Radiation Belts observed by CARMEN/SAC-D

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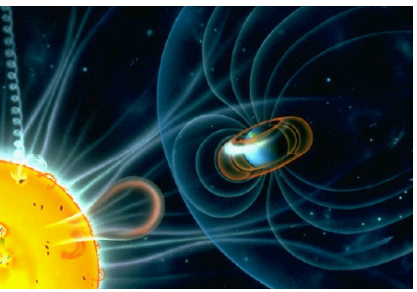
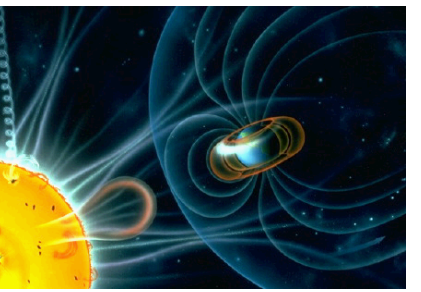
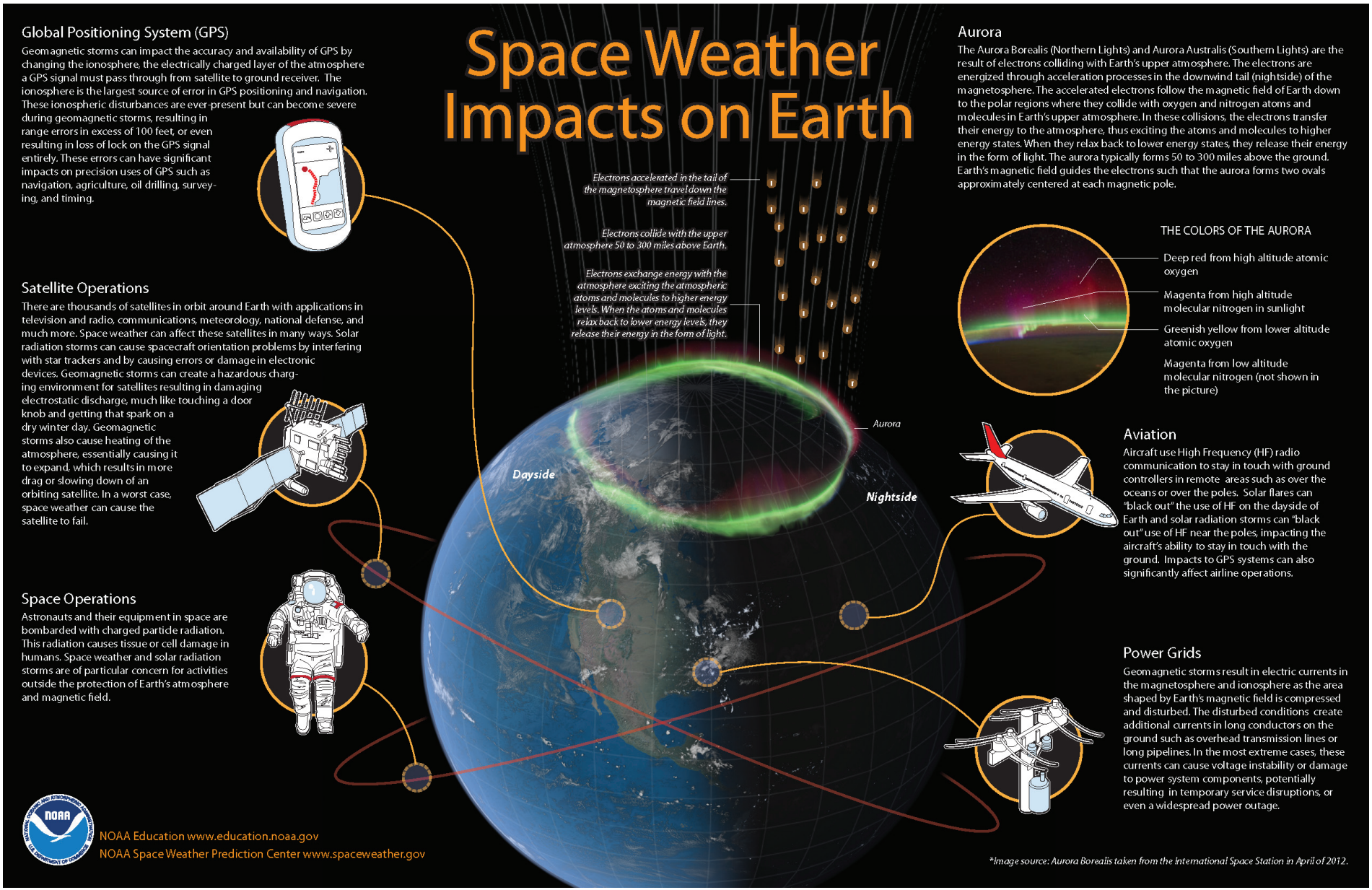
10th Reunión de Ciencia SAC-D/Aquarius, Bs As, November 17th, 2015

Overview

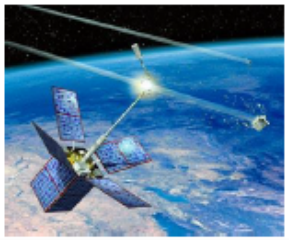
Space Weather



WMO & Space Weather

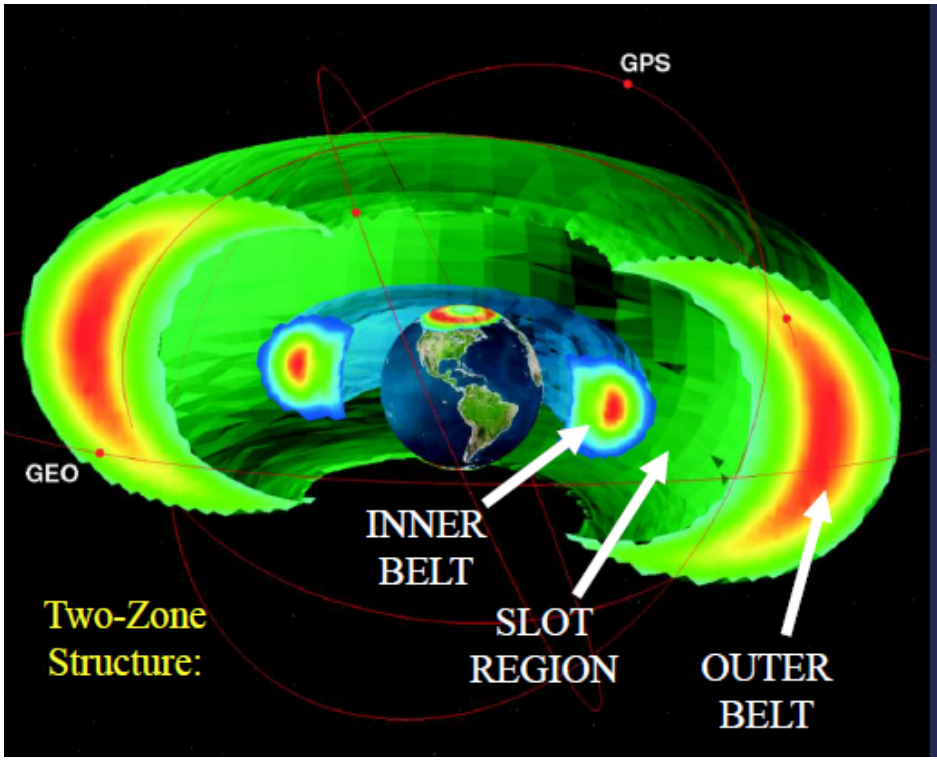
Service Level Activities

- Organize WMO Members to deliver coordinated services responding to ICAO requirements
- Prepare for extreme events in a multi-hazard Disaster Risk Reduction approach
- Analyze requirements for applications including ionospheric disturbances (radio propagation and GNSS), satellites, and ground infrastructure (power grids)
- Provide training on delivery and use of services



Many other institutions have Space Weather programs: NASA, ESA, UN (Outer Space), Met Office, NOAA, COSPAR, etc

Radiation Belts & Space Weather

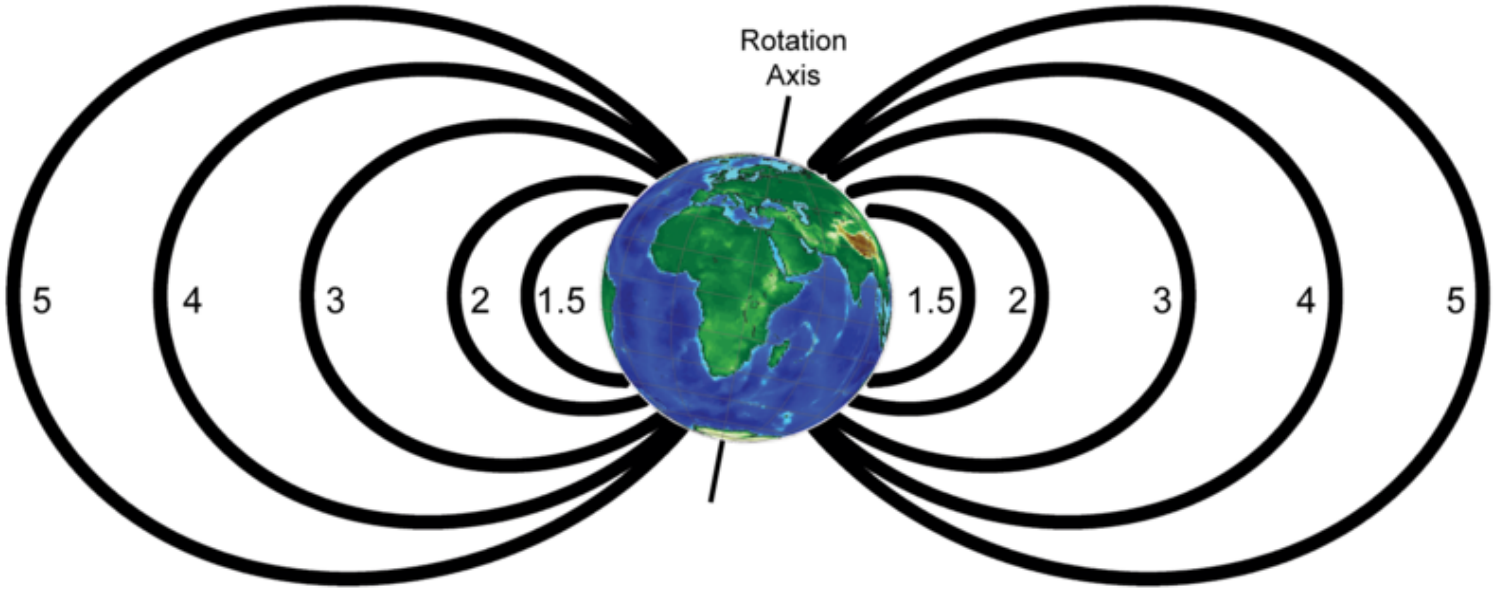


- Radiation belts
  - energies >100 keV
  - two-zone structure
- Inner belt: fairly stable
- Outer belt: can change on the time scale of an hour

Radiation belts

- Inner: $\sim$ 0.2-2 R_E
- Outer: $\sim$ 3-9 R_E
- Flux of energetic particles strongly dependent on Space Weather conditions in the outer belt

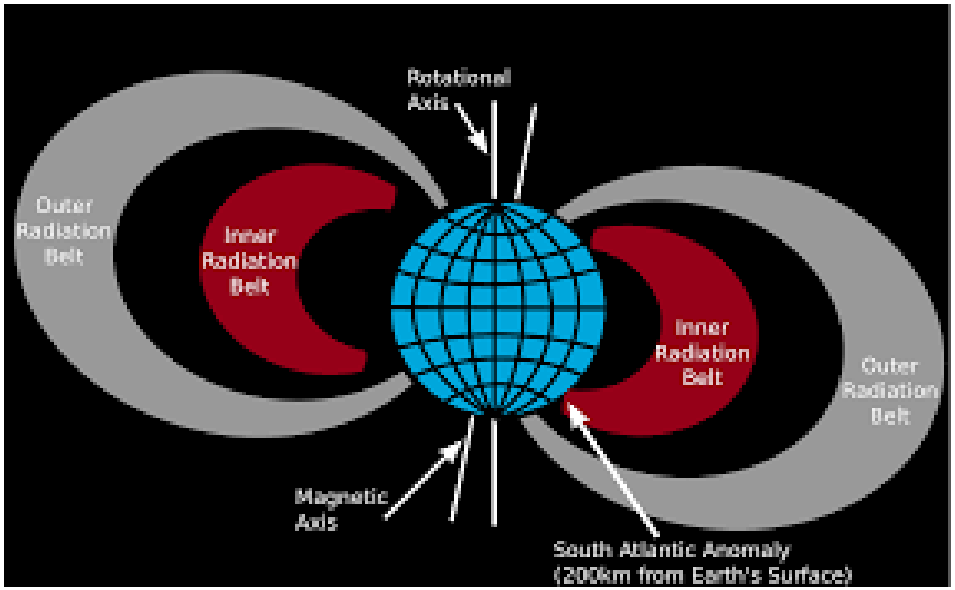
L shells on Earth

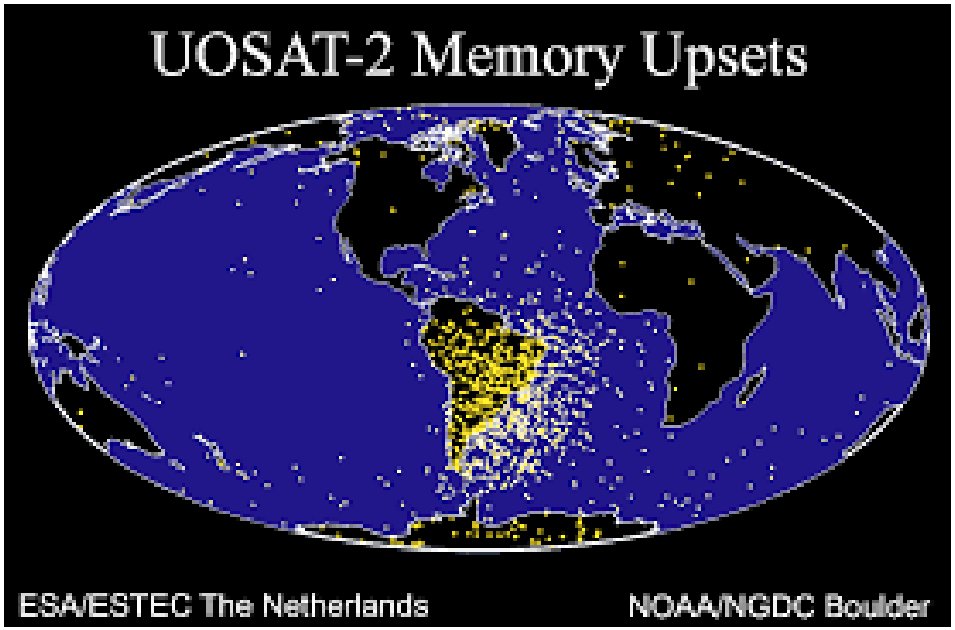


L parameter

- For a centered dipole magnetic field model:
  $r = L\cos^2(\lambda)\mathrm{R}_E$
- Constant altitude runs over different particle populations

South Atlantic Anomaly





Caused by non-concentricity of Earth and its magnetic dipole

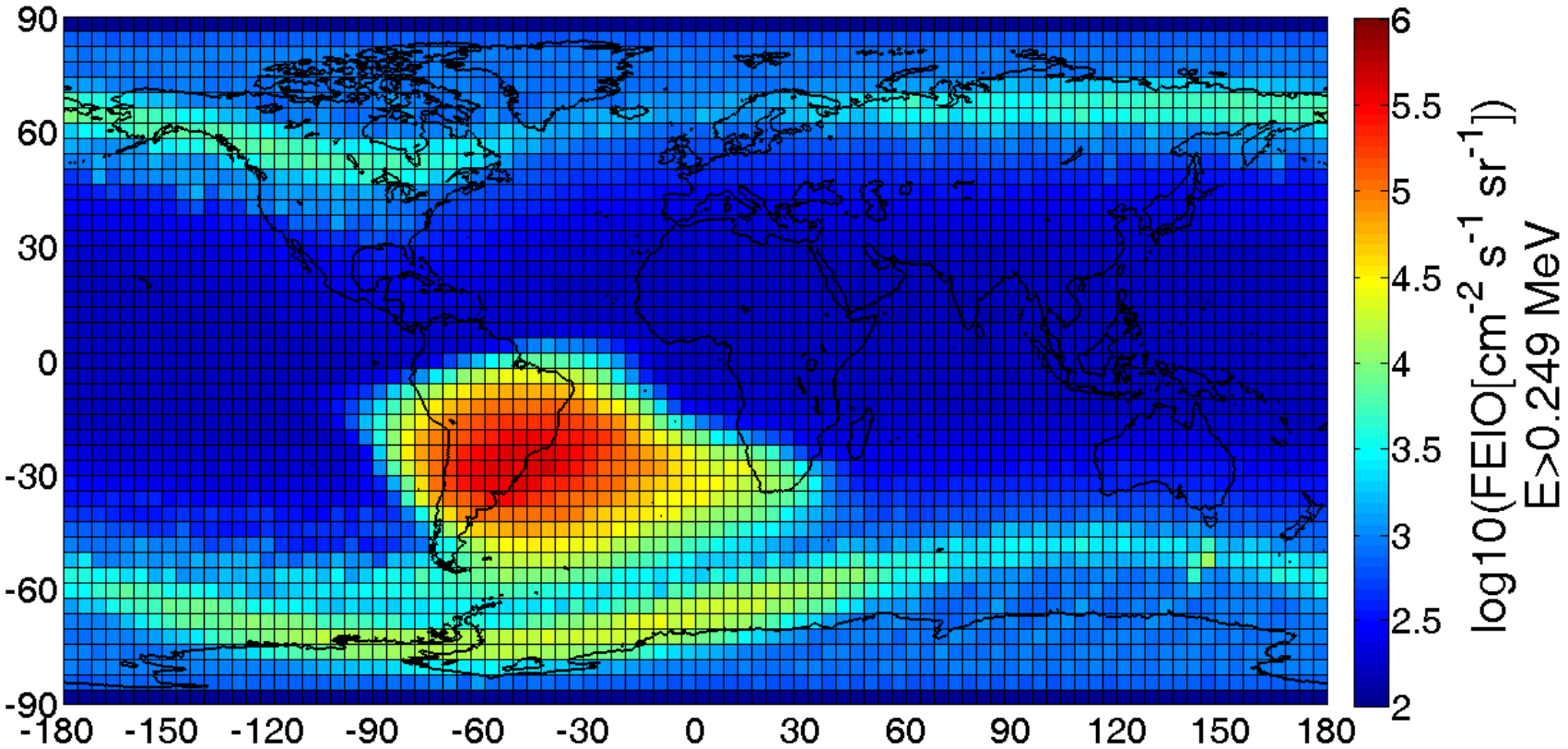
- SAA is the near-Earth region where the Earth's magnetic field is weakest, relative to an idealized Earth-centered dipole field.
- Memory upsets and many other consequences on satelites passing through SAA.

