Observation of VLF transmitter induced electron precipitation of up to 400keV

Coralie Neubüser*, R. Battiston, W. J. Burger, A. Oliva, D. Recchiuti and M. Piersanti

*TIFPA-INFN, Trento (Italy). Email: coralie.neubueser@tifpa.infn.it

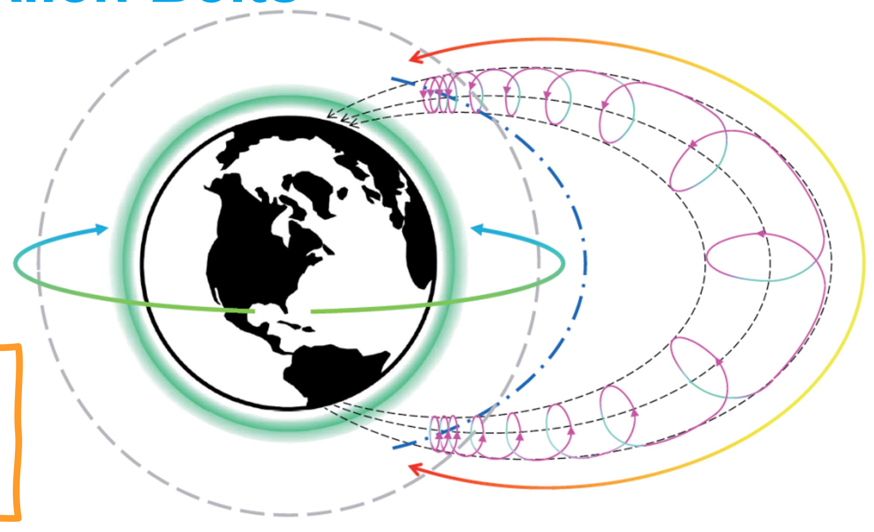
on behalf of the CSES-Limadou Collaboration

Sharing is encouraged

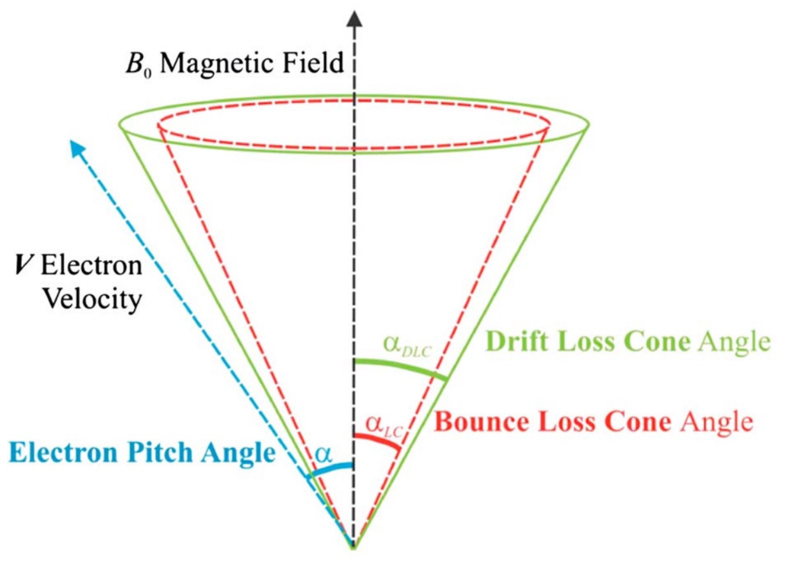
Trapped particles in Van-Allen Belts

- Gyromotion of charged particles along magnetic field lines
- Bouncing between conjugate points
- Longitudinal drift Est-wards for negatively charged particles

Pitch angle of particle determines whether it's precipitating or bouncing along magnetic field line



Bounce and Drift Loss Cones (B/DLC)



