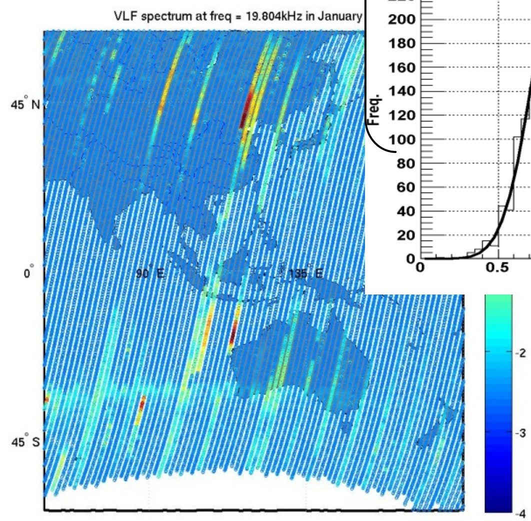


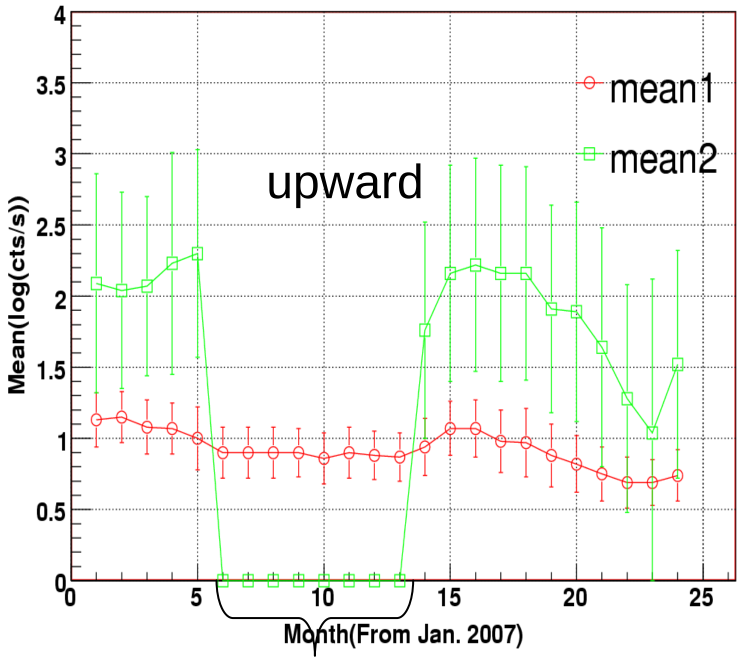


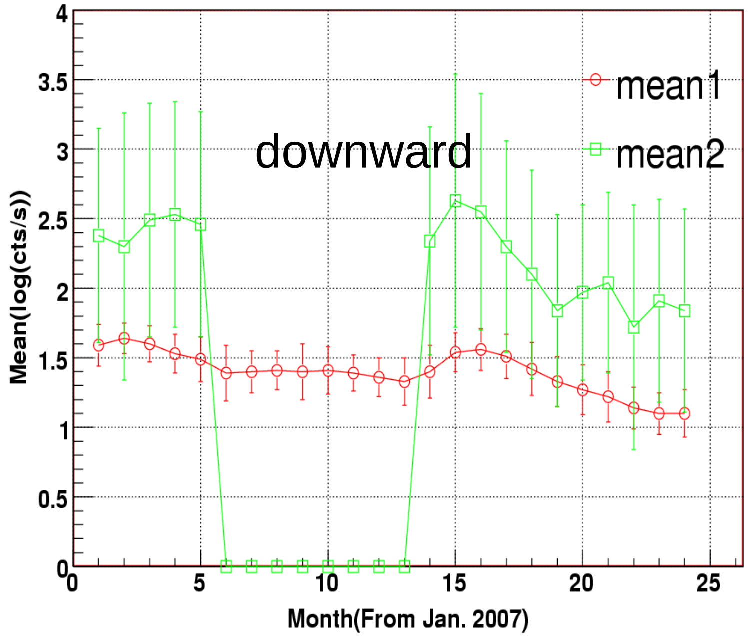












VLF electron belts vanished from June 2007-January 2008.

Green – electron belts

The Gaussian fit result of the electron belts in 2007-2008 for each of individual months

What we do with the NWC belts?

- NWC ON：
  - 2007.3~5 & 2008.3~9 (**10 months** totally)
  - Orbit number：14172-15668 & 19476-22740 (total: **4762**)
- NWC OFF：
  - 2007.7~2008.1 (**7 months** totally)
  - Orbit number： 15958-19148 (Total: **3191**)
- accumulate to get average counting rate in each of investigated range, to get signal by on-off method to subtract background.

  -- Spatial distribution of drift loss cones by (on -off)/(off)

  -- Spectrum distribution along L value, by (on-off)

  -- To make time-averaged spectrum, by (on-off)