ICARE-NG, CARMEN-1, SAC-D

The particle detectors

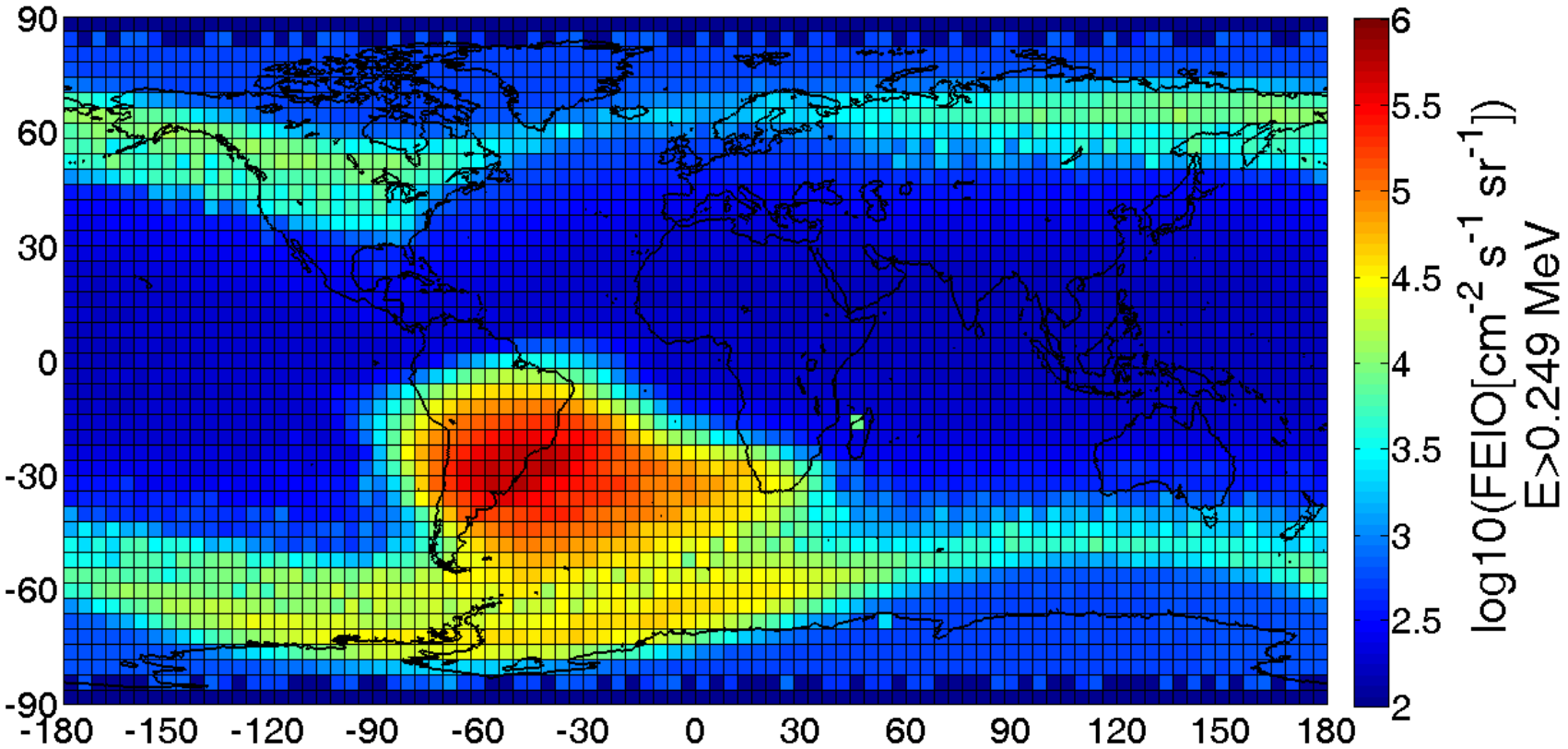
- Three detectors to measure electron and proton fluxes
- Energy range for electrons: 250keV to 3.2 MeV
- Energy range for protons: 12.8 MeV to 190 MeV
- FEIO (44 channels): Omni-directional Integral Electron Flux

Global map for electron flux (low energies, 2011-2012)



- FEIO (Omni-directional Integral Electron Flux)
- $E > 249$ keV
- From 2011 to 2012

Global map for electron flux (low energies, 2014-2015)



- FEIO (Omni-directional Integral Electron Flux)
- $E > 249$ keV
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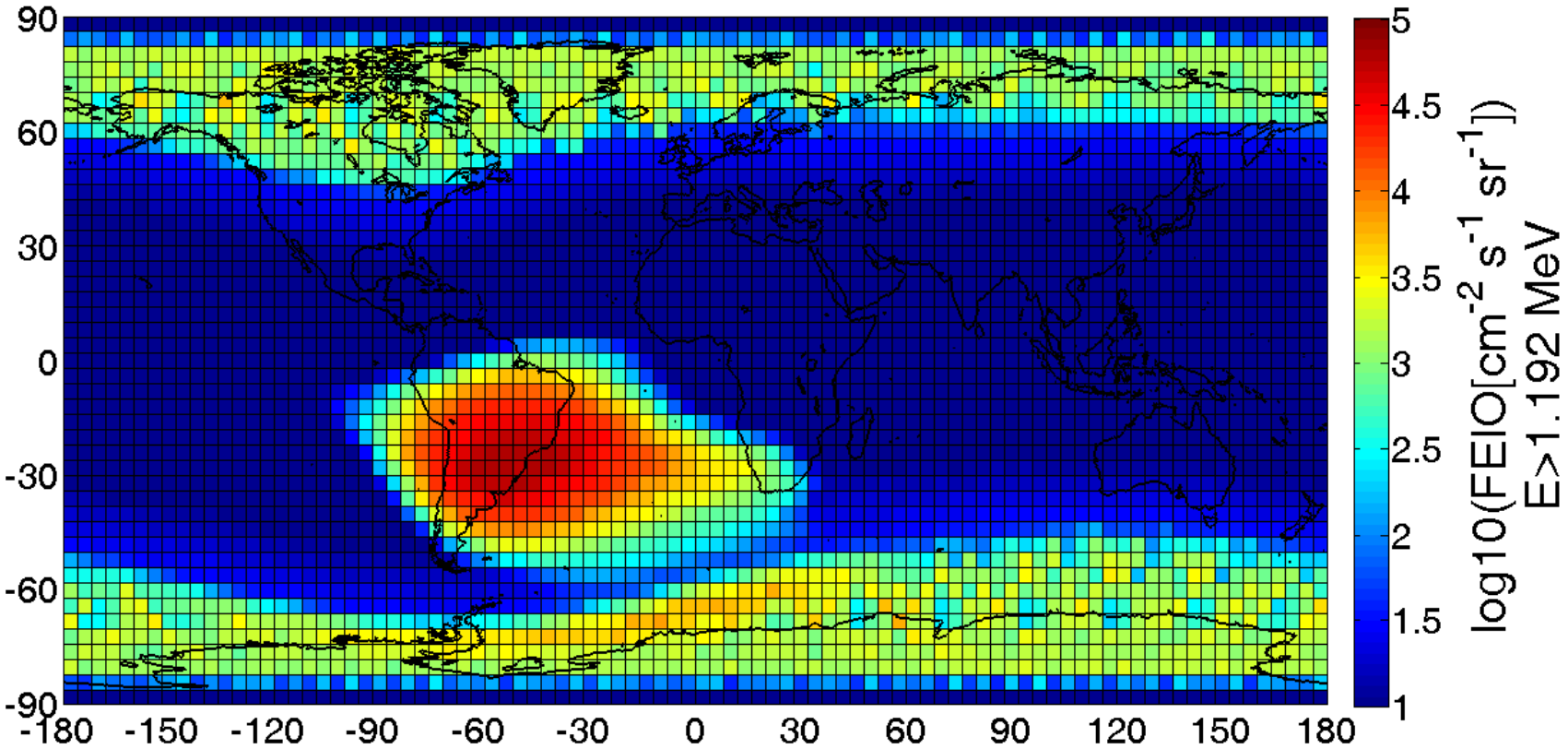
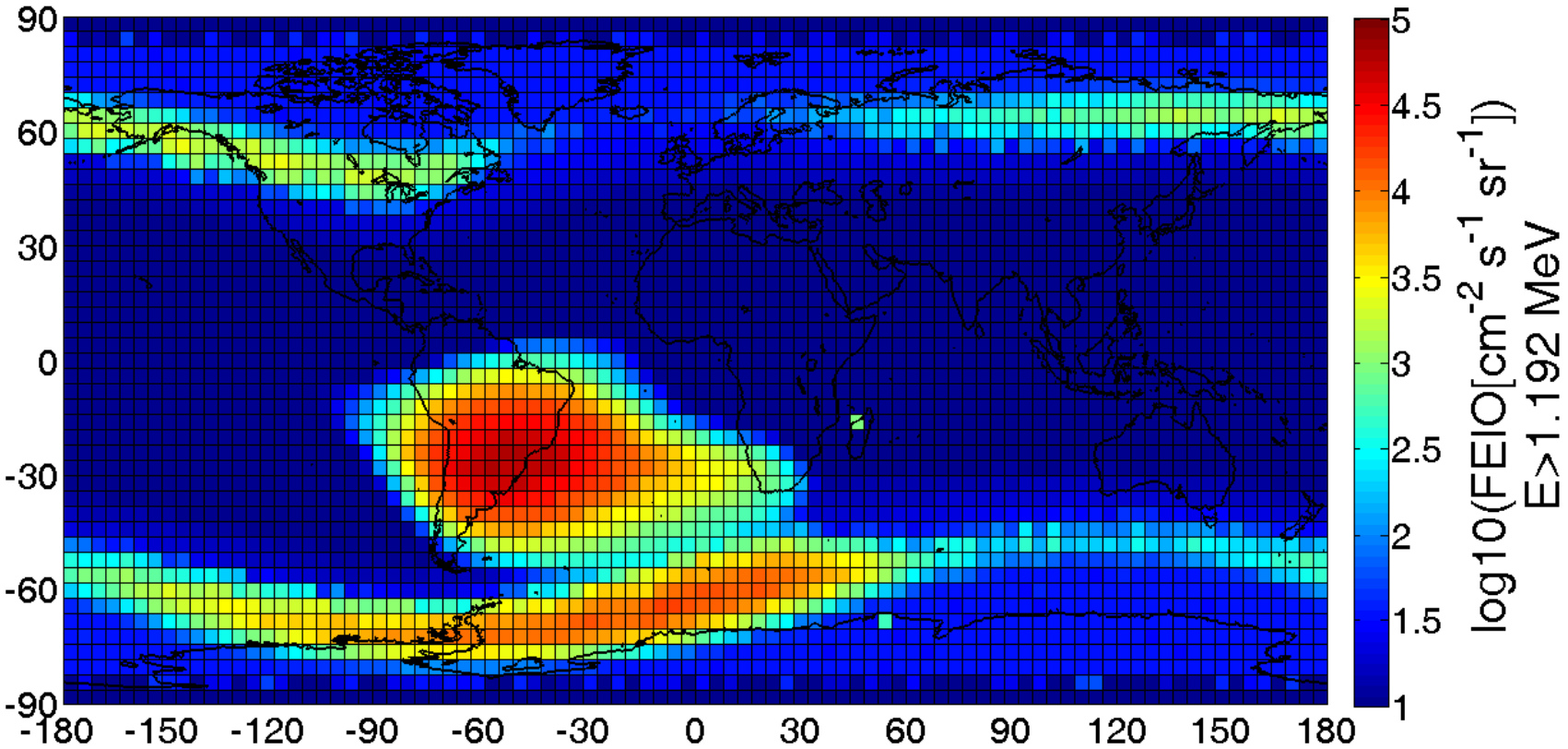
Global map for electron flux (high energies, 2011-2012)



- FEIO (Omni-directional Integral Electron Flux)
- $E > 1.192$ MeV
- From 2011 to 2012

Global map for electron flux (high energies, 2014-2015)



- FEIO (Omni-directional Integral Electron Flux)
- $E > 1.192$ MeV
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South Atlantic Anomaly

Different energies at SAA (full mission)

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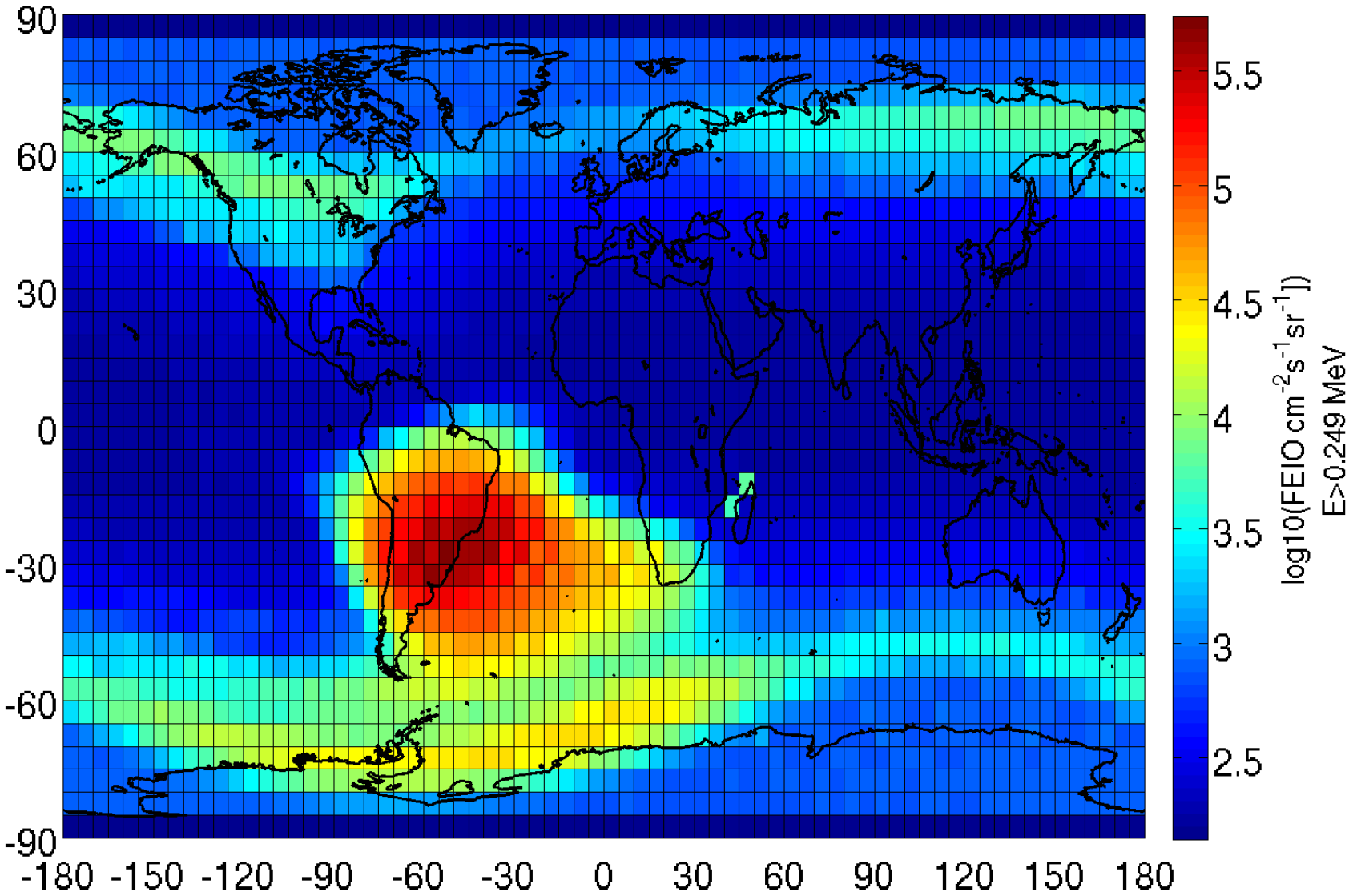

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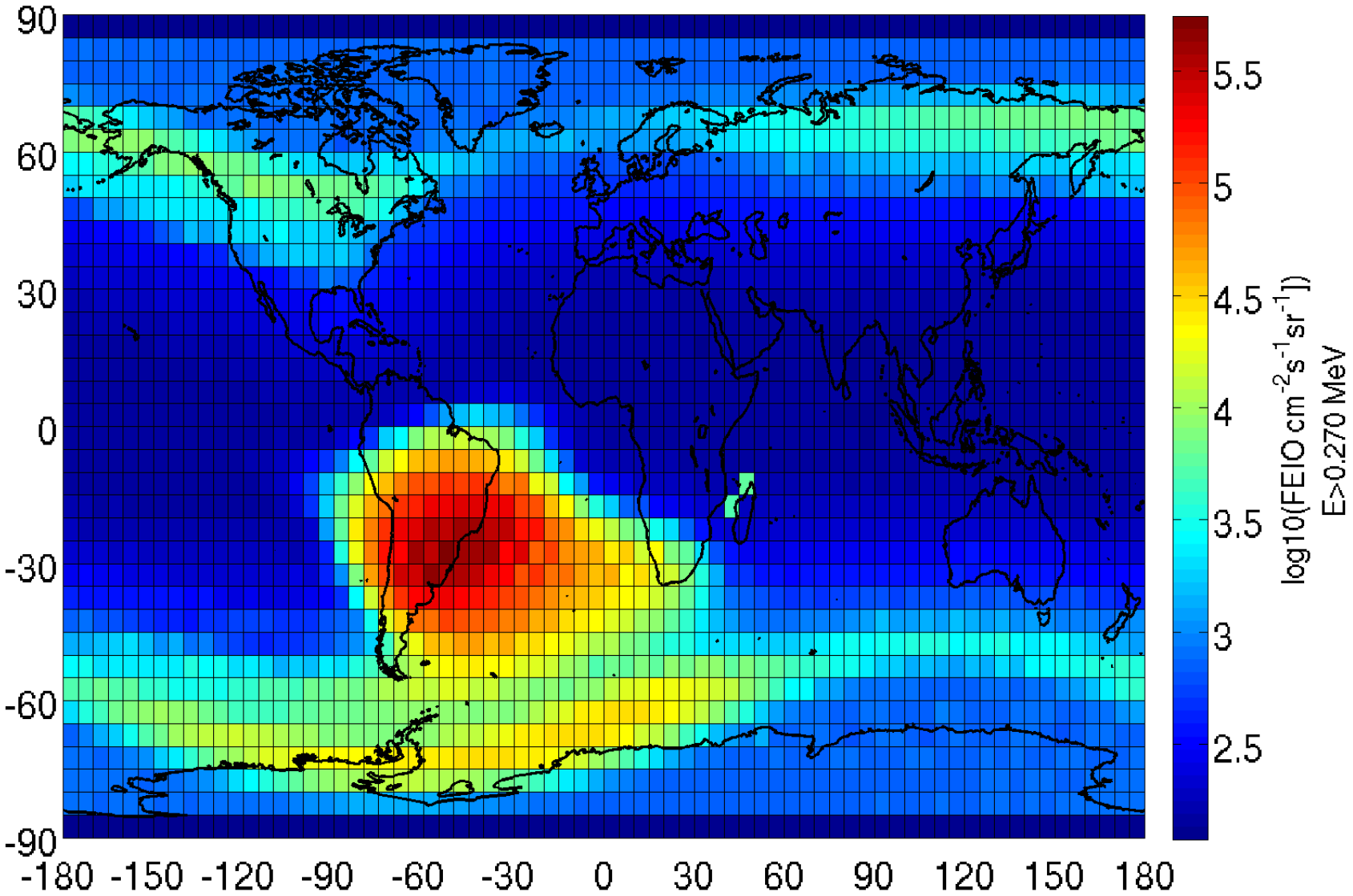