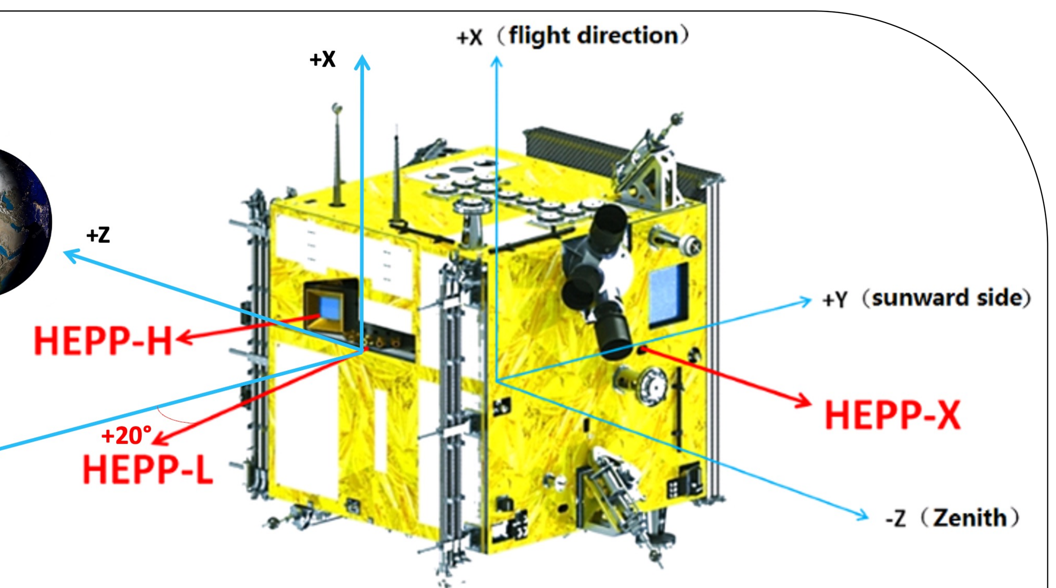
[J.C. Rodger et al., (2013) doi:10.1002/2013JA019439]

Pitch angle = angle between velocity vector and magnetic field line

- Trapped particles have a range of pitch angle at the geomagnetic equator from 90° down to the bounce loss cone angle α_{BLC}
- Below α_{BLC} the particle mirrors below the atmosphere (~100km)
- Particles with pitch angles $\alpha_{BLC} < \alpha < \alpha_{DLC}$ are drifting around the world above the atmosphere until reaching the SAA at which the $\alpha_{BLC} \gg \alpha$

CSES-01 Satellite

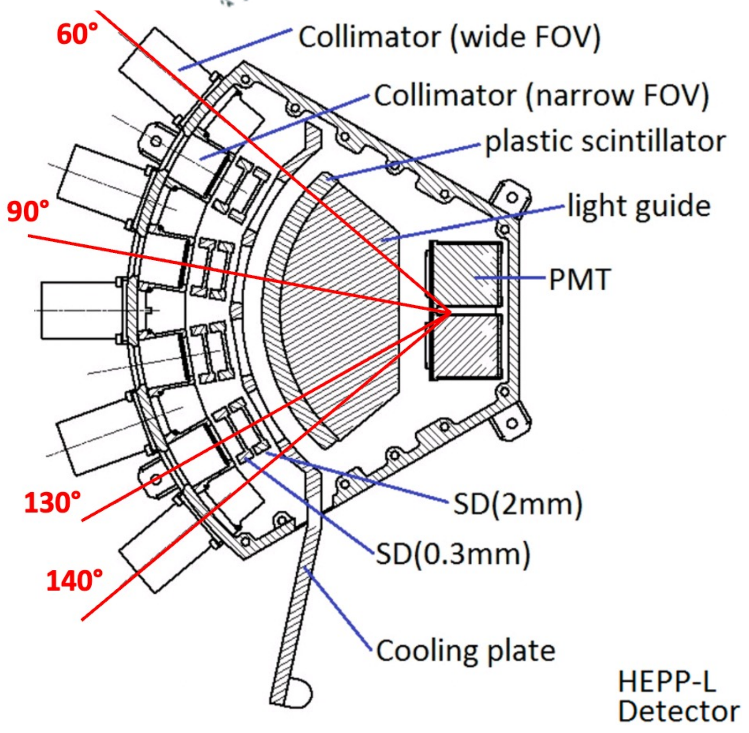
- Launch February 2nd, 2018
- 9 payloads on board
- Sun-synchronous
- 97º inclination, 5-day period
- ~500km altitude



High Energy Particle Package (HEPP-L)