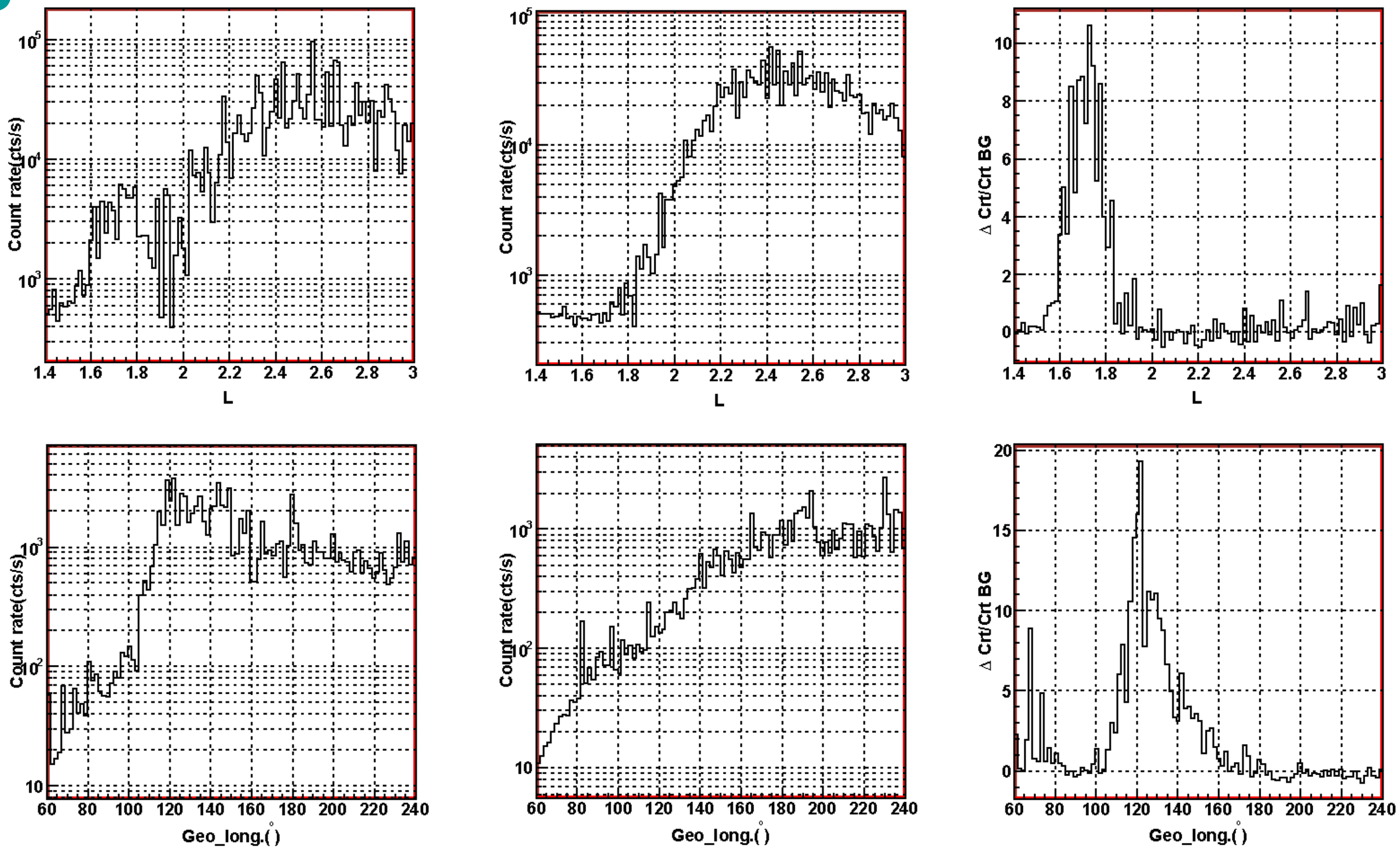
  -- Day/night spectrum comparison

Spatial distribution of the NWC electron belts

NL region:

cts/s- L

Cts/s-long



(a) **NWC on** (b) **NWC off** (c) **((on)-(off))/(off)**

The spatial distribution range

Table 1. The main area of the NWC belts(wisp range).

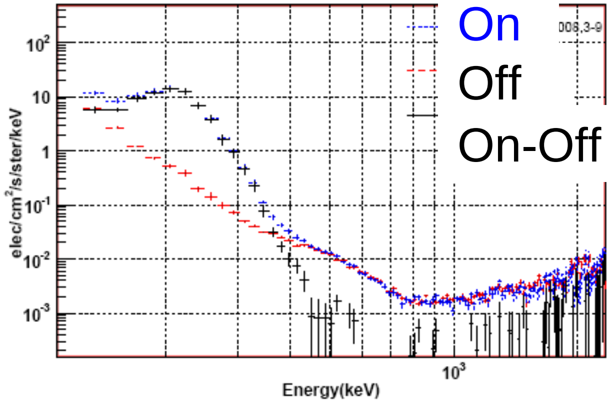
	NL	SL	NE	SE
L	1.5~1.9	1.6~2.1	1.6~2.2	1.6~2.1
L@$R(L)_{max}$	1.72	1.82	1.9	1.75
$\lambda(°)$	105E~170E	110E~180E	155E~70W	150E~60W
λ@$R(\lambda)_{max}(°)$	120E	117E	125E	160E
NWC local time	16:50~22:30	16:50~22:30	21:00~7:40AM	21:00~7:40AM

These regions are defined as NWC belts for further analysis

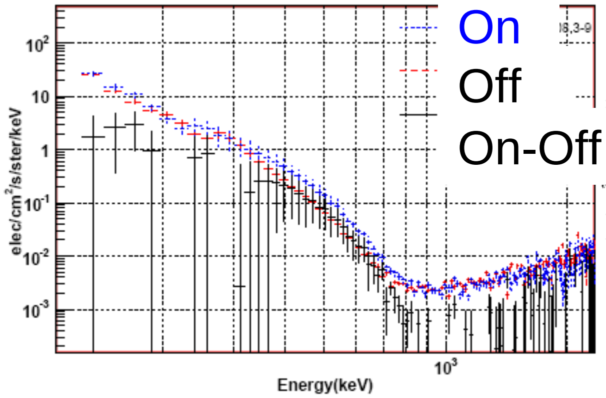
The character of time averaged spectrum of the NWC belts

Spectrom (On/Off)