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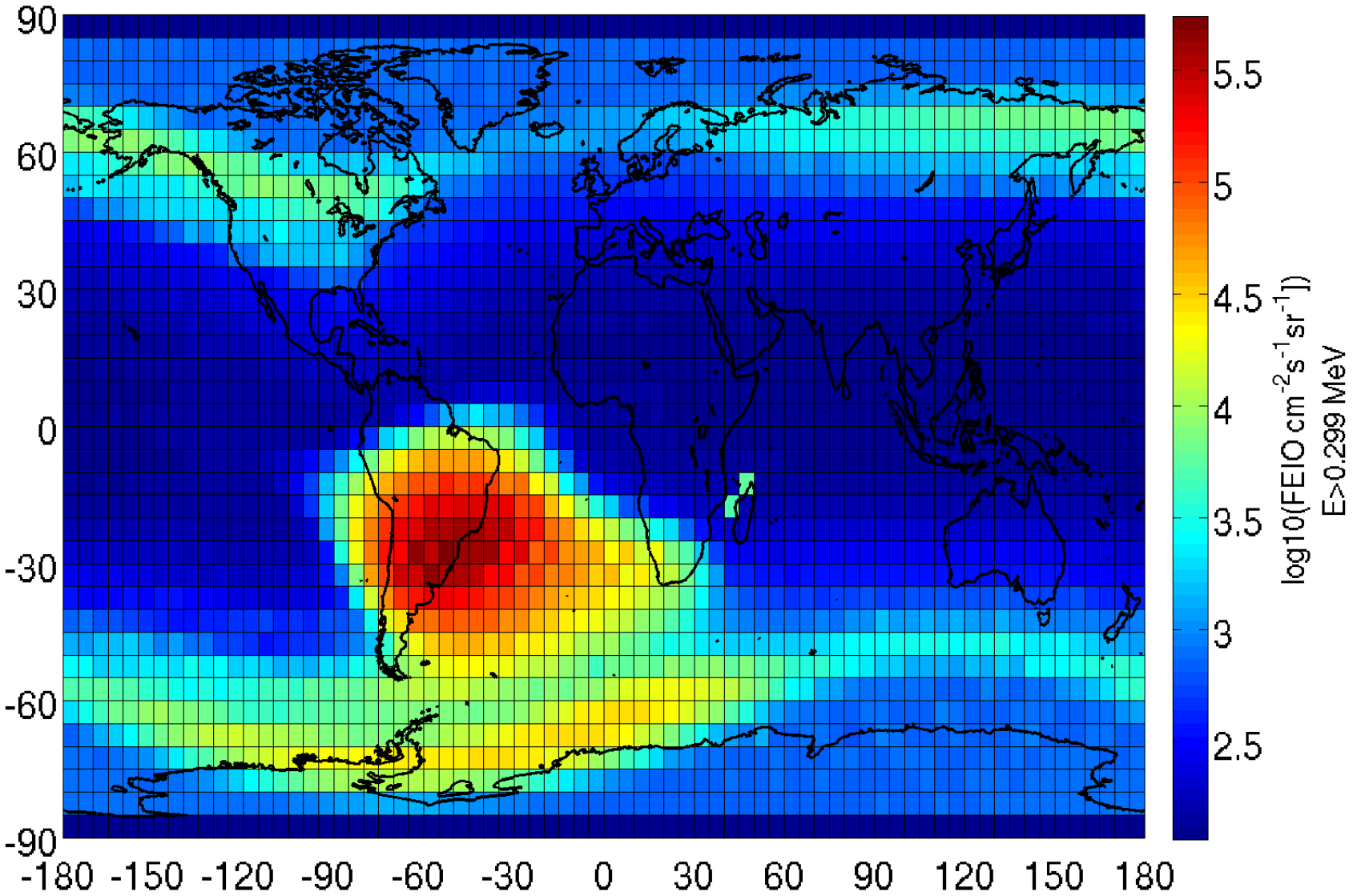
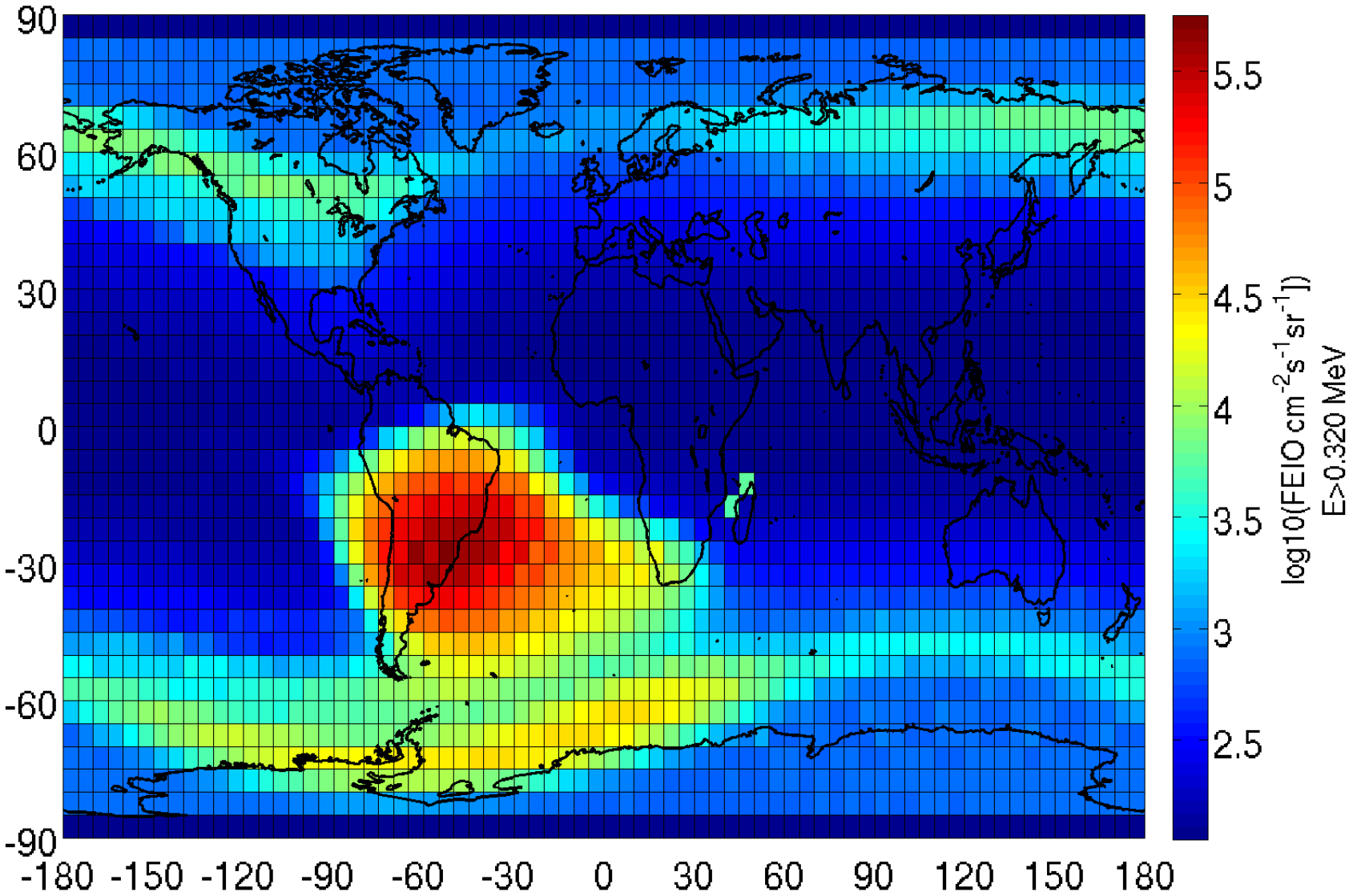
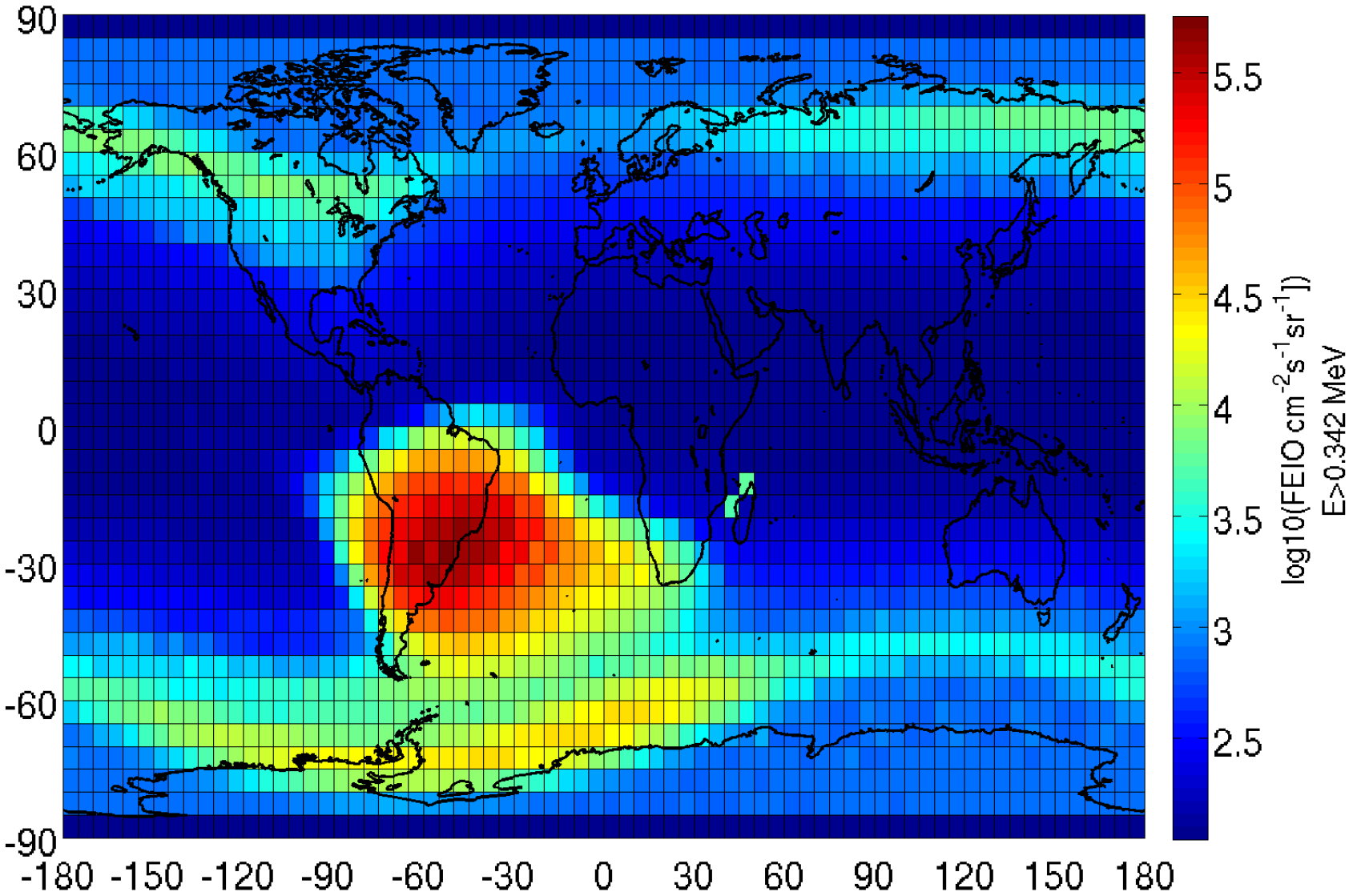


Different energies at SAA (full mission)



Different energies at SAA (full mission)



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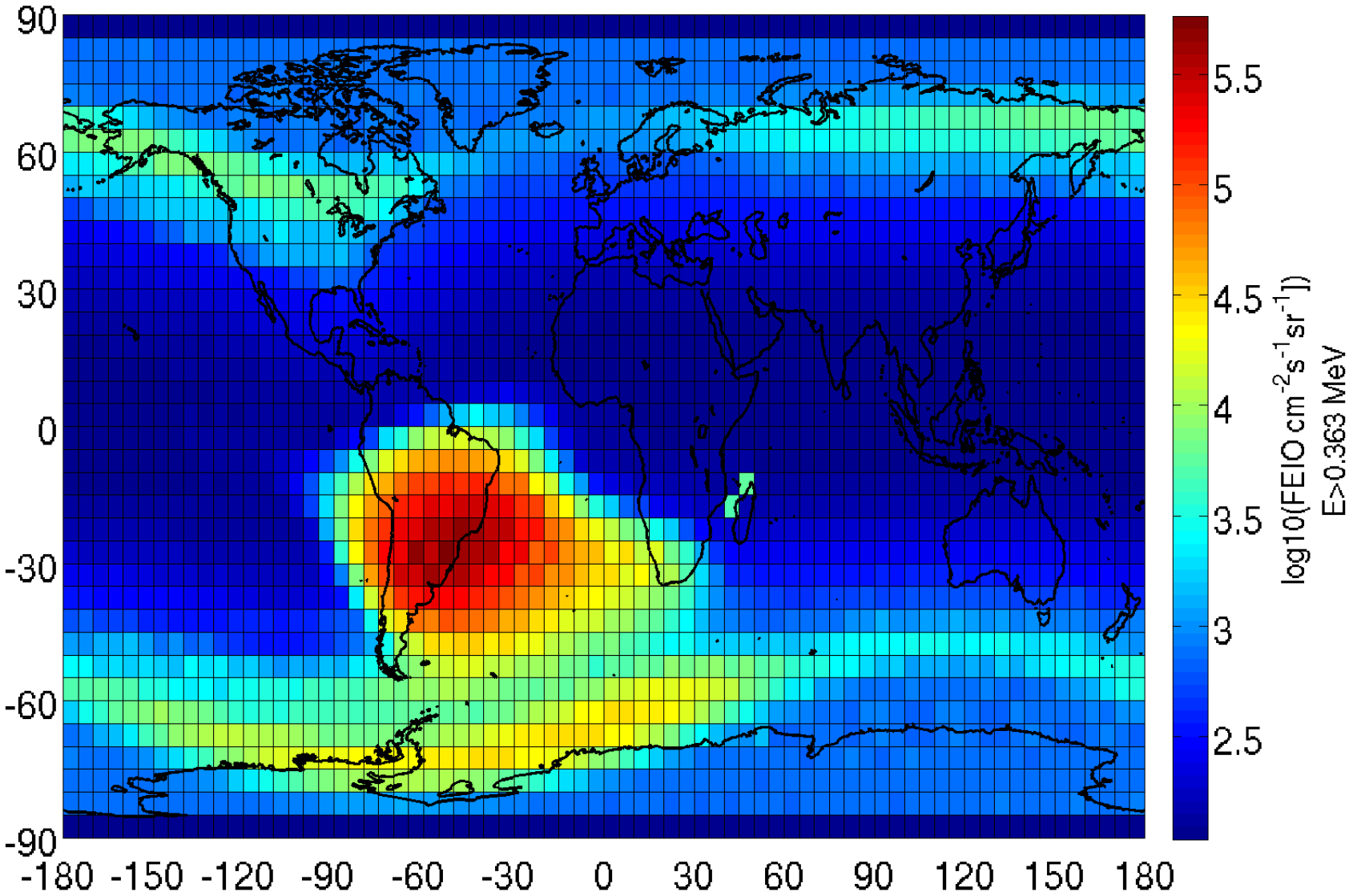
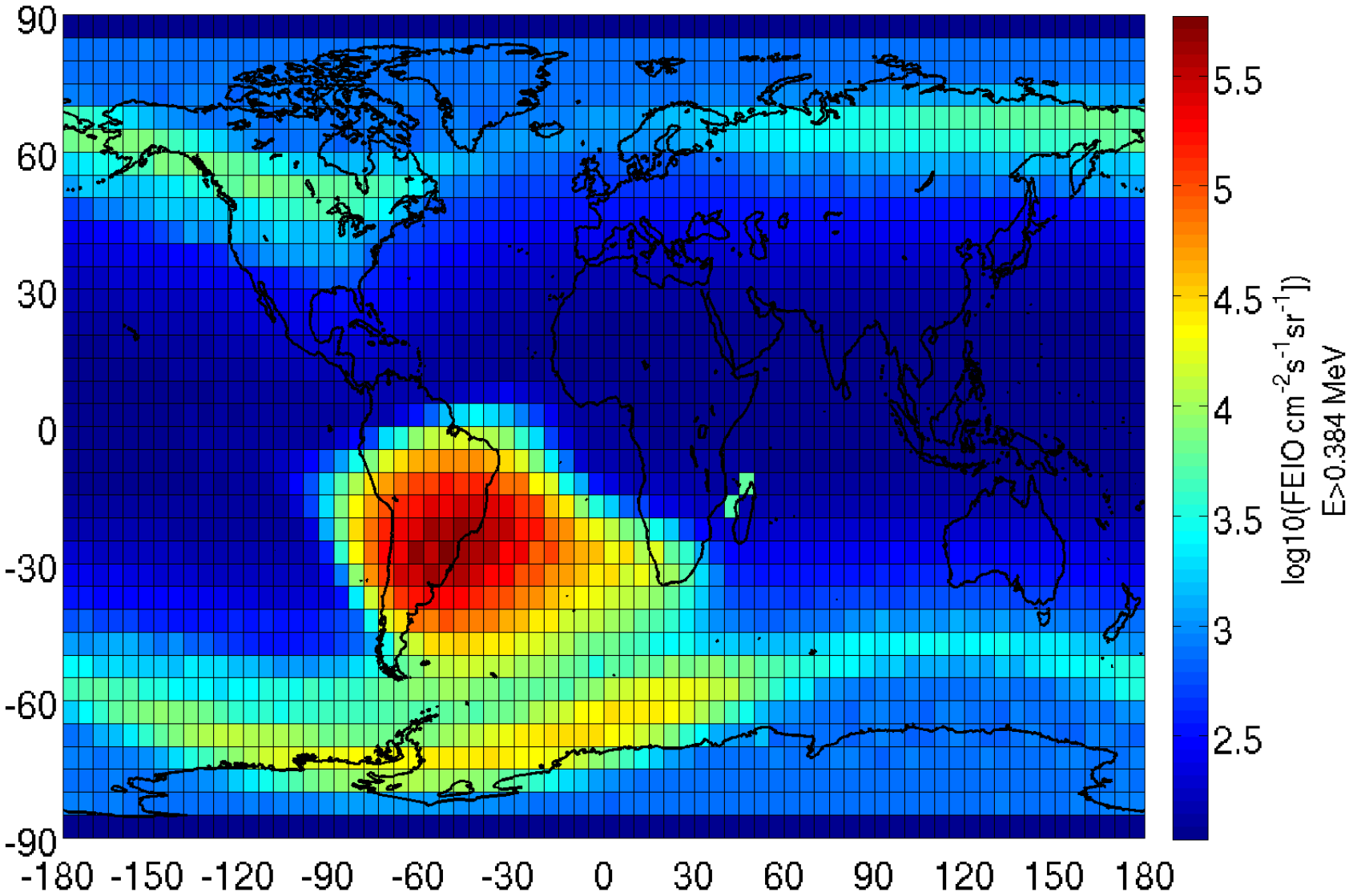


Different energies at SAA (full mission)



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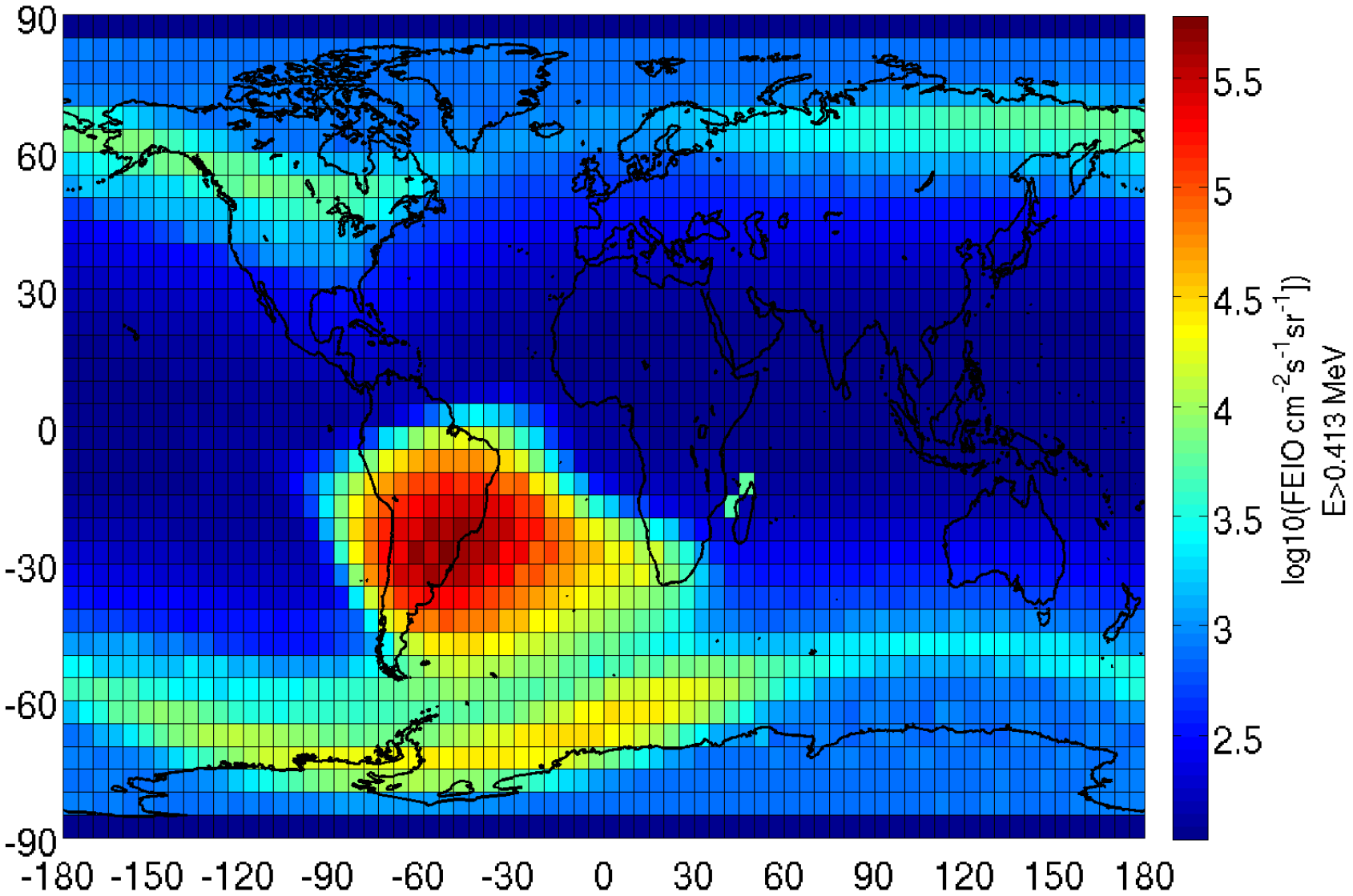
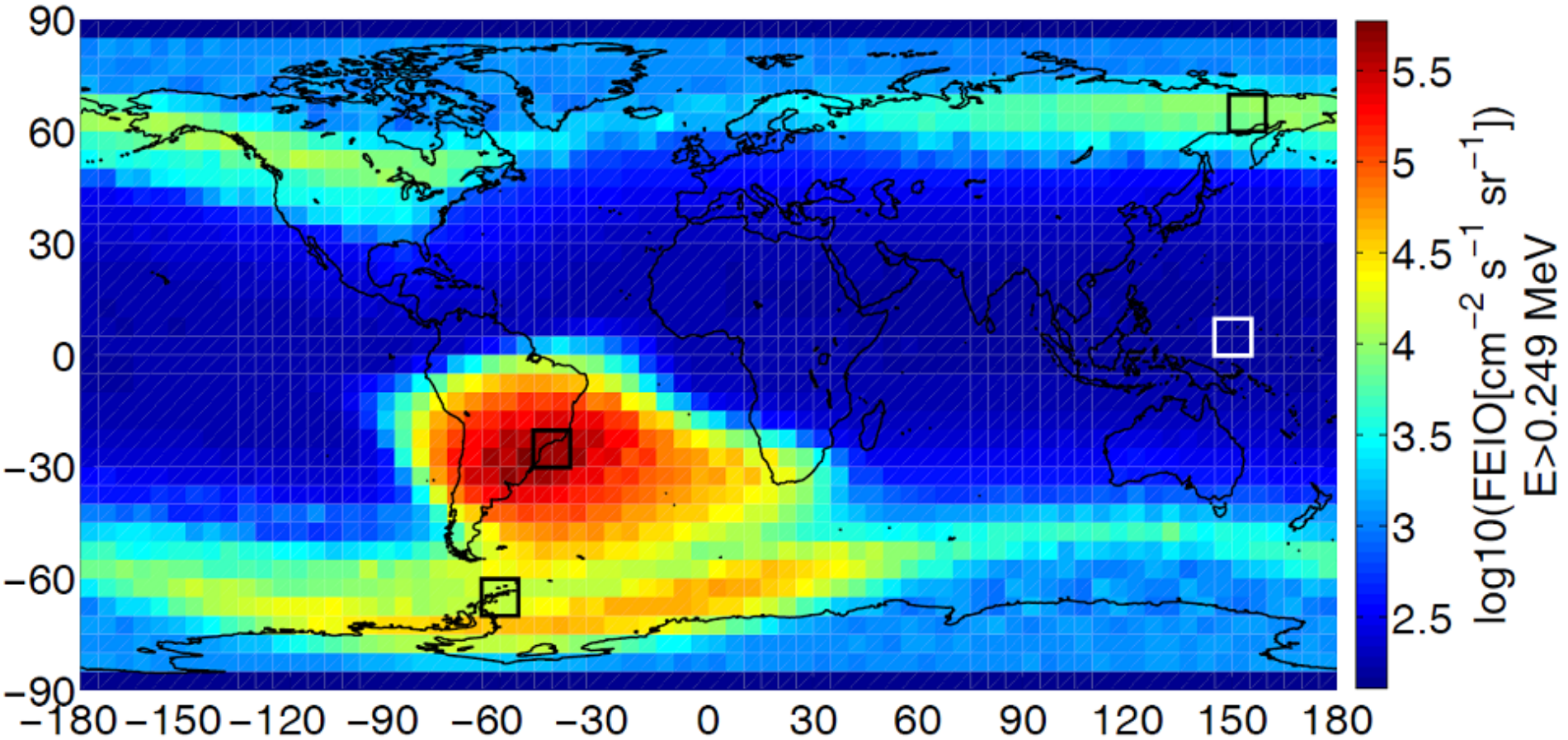