- Silicon telescope array
- 9 Silicon units (cannons) consisting of 1 thin + 1 thick chip
- 4 narrow and 5 wide collimators: 13º/30º opening angle, arranged 10º apart from each other → overlapping views
- Electron energy range **0.1-3MeV**, 10% resolution
- **Angle of cannons with respect to satellite zenith (equal to pitch angle at the poles)**
- Cannons oriented orthogonal to XZ plane of the satellite

Pitch angle of 97º at geomagnetic equator

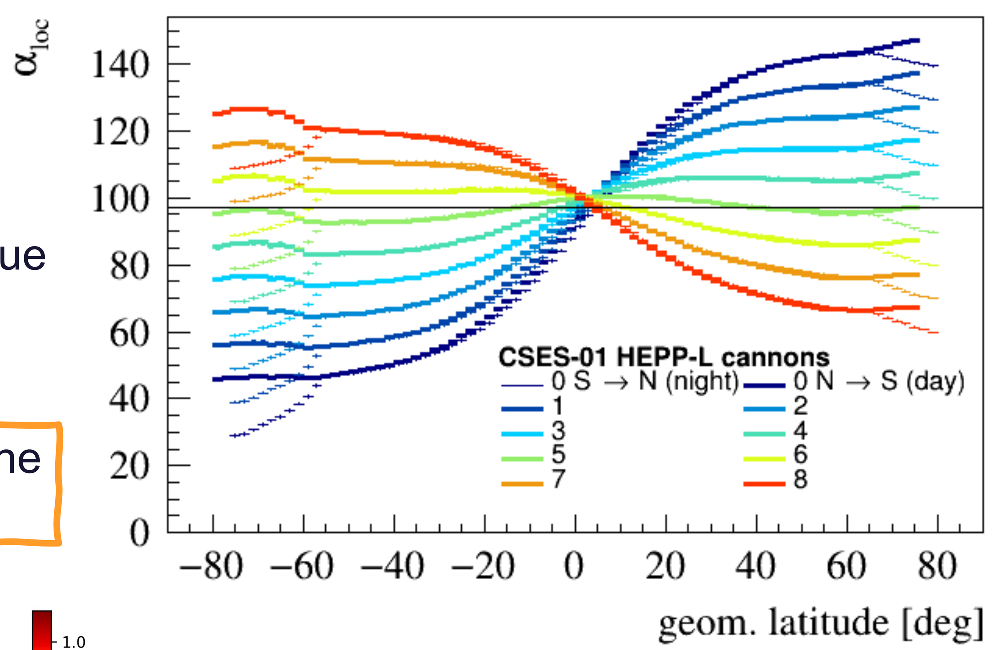


[X.Q. Li et al., (2019) doi:10.1007/s41605-019-0101-7]