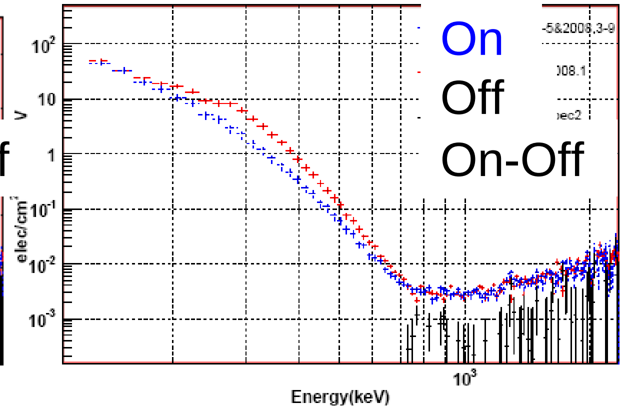
L:1.6-1.65, NL



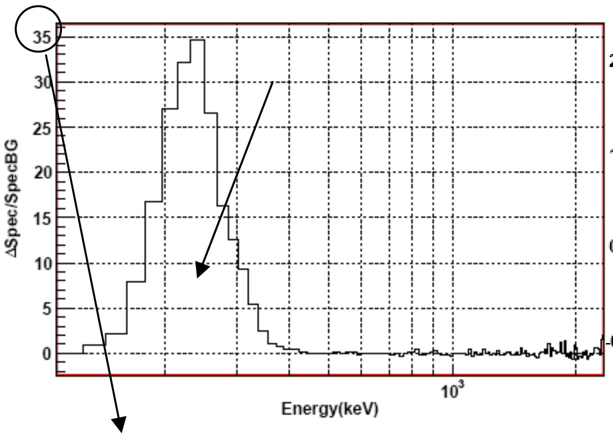
L:1.9-1.95, NL

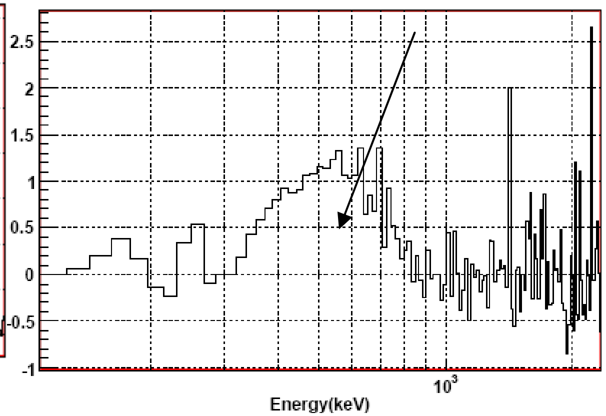