Fluxes at four different regions

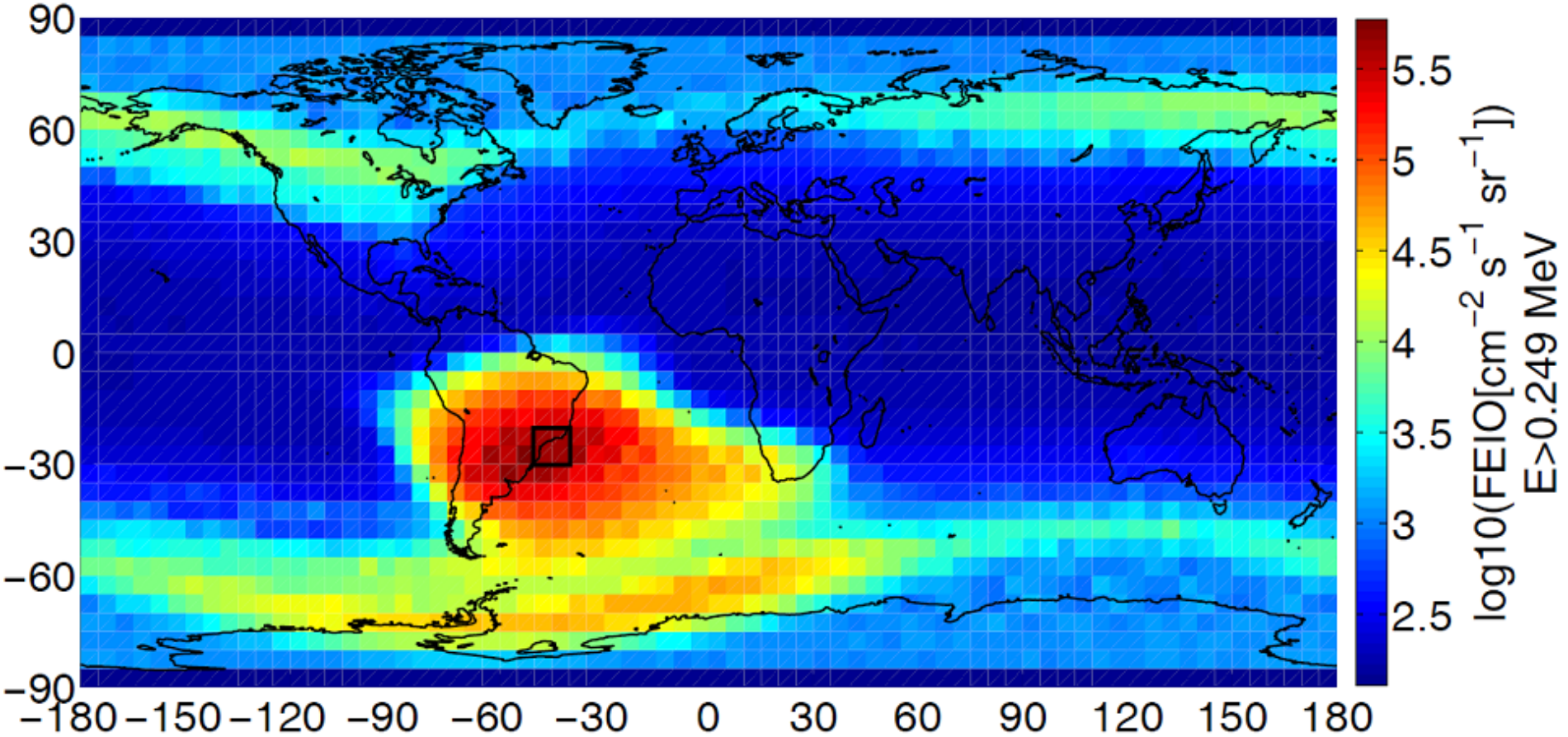
Analysis of Fluxes Distribution

Four different regions



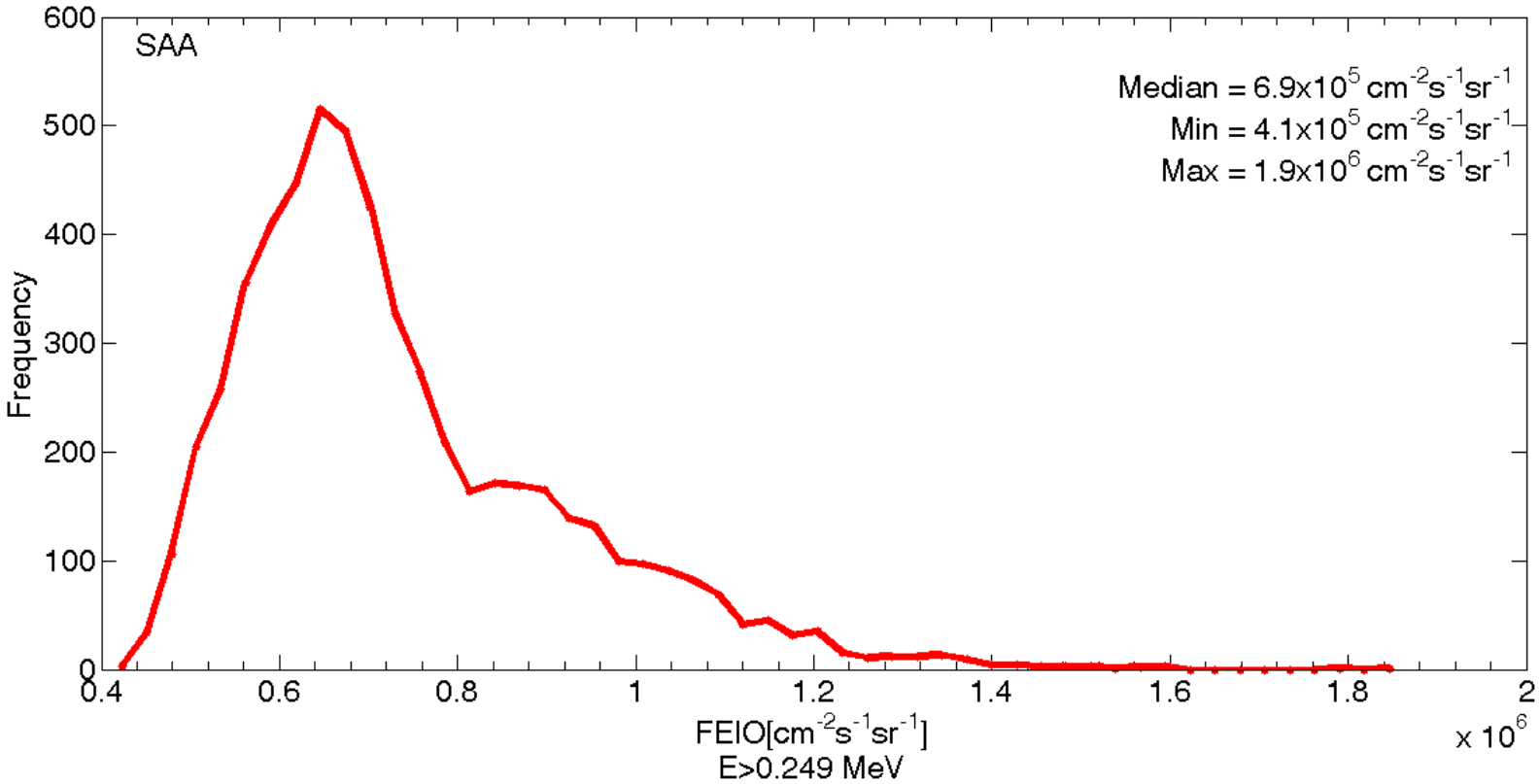
- FEIO (Omni-directional Integral Electron Flux)
- Full mission (from Aug/30/2011 to Jun/06/2015)

Region 1: AAS, from Aug/30/2011-Jun/06/2015



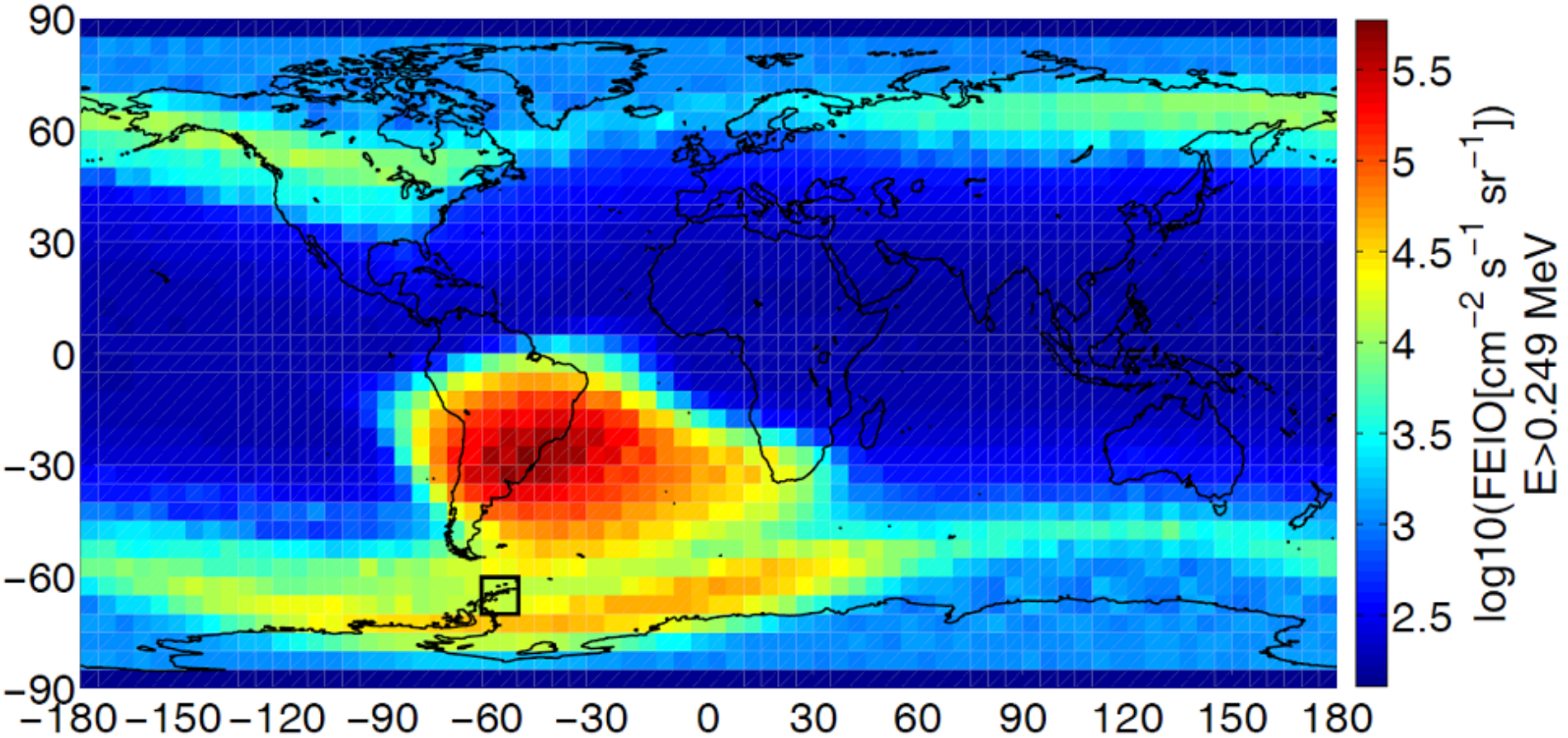
- Latitude: -30 to -20 deg, Longitude: -50 to -40 deg
- Region 1 corresponds to L $\sim$ 1.35

Observed Distribution of fluxes at SAA (full mission)



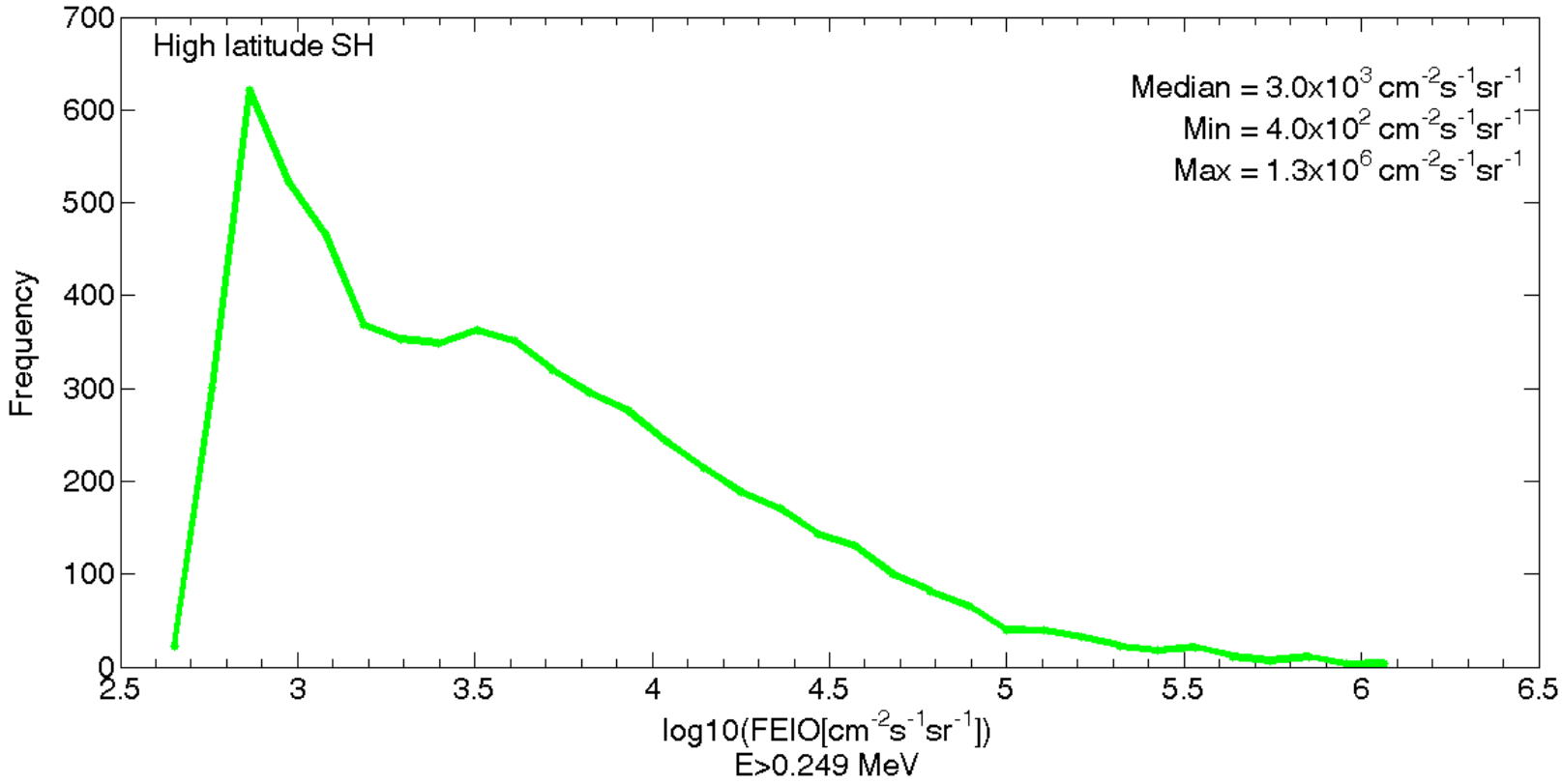
- Region 1 ($L = 1.35 \pm 0.1$)
- PDF near to a log-normal for fluxes $\sim (4 - 8) \times 10^5$ cm^{-2}s^{-1}sr^{-1}
- Larger tail for fluxes $> 10^6$ cm^{-2}s^{-1}sr^{-1}

Region 2: South High Latitude Polar



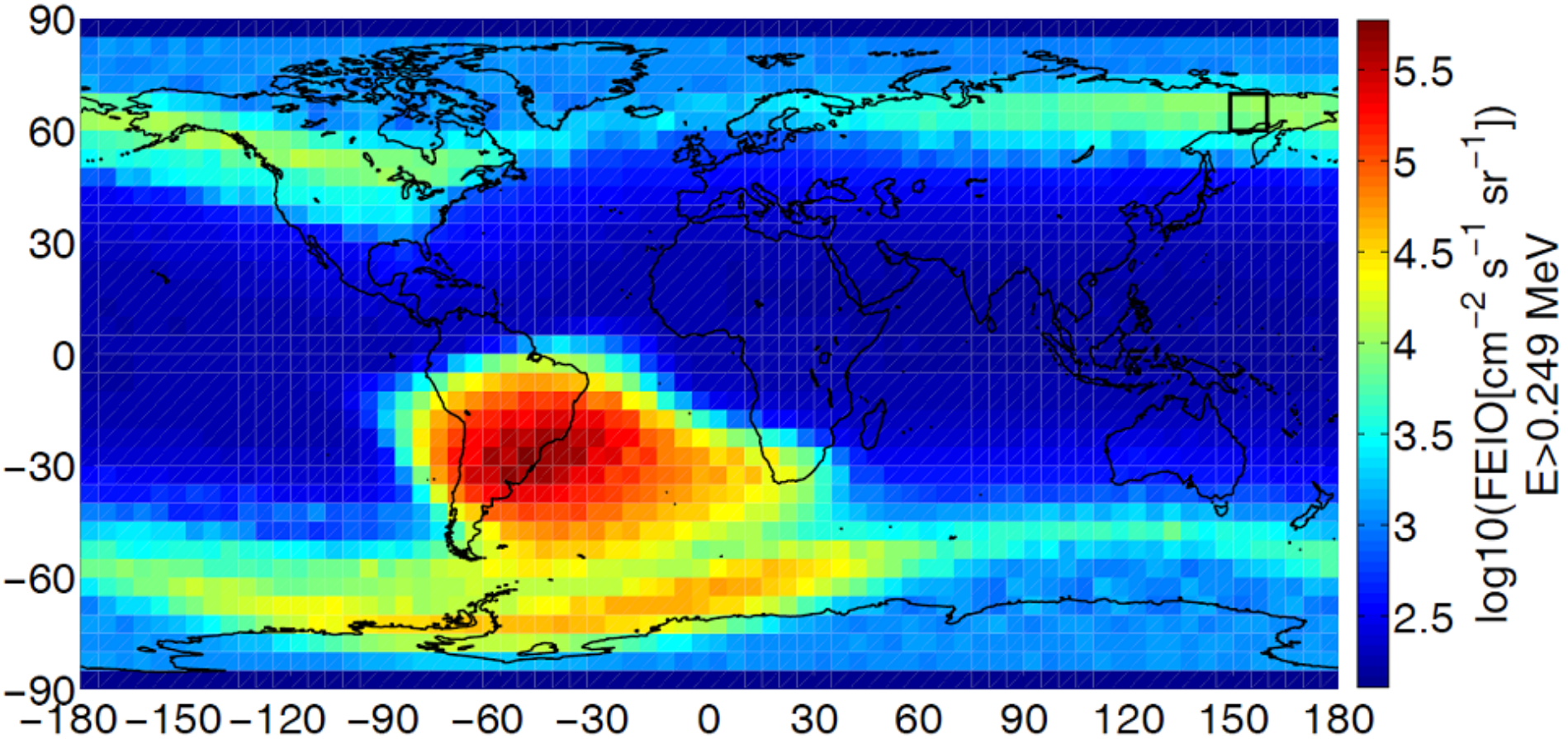
- Latitude: -70 to -60 deg, Longitude: -65 to -55 deg
- Region 2 corresponds to L $\sim$ 3

Observed Distribution of fluxes at SHL (full mission)