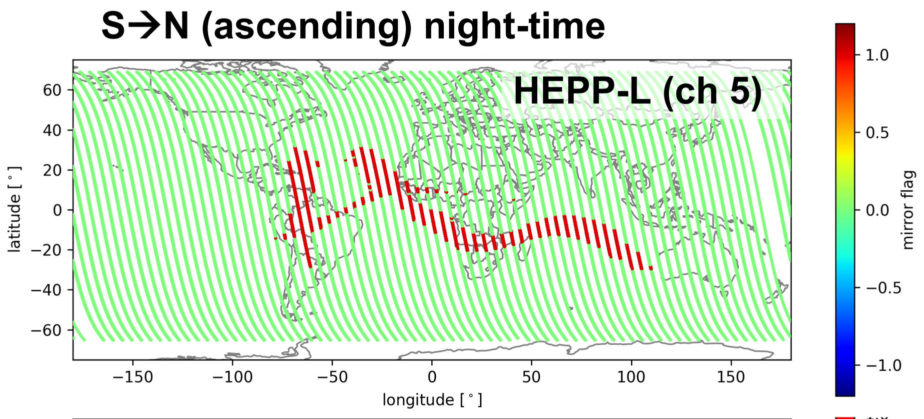
Pitch angle distribution

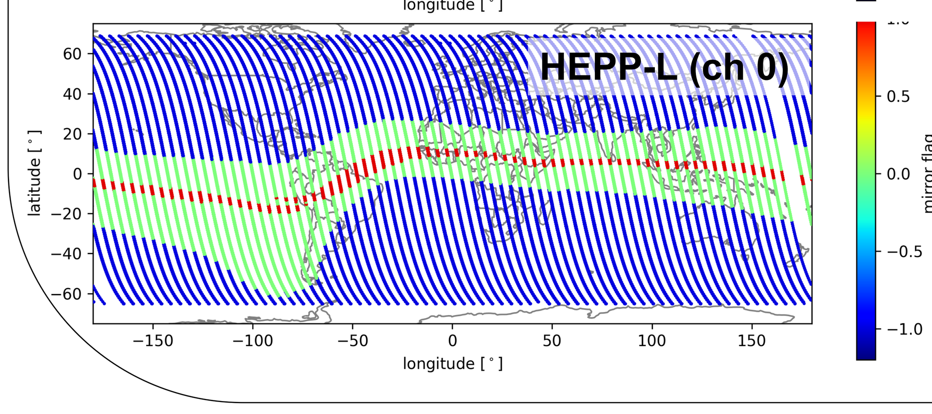
- Pitch angle of 97º at geomagnetic equator
- Difference in nigh/day-time orbits due to asymmetry in Z (+60º from +Z, -40º from -Z)

Cannon 5 stays closest to 90º along the orbit



S→N (ascending) night-time





Evaluation of mirror-points

Trapped particles (DLC)
Mirror points above satellite altitude
Mirror points below atmosphere (BLC)

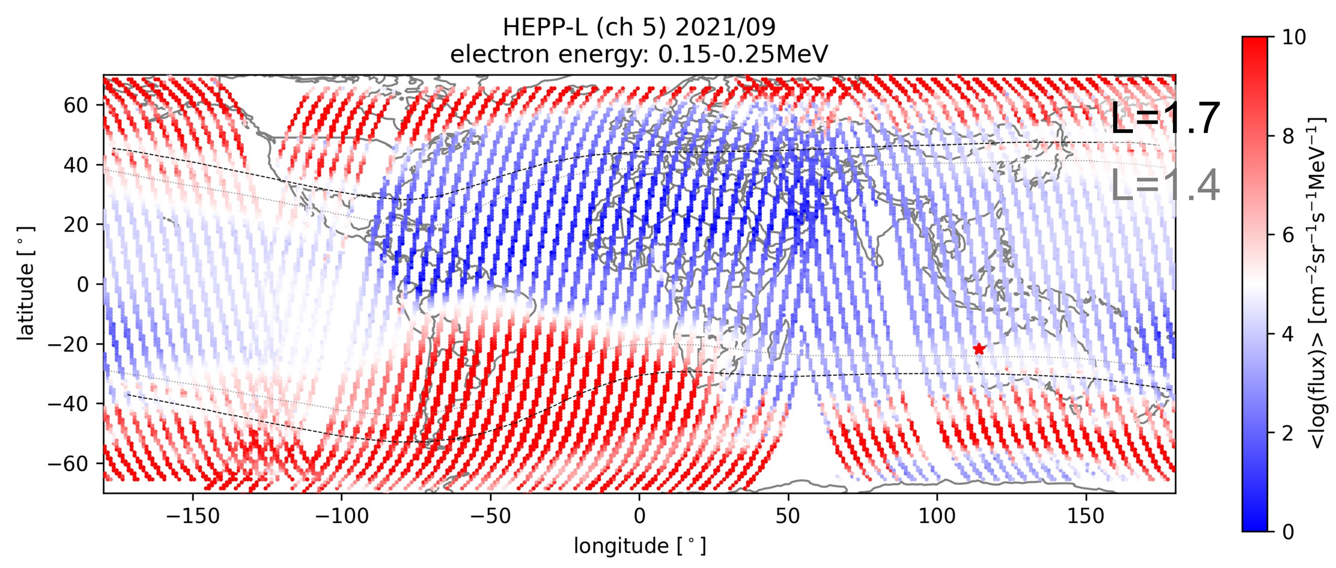
- mirror-points for particles visible with cannon 5 above satellite at low latitudes