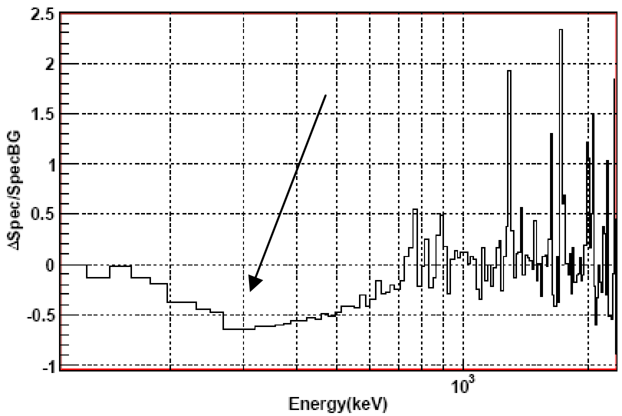
L:2.05-2.1, NL



(On-Off)/Off: Spectrum/BG



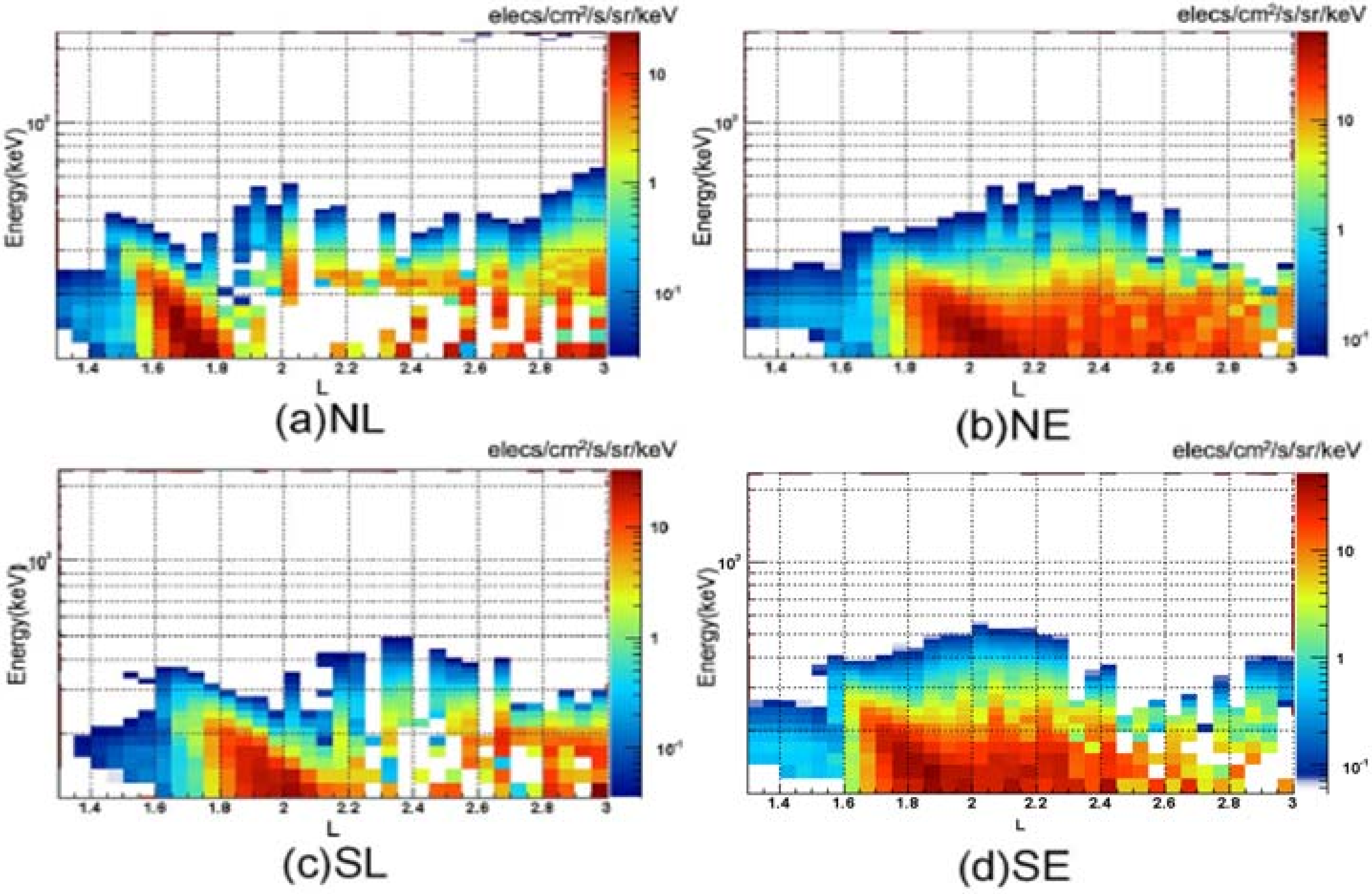




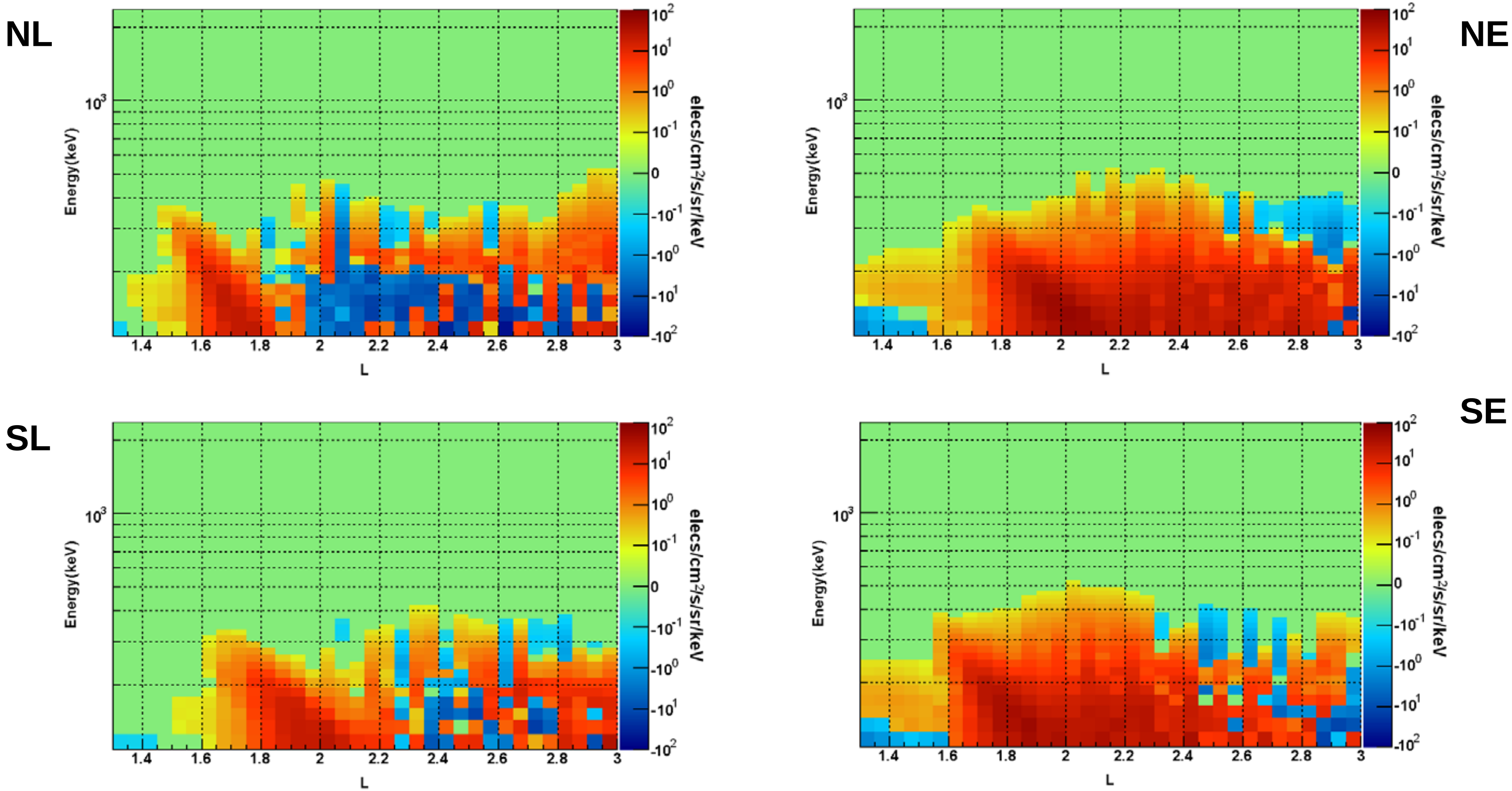
The value can reach 100.