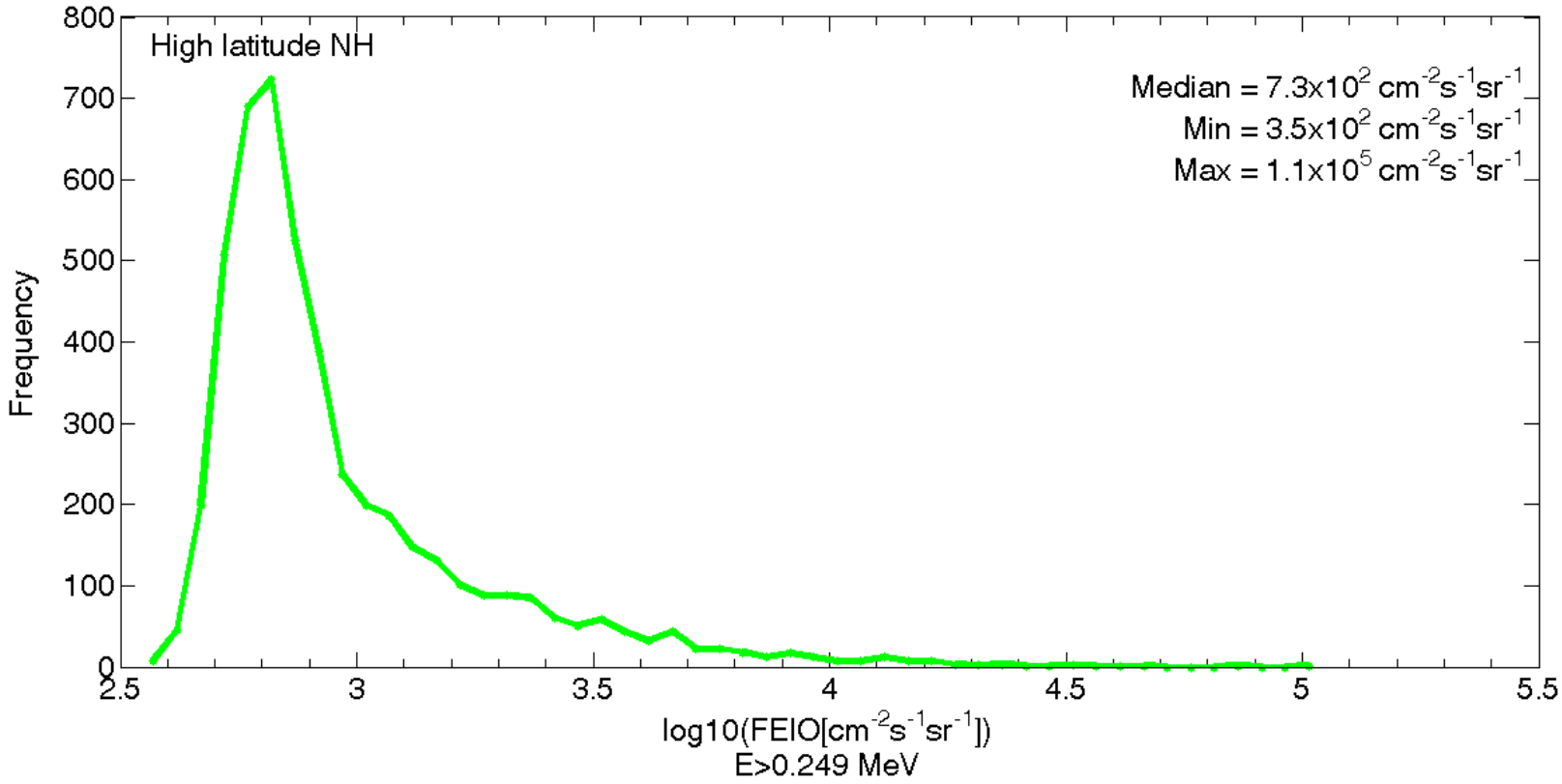
- Region 1 ($L = 3.0 \pm 0.5$)
- PDF covers a huge range (10^2 to 10^6 $cm^{-2}s^{-1}sr^{-1}$)
- Near to a superposition of two log-normal
- Larger tail for fluxes $> 10^4$ $cm^{-2}s^{-1}sr^{-1}$

Region 3: North High Latitude



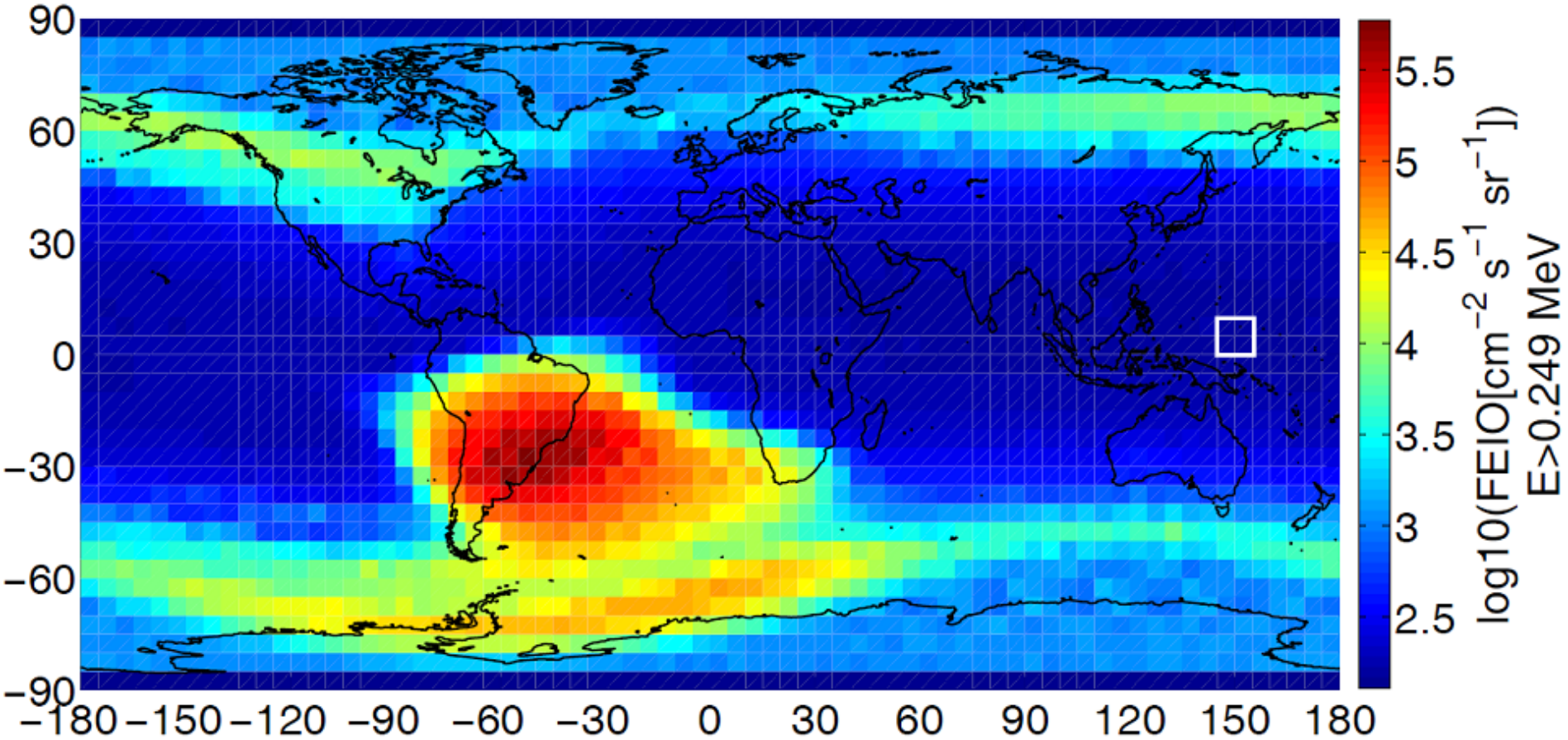
- Latitude: 60 to 70 deg, Longitude: 150 to 160 deg
- Region 3 corresponds to L $\sim$ 4.5

Observed Distribution of fluxes at NHL (full mission)



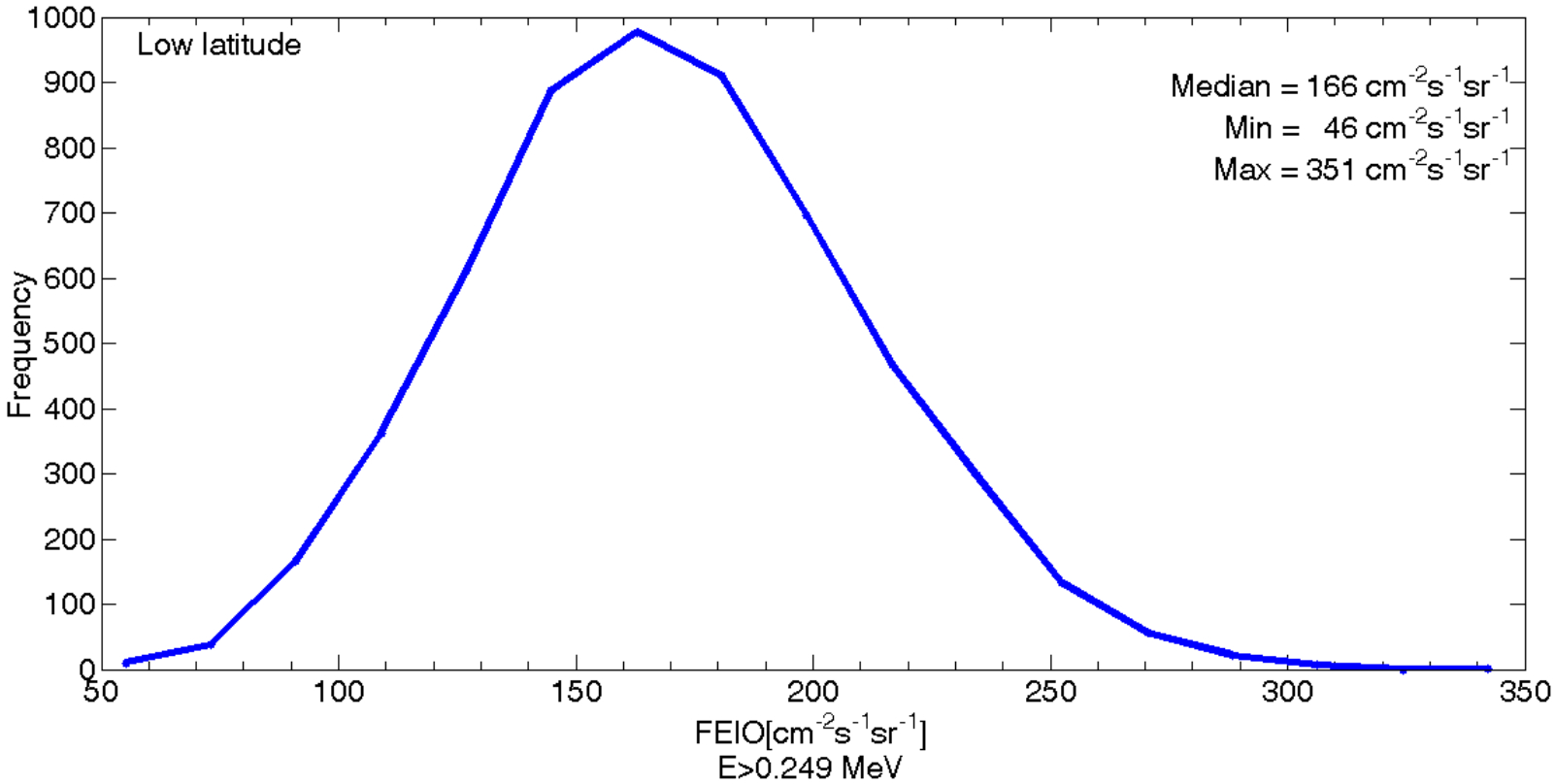
- Region 3 ($L = 4.5 \pm 1.5$)
- PDF covers a huge range (10^2 to 10^5 $cm^{-2}s^{-1}sr^{-1}$)
- Near to a log-normal
- Larger tail for fluxes $> 10^3$ $cm^{-2}s^{-1}sr^{-1}$

Region 4: Low Latitudes



- Latitude: 0 to 10 deg, Longitude: 145 to 155 deg
- Region 4 corresponds to L $\sim$ 1.05

Observed Distribution of fluxes at Low Latitude (full mission)

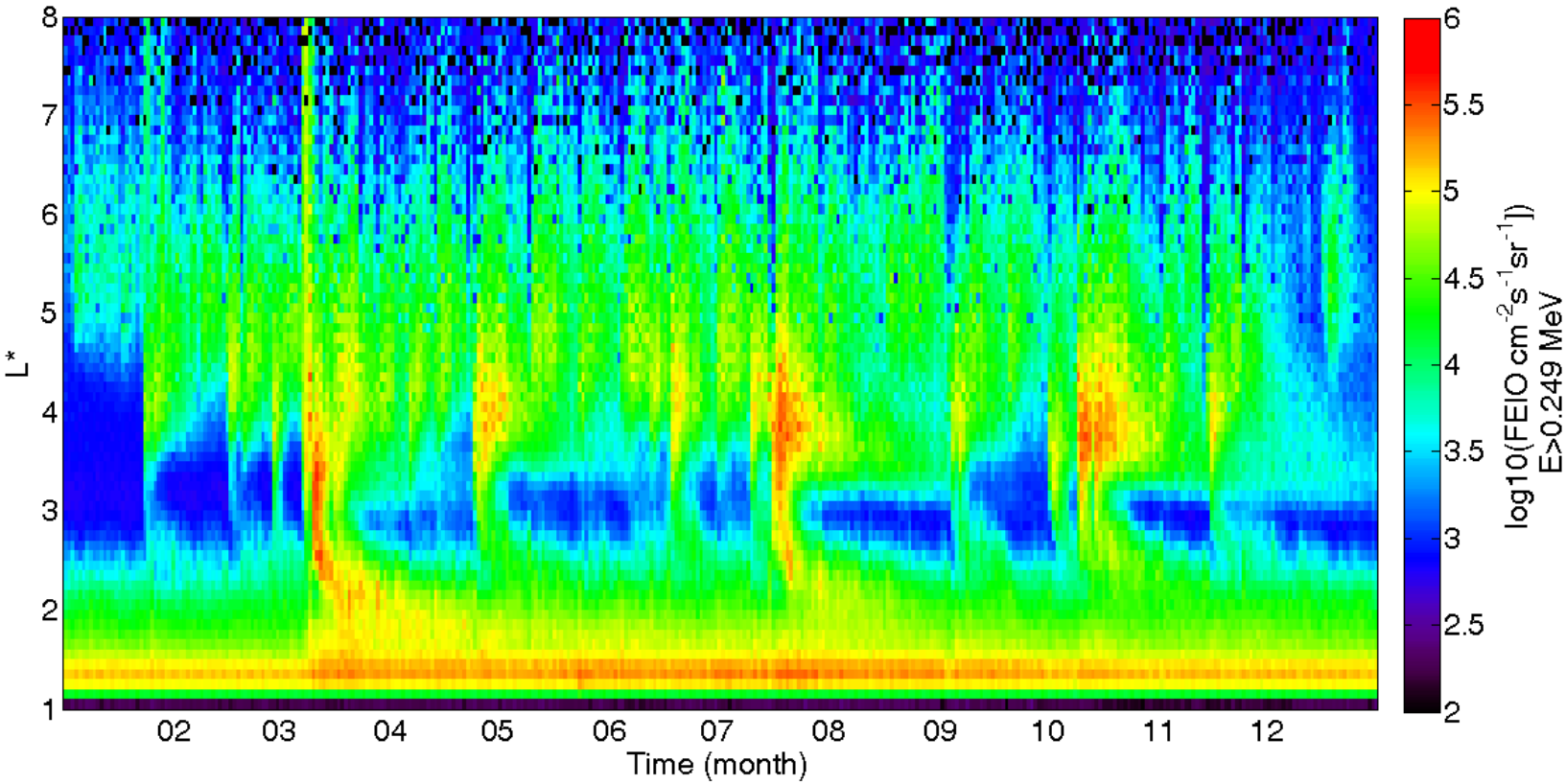


- Region 3 ($L = 1.05 \pm 0.01$)
- PDF covers a range between ~ 50 to ~ 350 cm^{-2}s^{-1}sr^{-1})
- Near to a normal

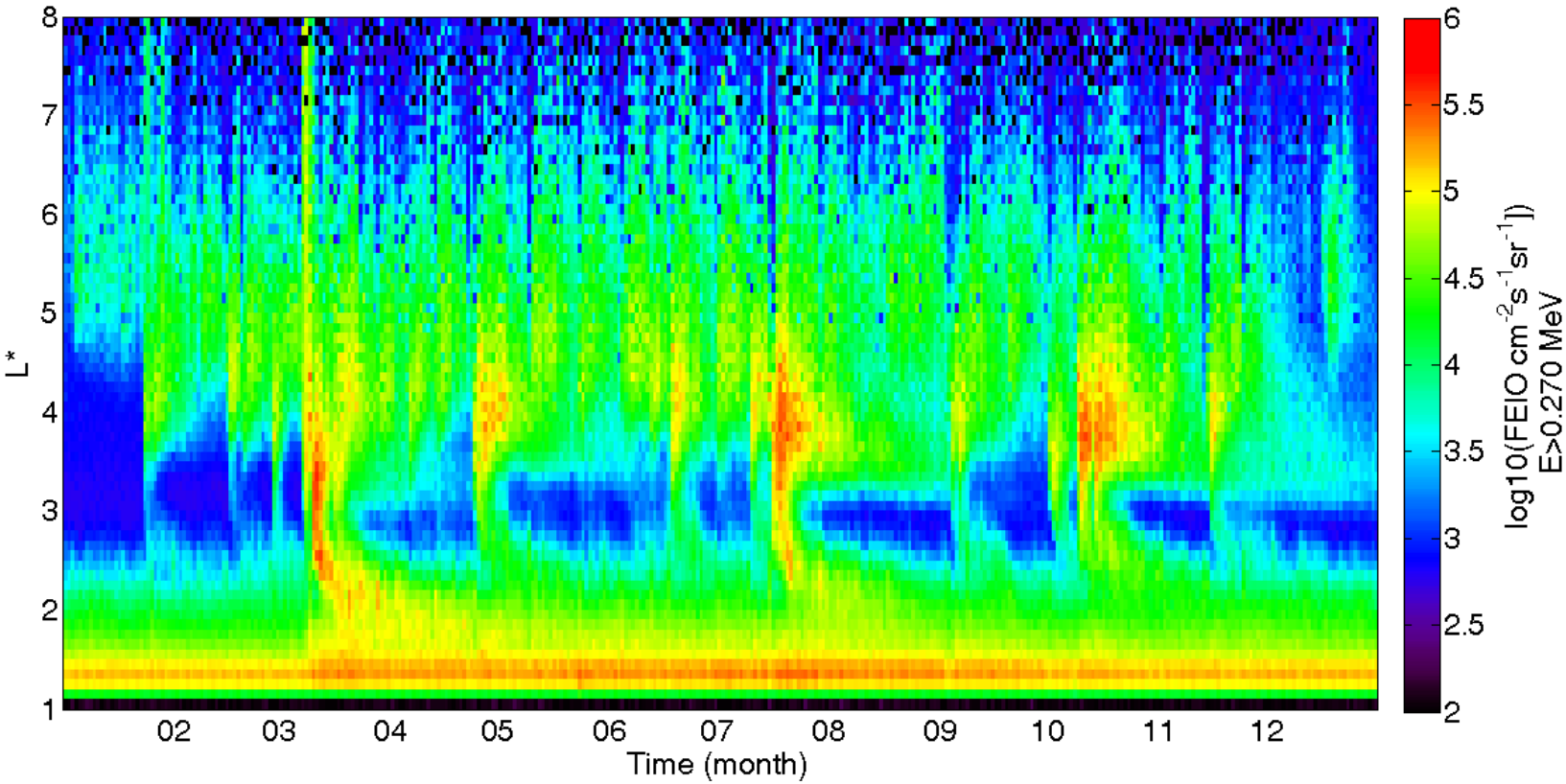
Particles according with L/energy

The answer of the fluxes of particles for an extreme Space Weather event is presented in a Poster in this conference [Lanabere et al.]