Complementary coverage with other cannons, see cannon 0 which is oriented more towards zenith

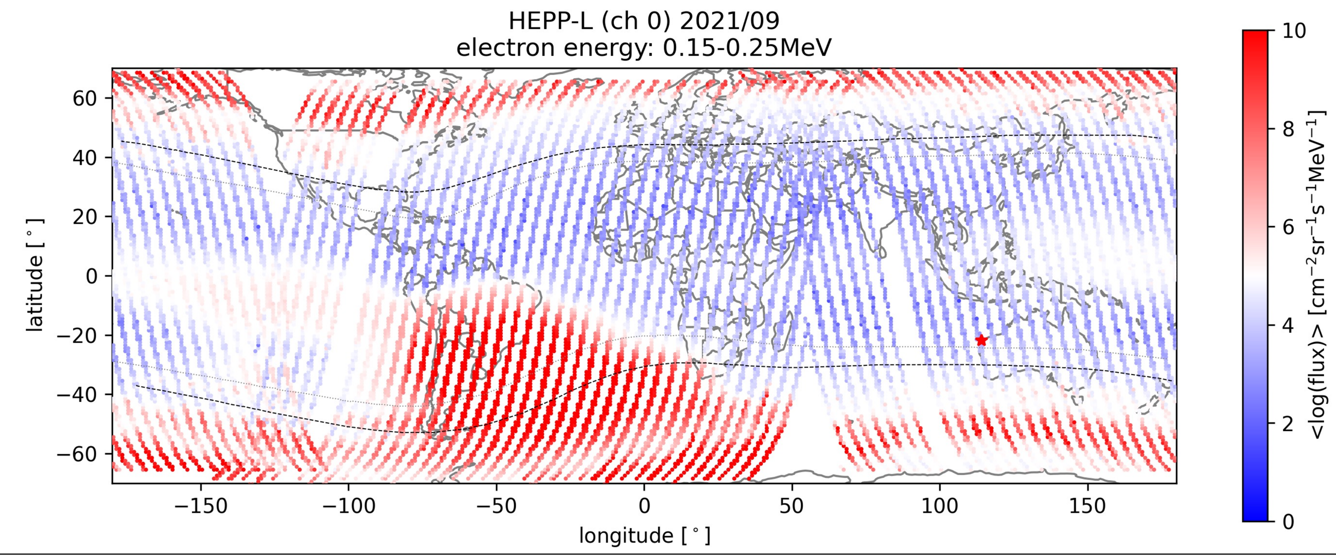
VLF transmitter causes particle precipitation

- Pitch angle scattering due to wave-particle interaction of Whistler waves from North West Cape transmitter in Australia (NWC) first seen by DEMETER

[J.-A. Sauvaud et al., (2008) doi:10.1029/2008GL033194]