The spectrograph in different L

(NWC night)



Including (on-off)<0

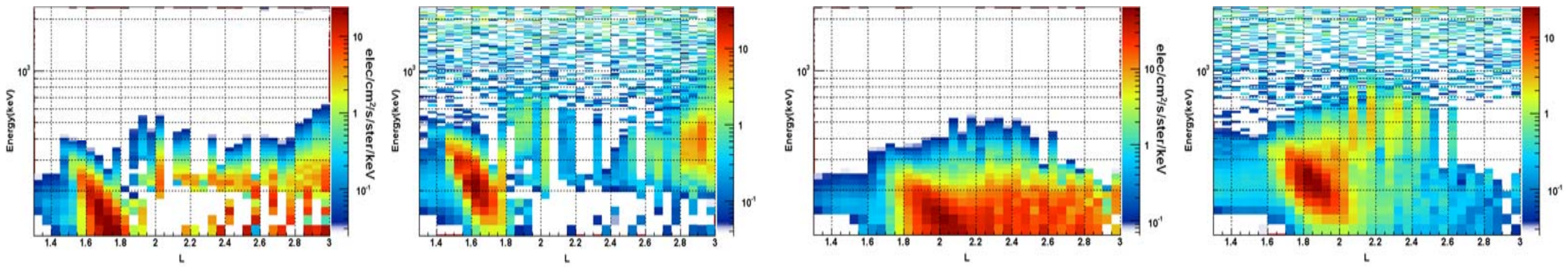


Set 0=|(on-off)| < 10^{-2}

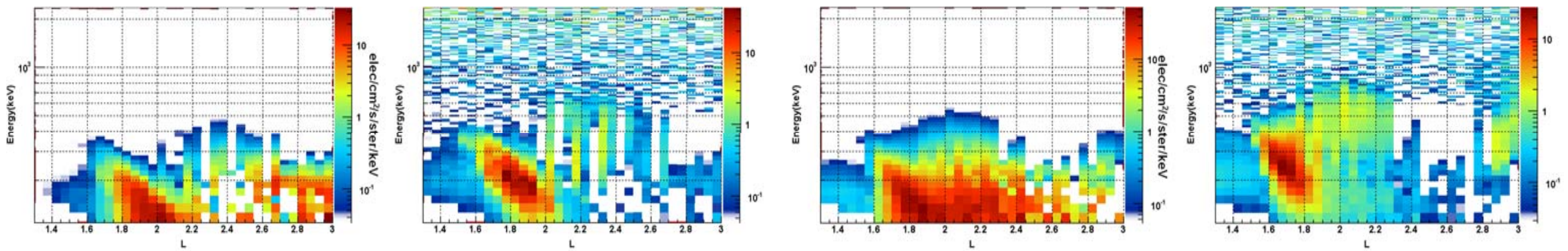
Signal to backgrand ratio

NL