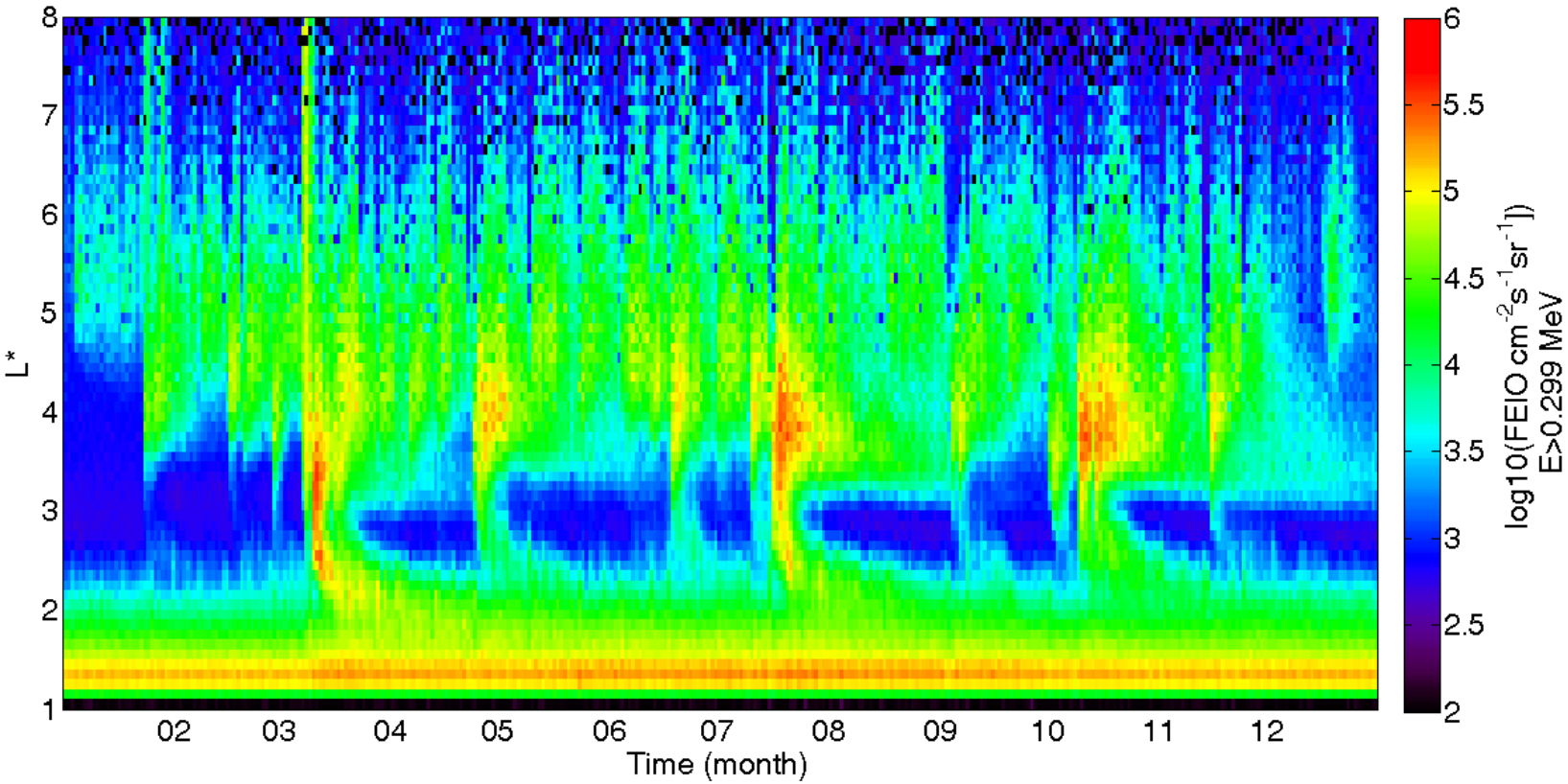
Distribution of particles, according with L and energy



Distribution of particles, according with L and energy



Distribution of particles, according with L and energy



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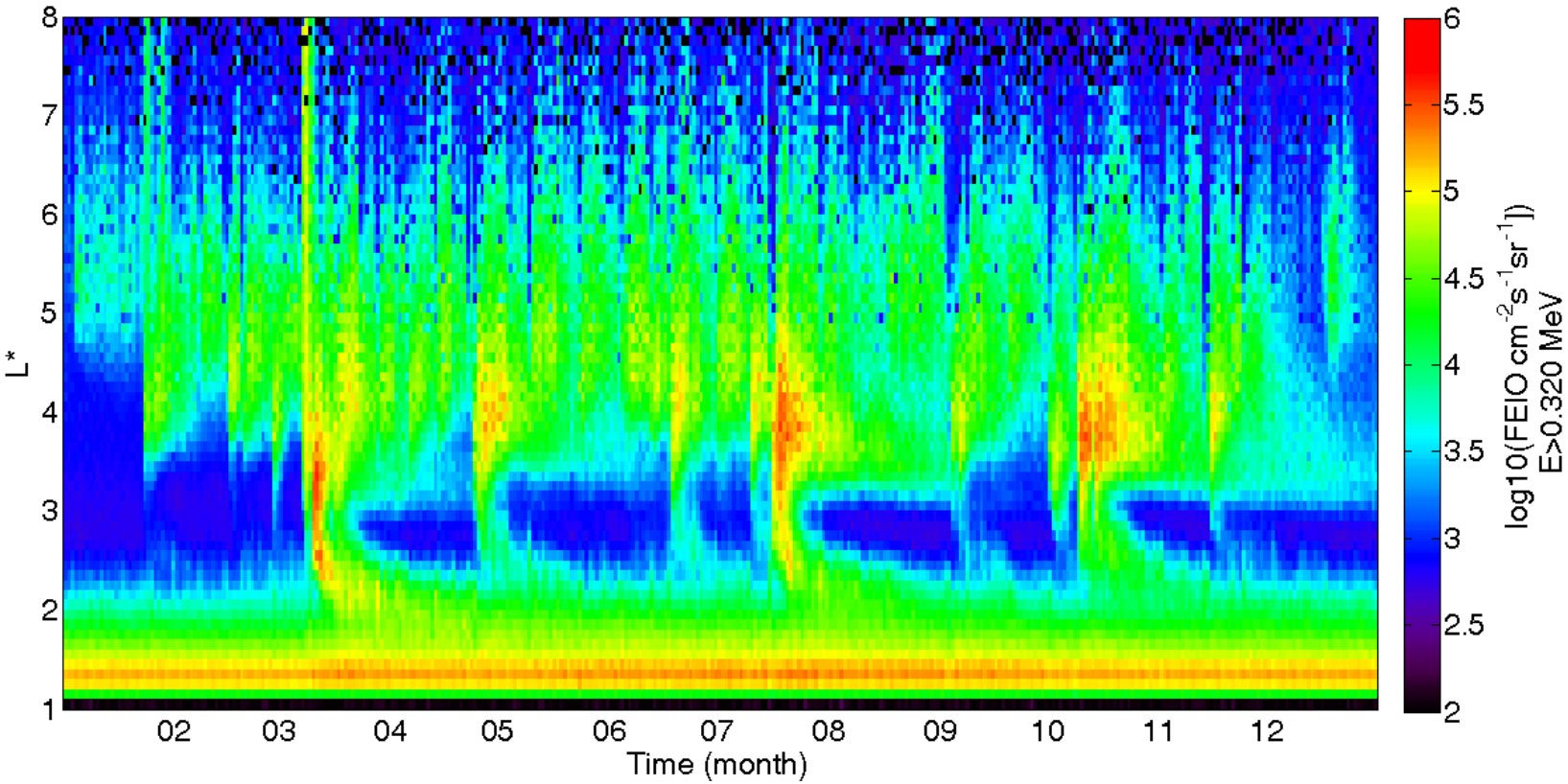
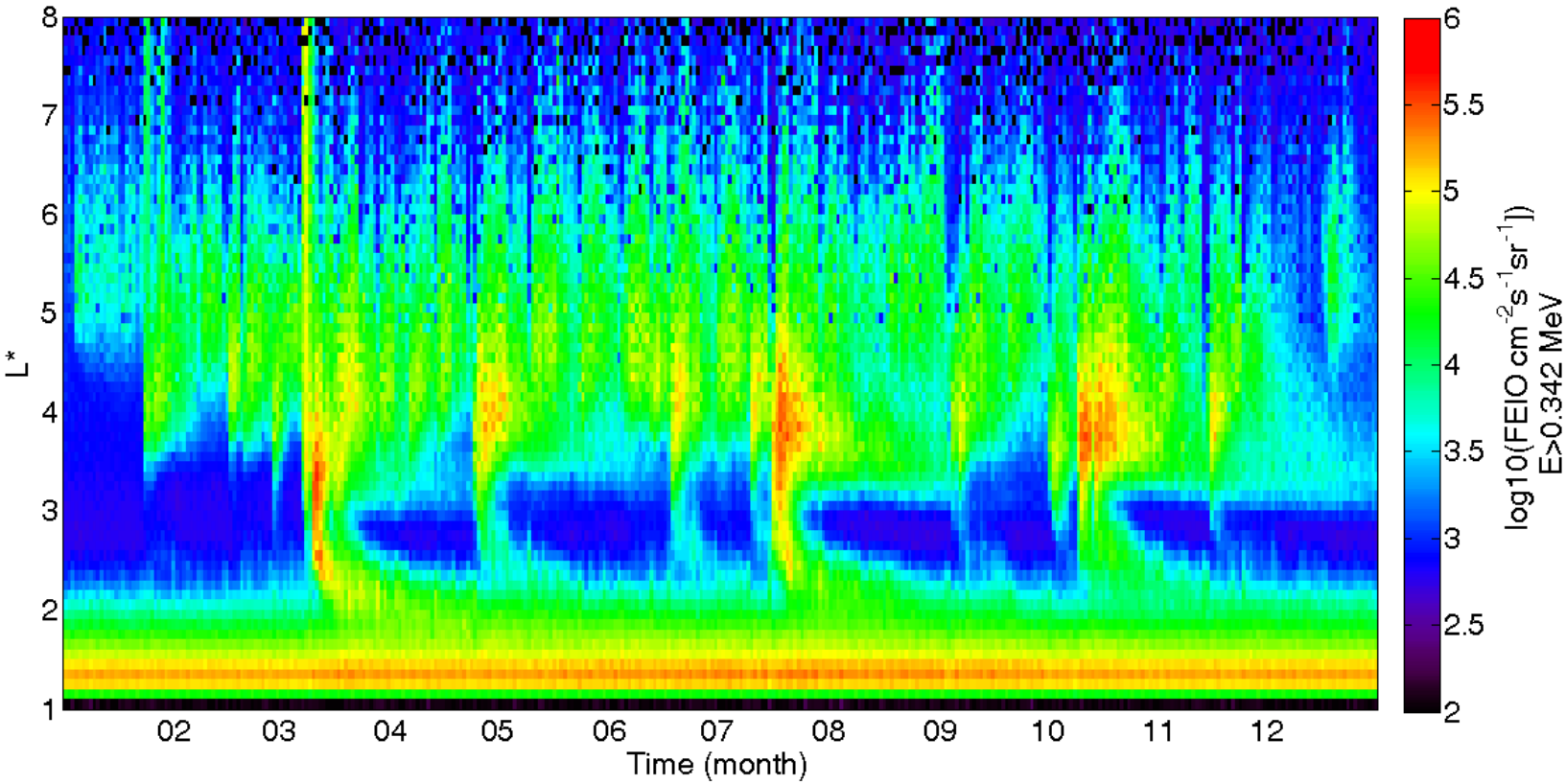


Distribution of particles, according with L and energy



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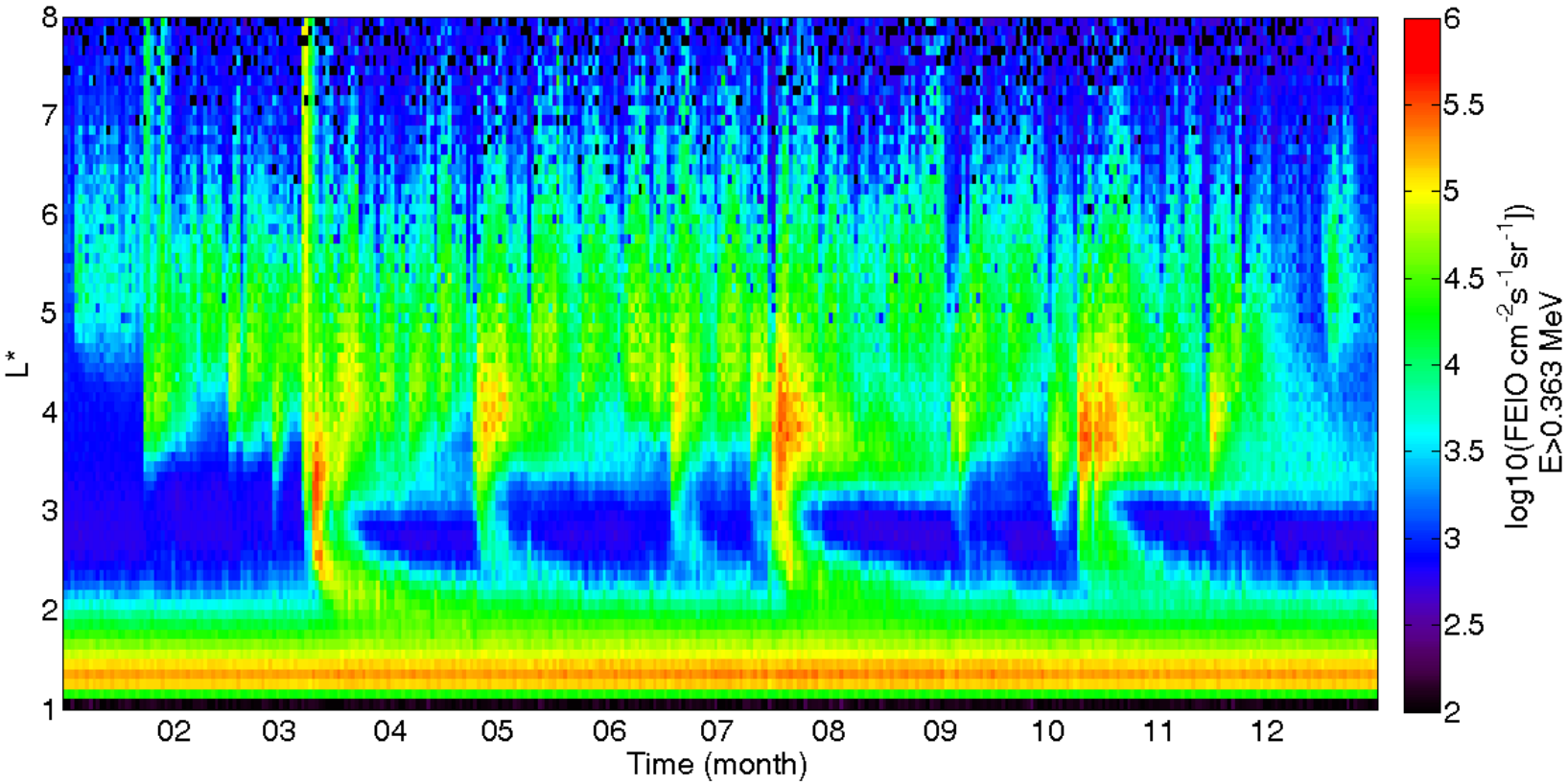

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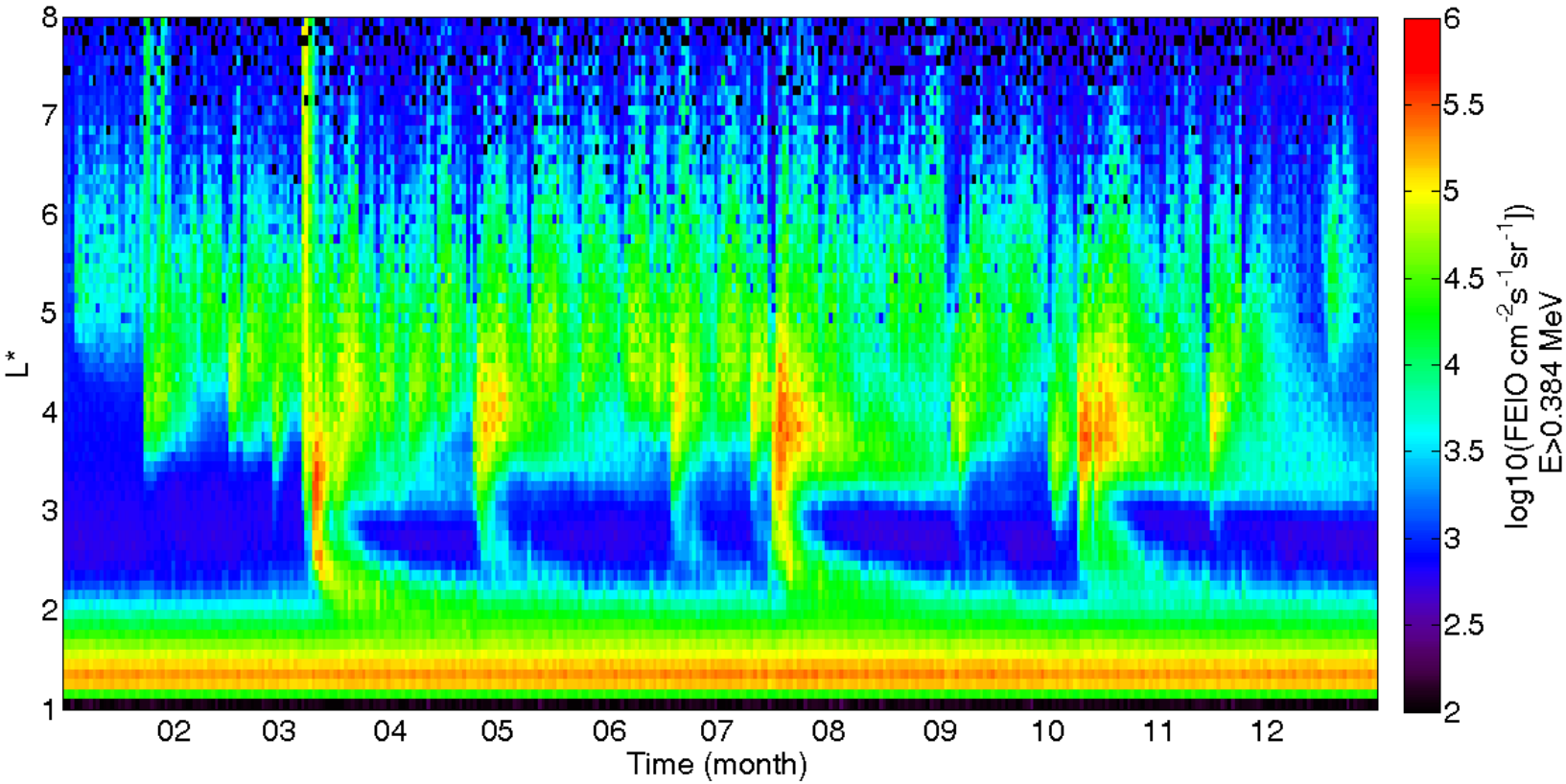

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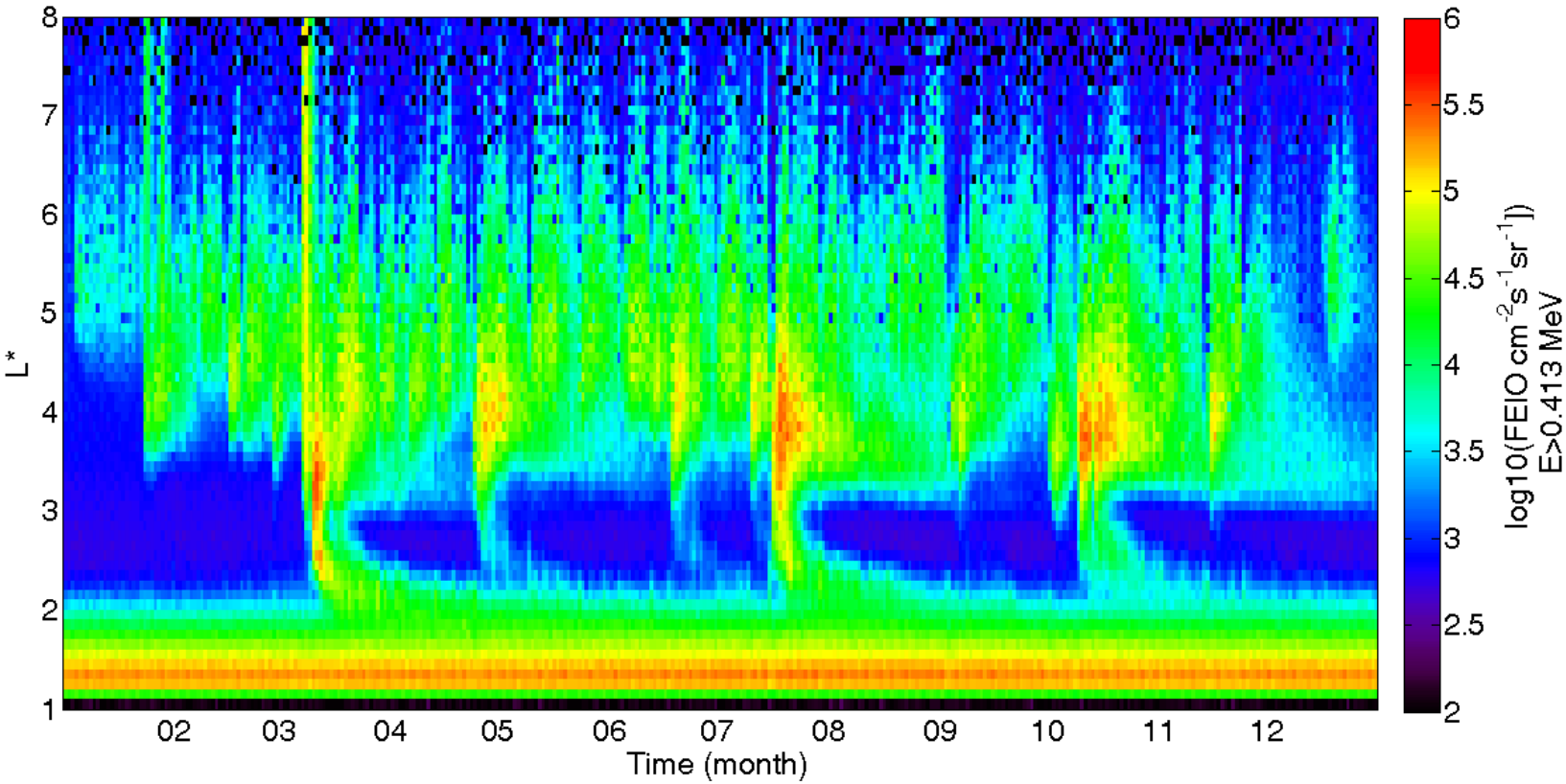

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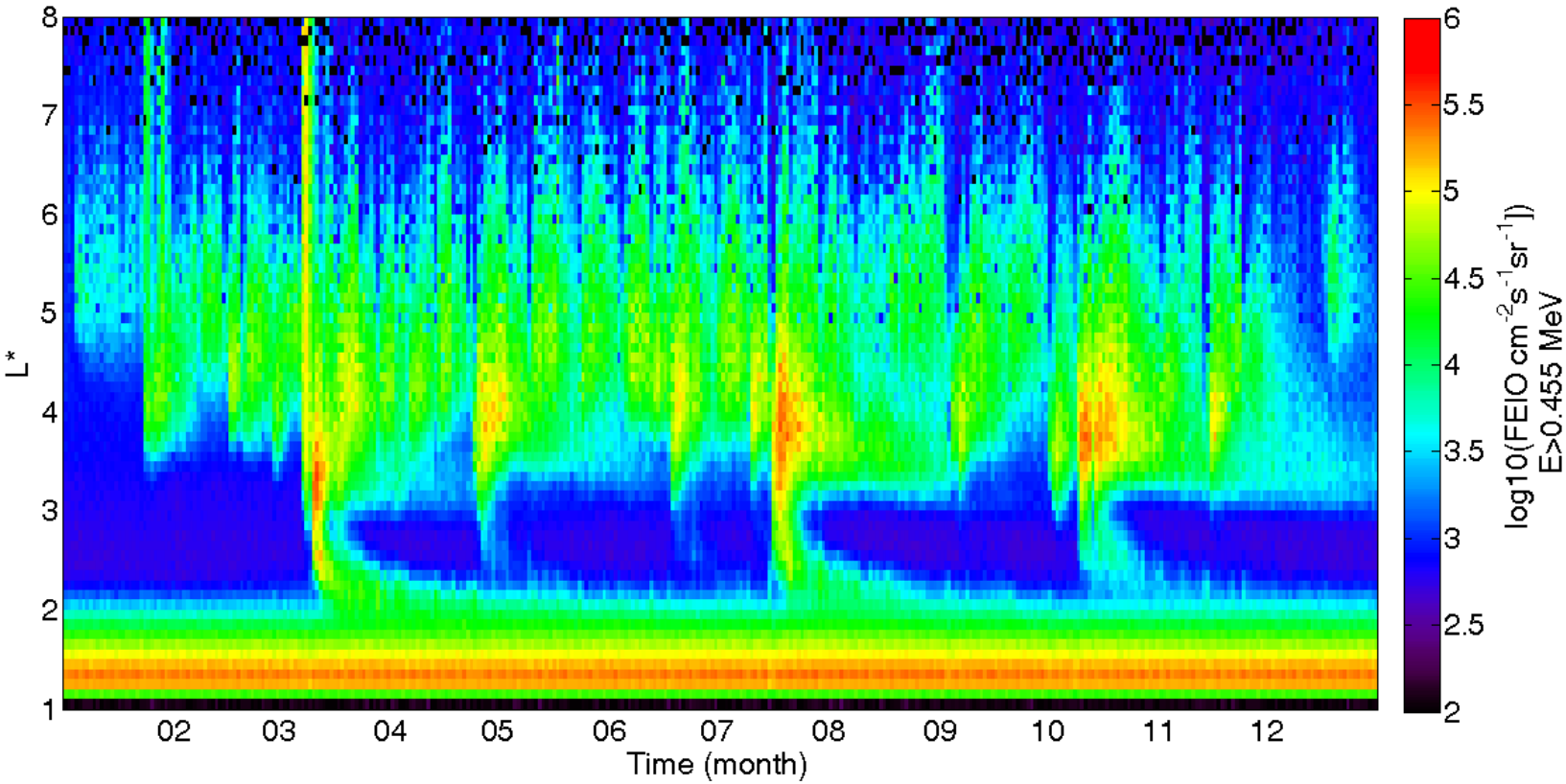

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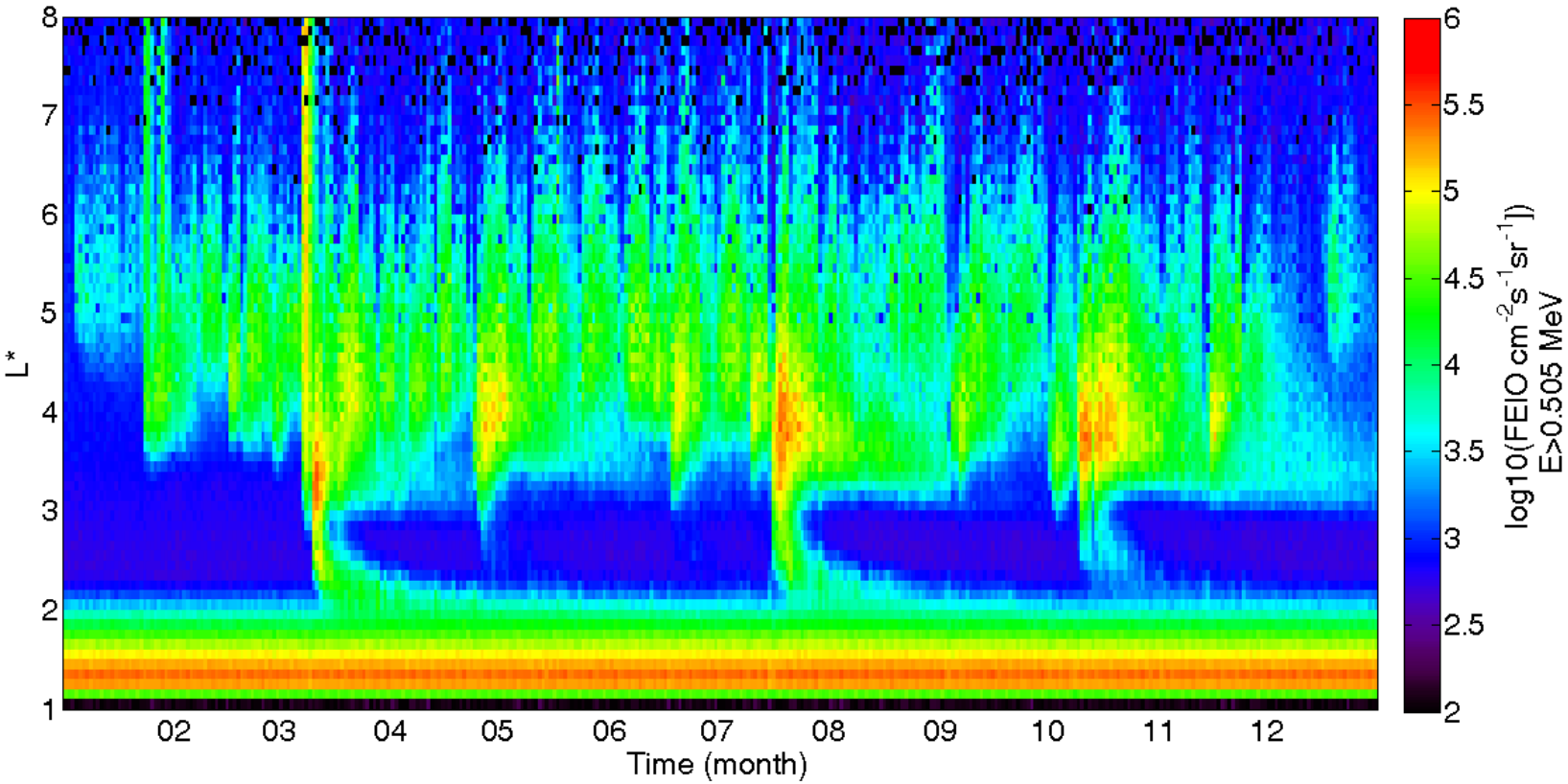

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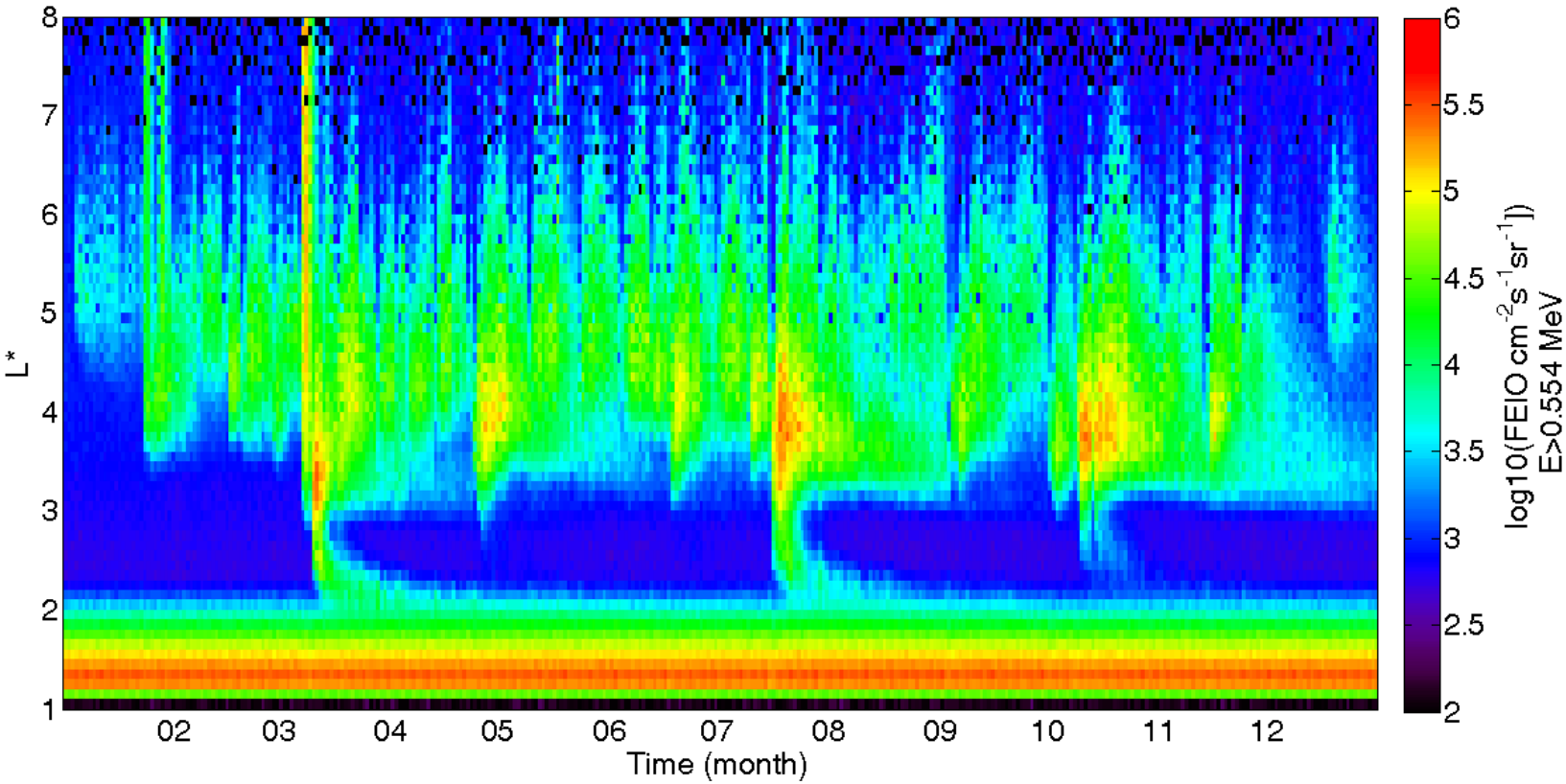

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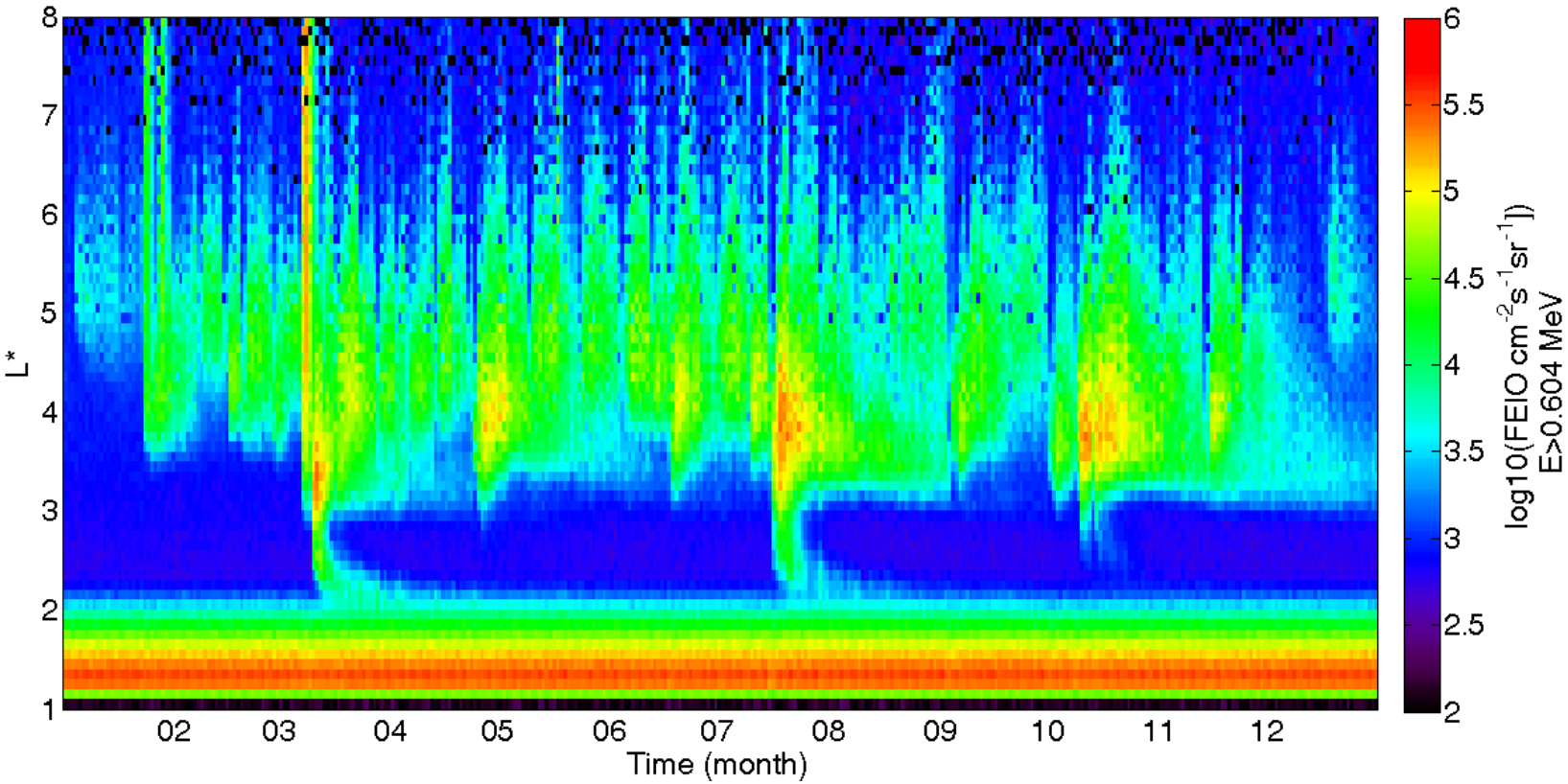

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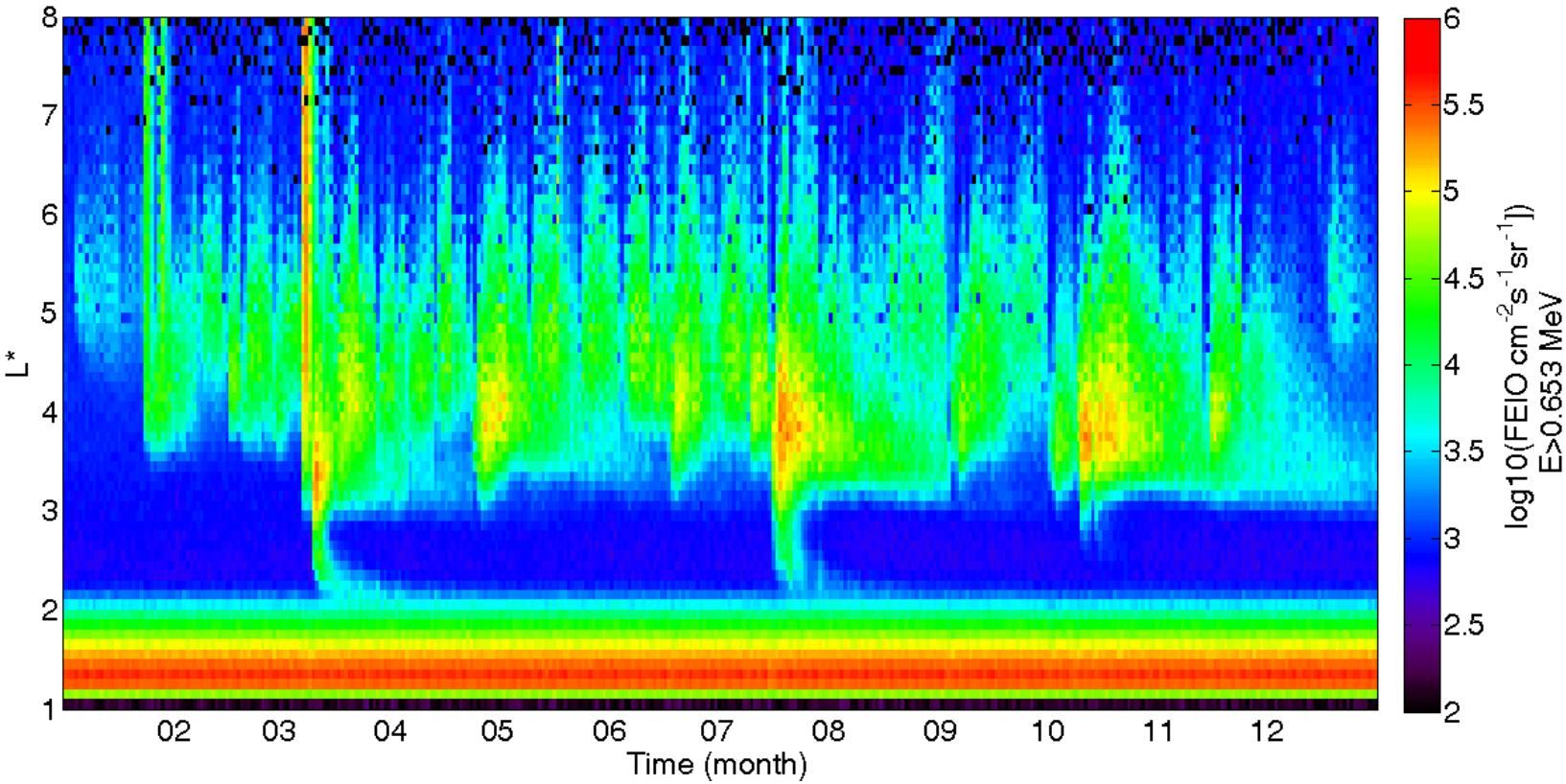

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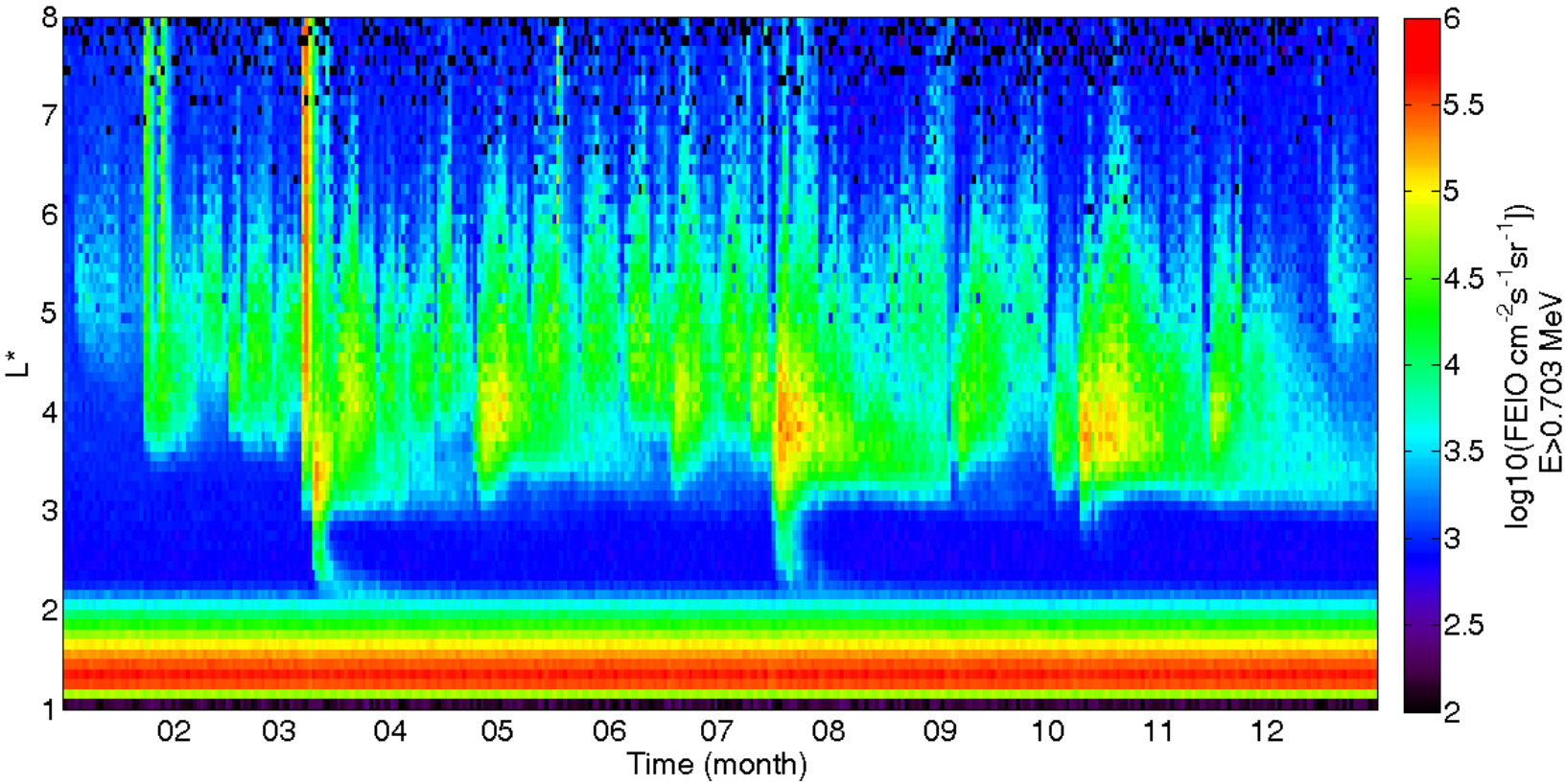