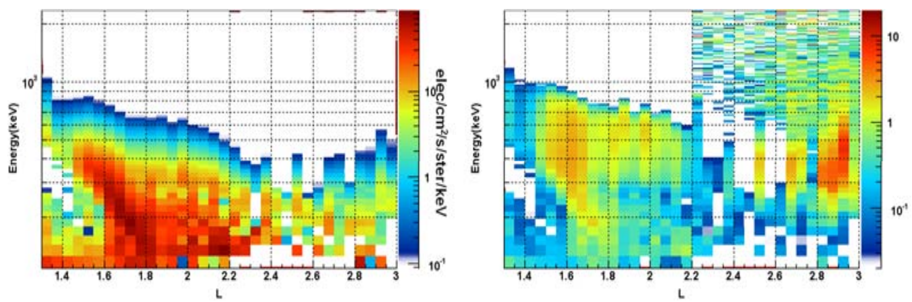
NE



SE



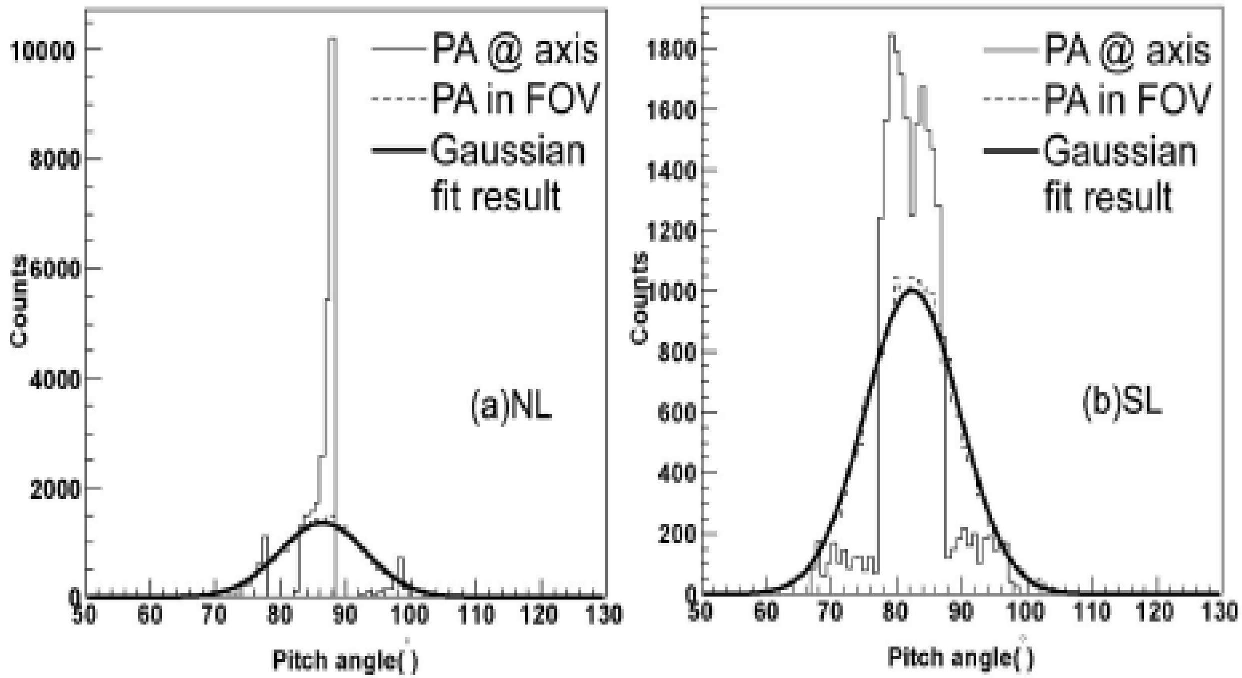
SL



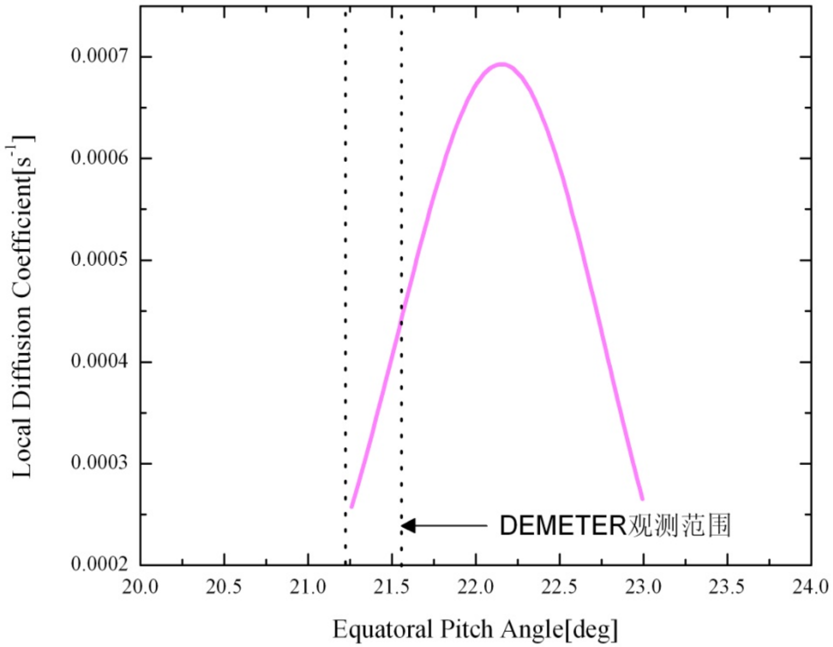
SAA

The pitch angle distribution of NWC electrons in NL and

SL region during NWC night time.