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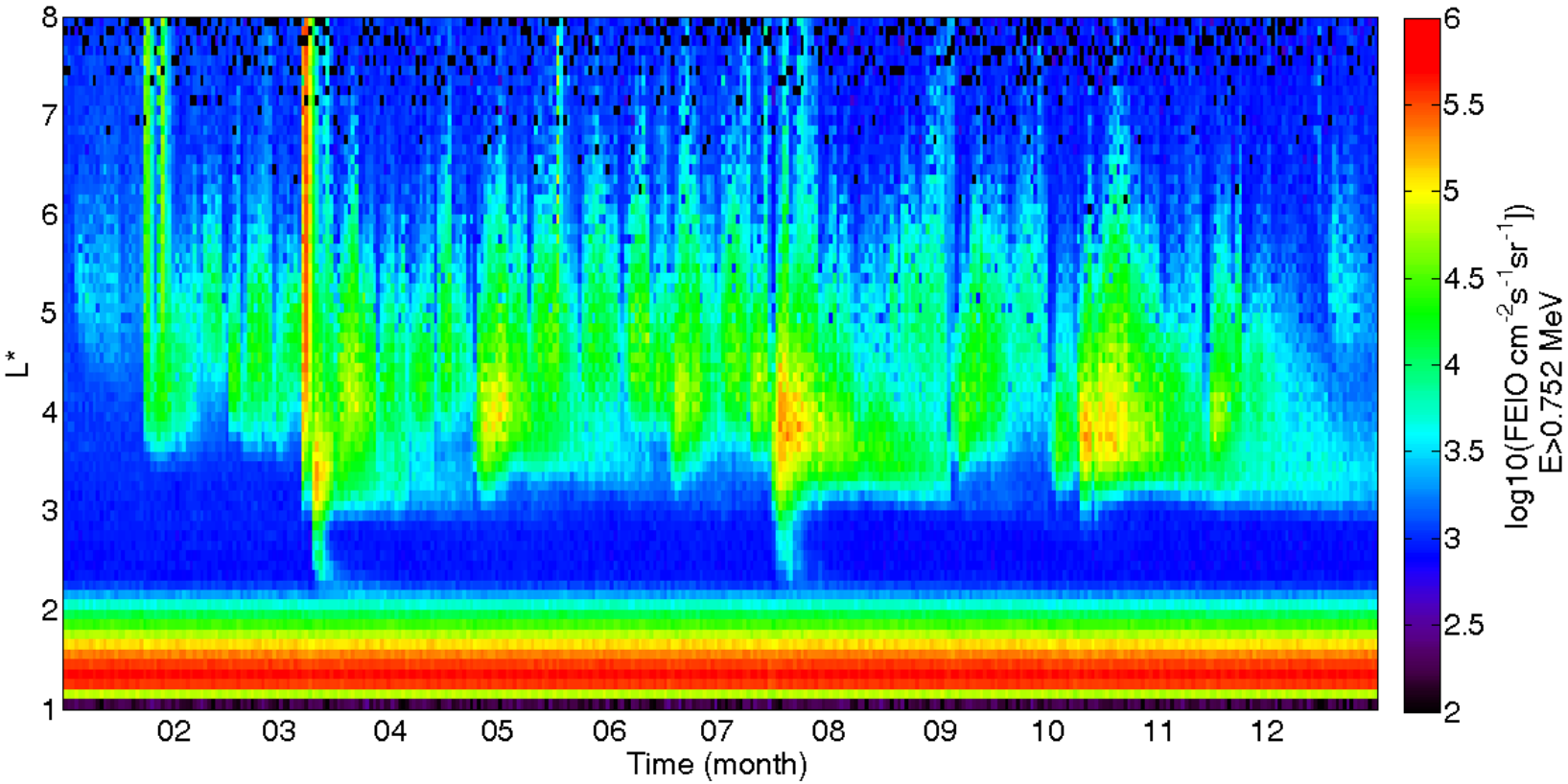
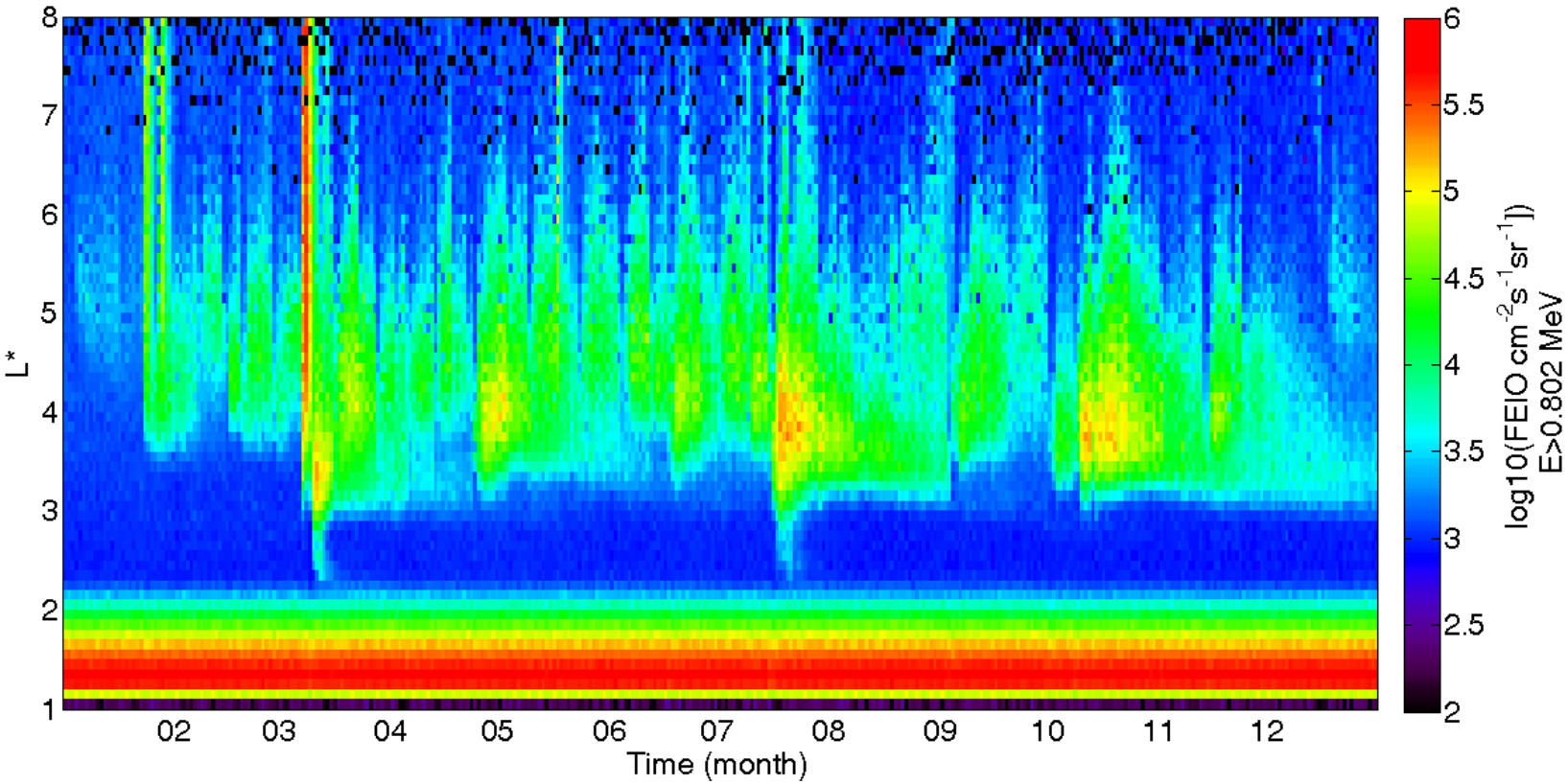


Distribution of particles, according with L and energy



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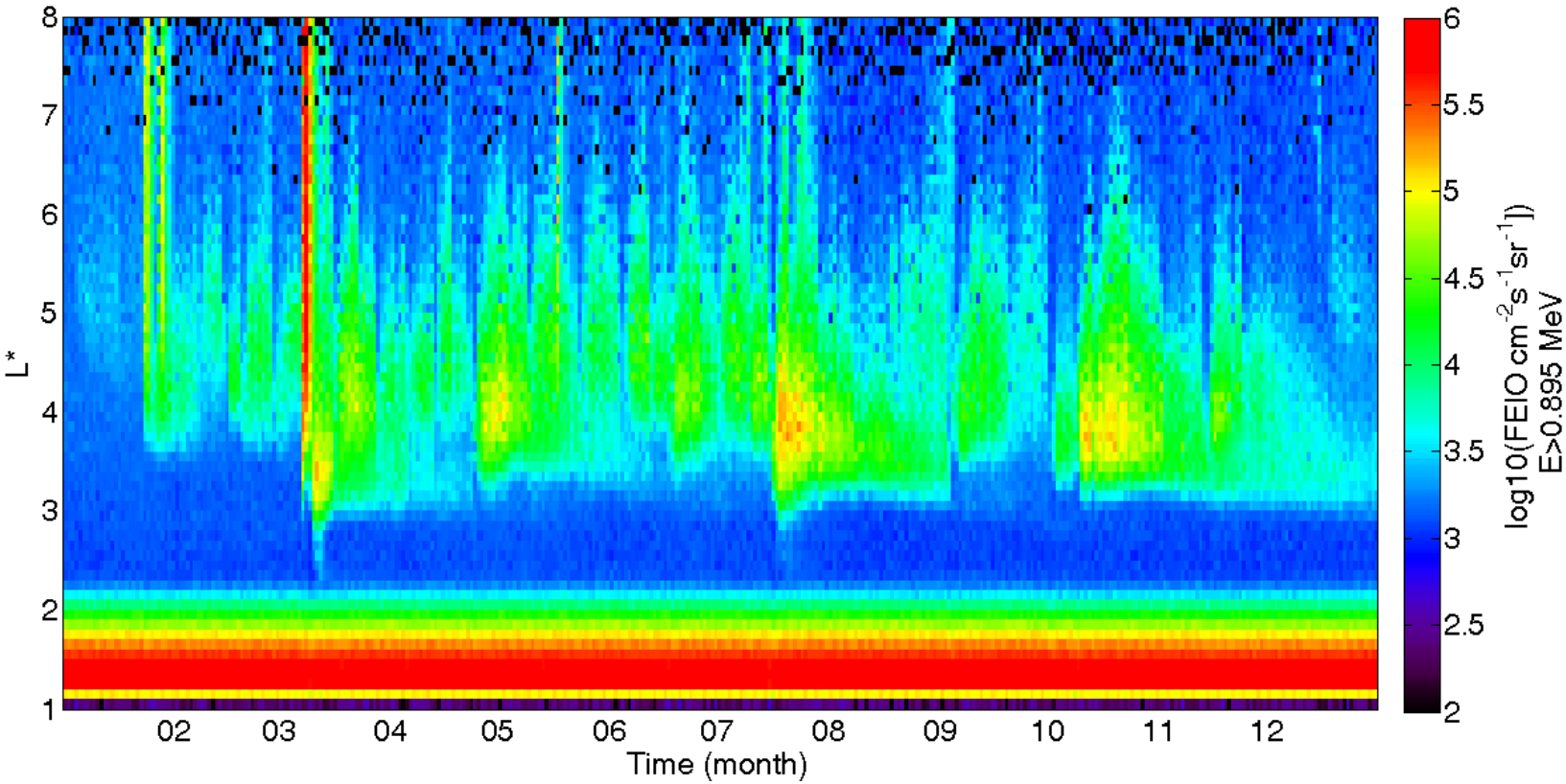

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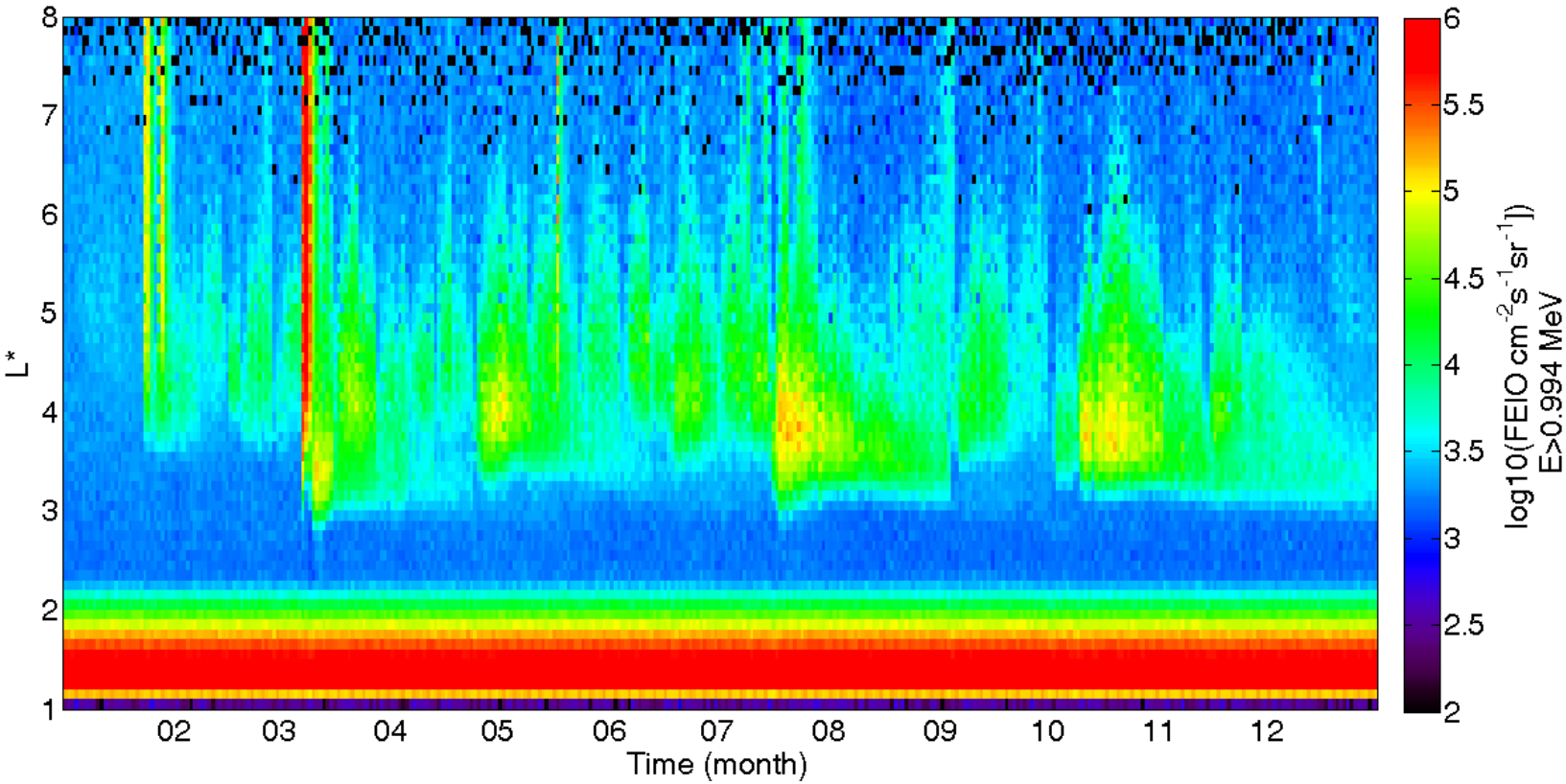

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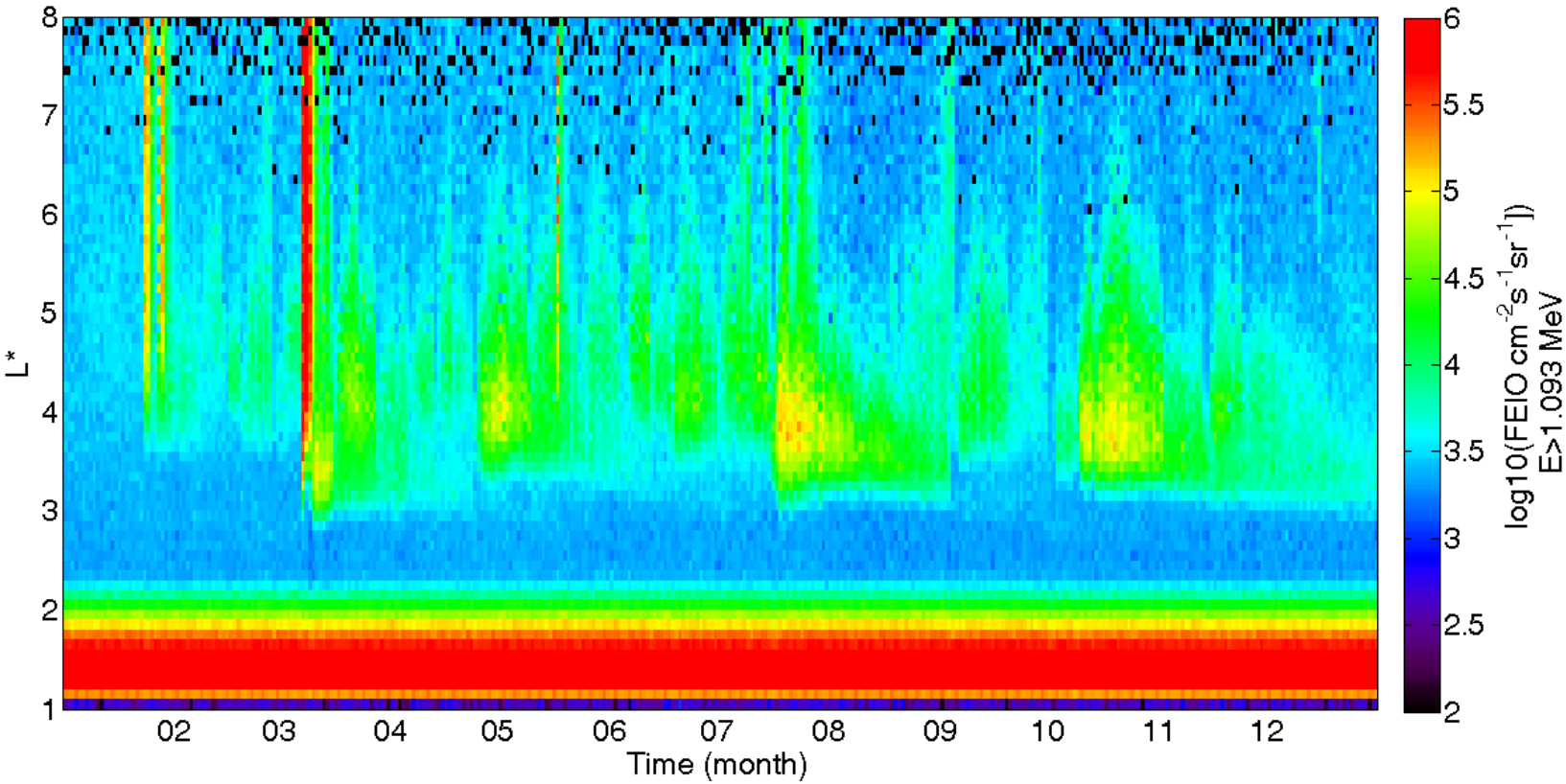

Summary and Conclusions

- The dynamics of the radiation belts strongly depends on Space Weather activity
- We constructed a global map of e- fluxes for E>259 keV: migration of AAS to the South
- For e- fluxes AAS moves to the North-West when E increses (from 259 keV to 413 keV)
- We analyzed the PDF of fluxes for four regiones:
  - AAS: PDF near to log-normal, with larger tail
  - South Polar: PDF as superposition of two log-normal, with larger tail
  - North Polar: PDF near to log-normal, with larger tail
  - Low Latitude: PDF near to a Normal
- We analyzed the distribution of particles on L and energies, we quantify the answer of the outer radiation belt to extreme Space Weather events

Many Thanks for your attention !!