Modeling estimation



$D_{\alpha\alpha}$ - Pitch angle on eqauitorial plane

E~220 keV, L=1.8,

ωm = 19.8kHz

$\delta\omega$ = 150Hz,

Δb =10pT ,

B_{eq} = 3.11* 105/L3T ,

$N_{0\ eq}$ =847cm3 @L=2

847 * (2/L)4

for Latitude of 40° ,

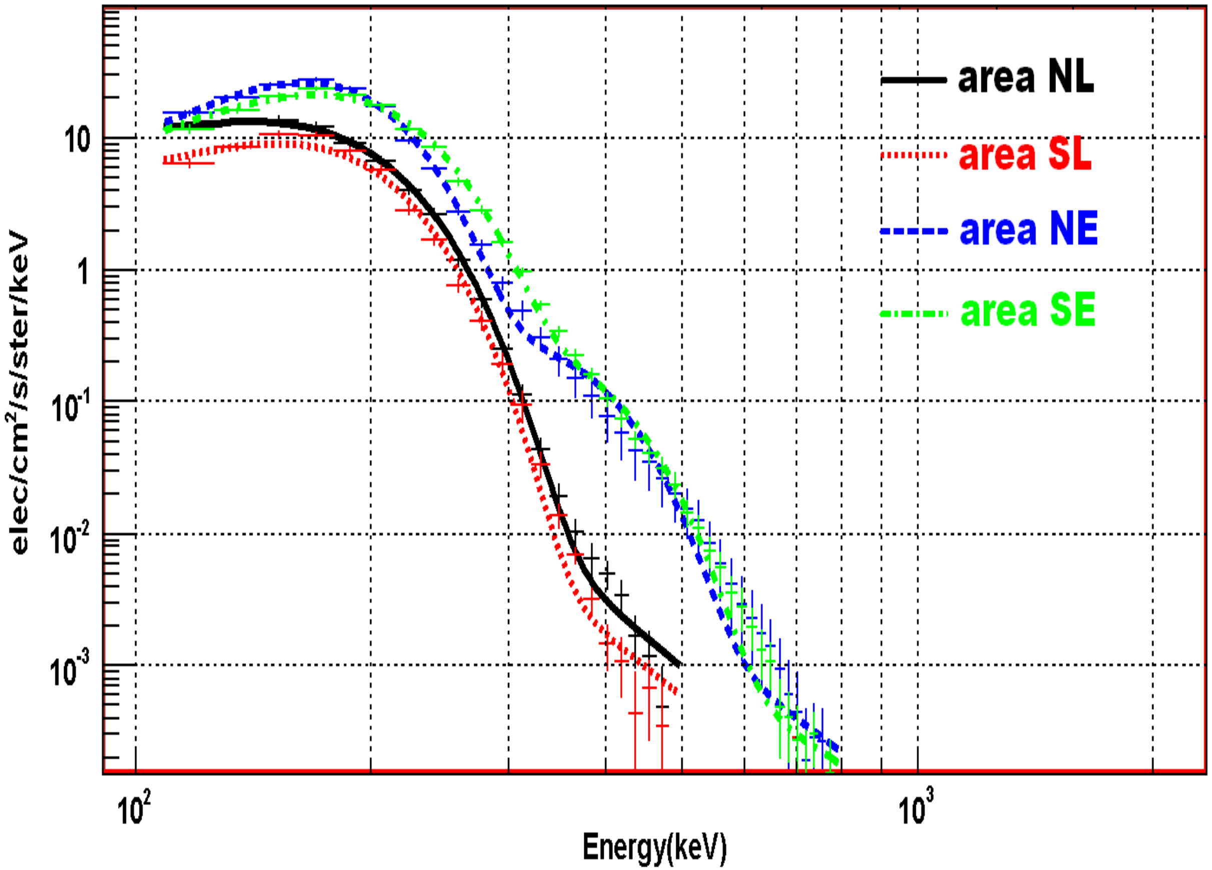
(21.2° , 21.6°)$_{eq}$ related to

(80° , 90°) $_{\text{NWC electron}}$

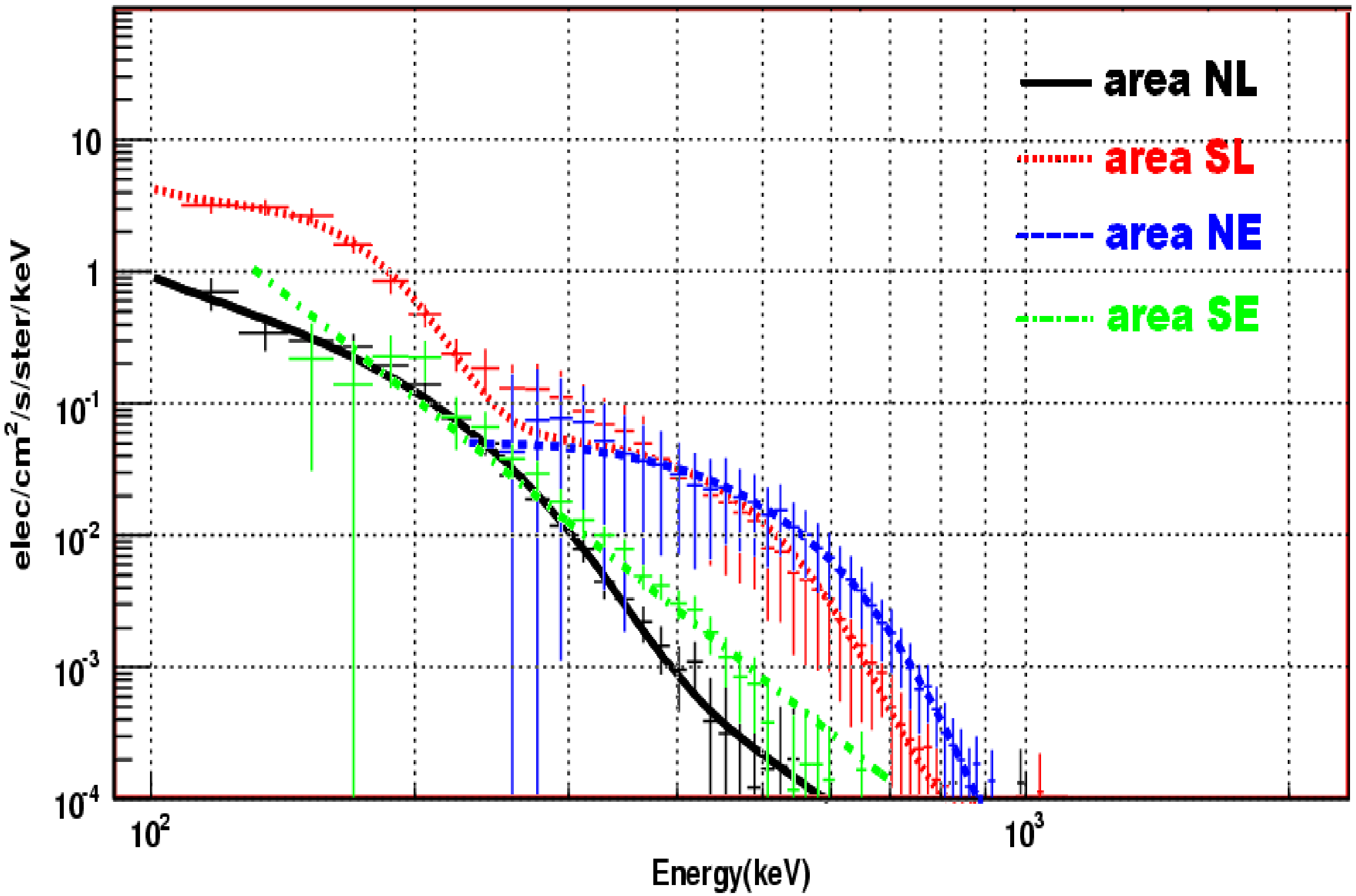
Cyclotron resonant wave-particle interaction cause Pitch-Angle diffusion

The VLF wave absorption by the ionospheric through the analysis of the spectrum of the VLF electron belts

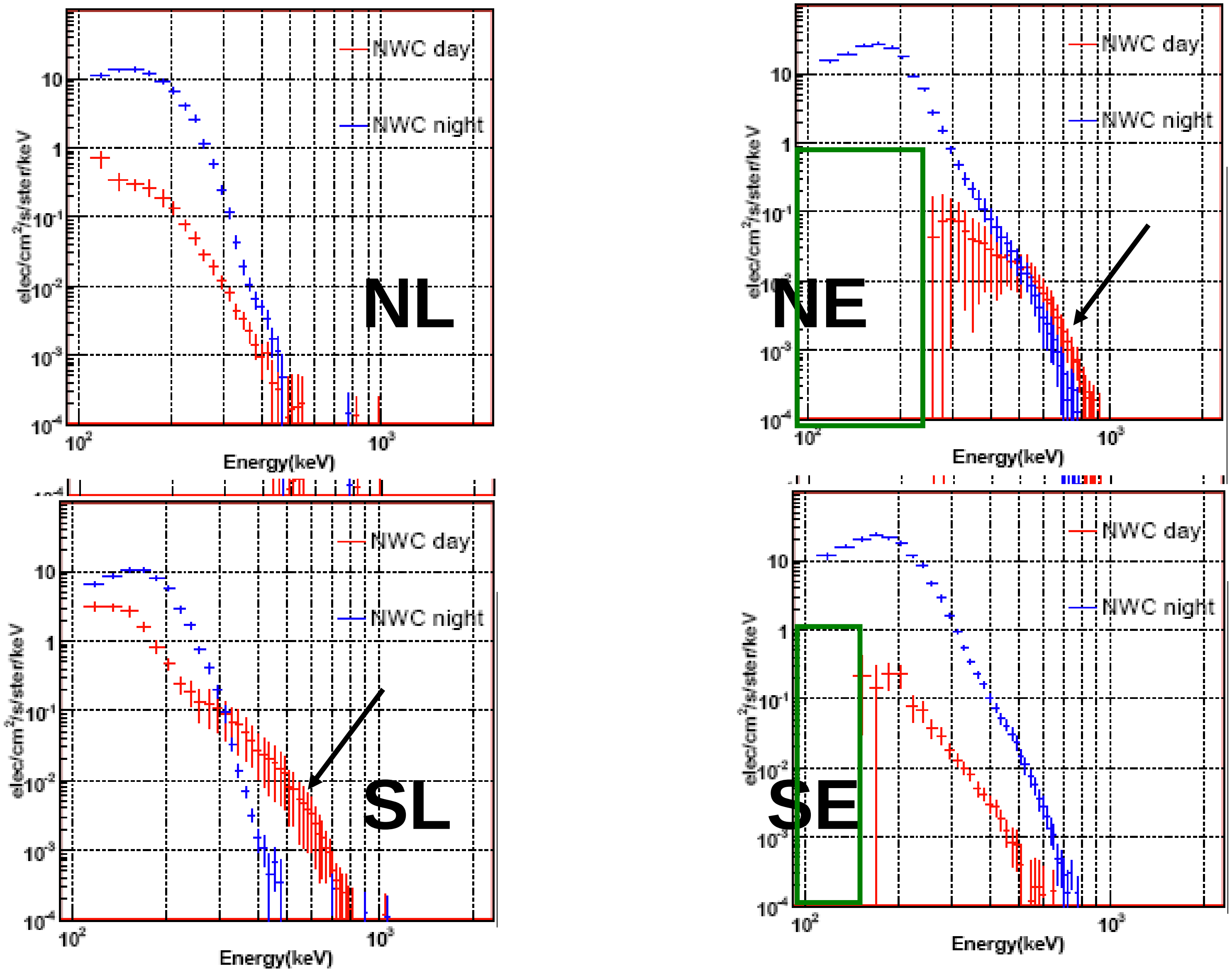
Time averaged spectrum of NWC electron (during NWC night time)



Time averaged spectrum of NWC electron (during NWC day time)



Compare NWC day and nignt



Spectra comparison between day and night time

NWC night

Area	Average Energy (keV)	Integrate influence (10^{-4} erg/cm^2/s/sr)	Integrated Flux (electrons/cm^2/s/sr)
NL	167.0 (11.1)	3.59 (0.12)	1344.1 (43.7)
SL	169.8 (12.8)	2.68 (0.10)	**986.8** (36.8)
NE	176.1 (7.4)	7.60 (0.16)	2696.2 (54.4)
SE	185.2 (8.5)	7.54 (0.17)	2543.5 (58.0)

NWC day

Area	Average Energy (keV)	Integrate influence (10^{-4} erg/cm^2/s/sr)	Integrated Flux (electrons/ cm^2/s/sr)	Flux ratio (night/day)
NL	157.7 (39.7)	0.096 (0.012)	38.0 (4.8)	**35.4**
SL	161.0 (31.7)	0.601 (0.065)	**233.7** (20.8)	**4.2**
NE	378.6 (363.0)	0.071 (0.032)	11.7 (5.9)	**231.1**
SE	203.8 (109.5)	0.063 (0.016)	19.4 (5.4)	**130.9**

Summary(1)

- Confirmed and more detailed: The precipitation in drift-loss cones form additional temporal electron belts with very strong flux enhancement during NWC night time. The belts cover very wide range in longitude range with the electrons transfusing into SAA. We call it NWC electron belt.
- Confirmed and more detailed: The flux spectrograph distributed in wide range of L (1.3~3) shows the "wisp" structure in L<~2 range; and the complicated structure including the electron lost in L >2 range .
- Confirmed the VLF wave from NWC transmitter cause the radiation belt electrons precipitation by wave-particle interaction. Both the enhancement and the lost flux of the electrons were studied.

Summary(2)

- Confirmed and detailed: The obvious D-layer ionosphere absorptions have been seen and studied quantitatively by comparison of day/night spectrum.

- The time average spectrum show clearly cut-off energy in 500 keV for local area and 800keV for east part which may implicated the electrons acceleration during the drift to the east.

- The pitch angle distribution around 90 degree provided by IDP is much beneficial to study the electron behavior within drift-loss cone. The theoretical calculation show consistency with the pitch angle diffusion by wave-particle interactions.

Thanks for your attention