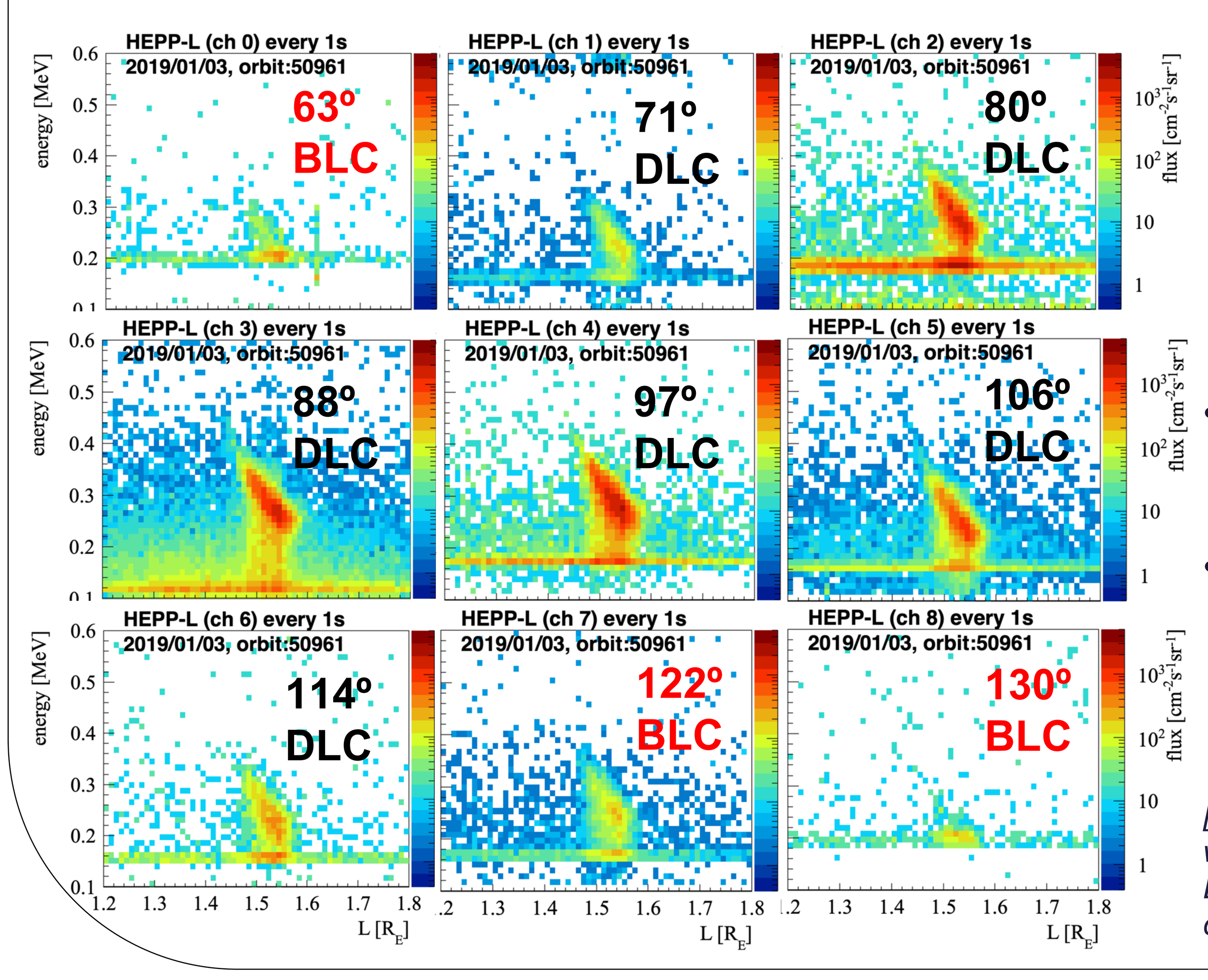
- Selection of measurements at night-time periods at NWC
- Enhanced electron flux East-ward from NWC (★) between L=1.4-1.7

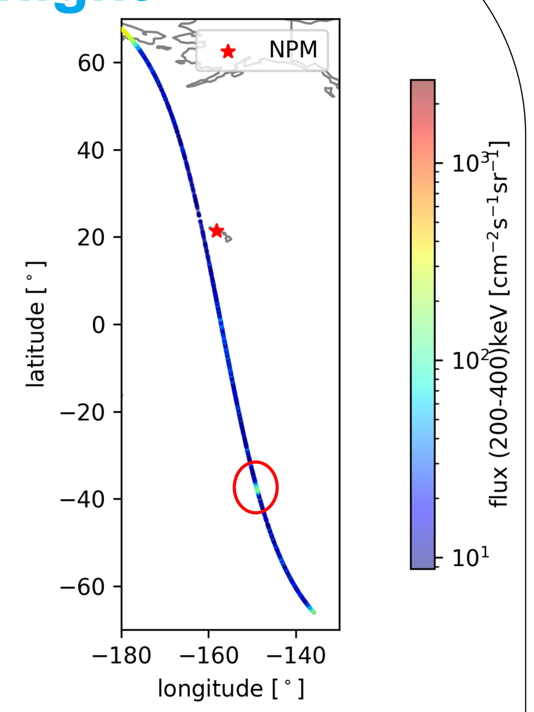


- Almost no VLF induces electrons seen due to accessible particle pitch ≠ 90º

Wisp structure example ascending night-time semi-orbit 03.01.2019

- Observed between L-shell: 1.45 and 1.6
- Electron energies from 200 to 400keV
- HEPP-L cannons allow observation in BLC and DLC at the same time





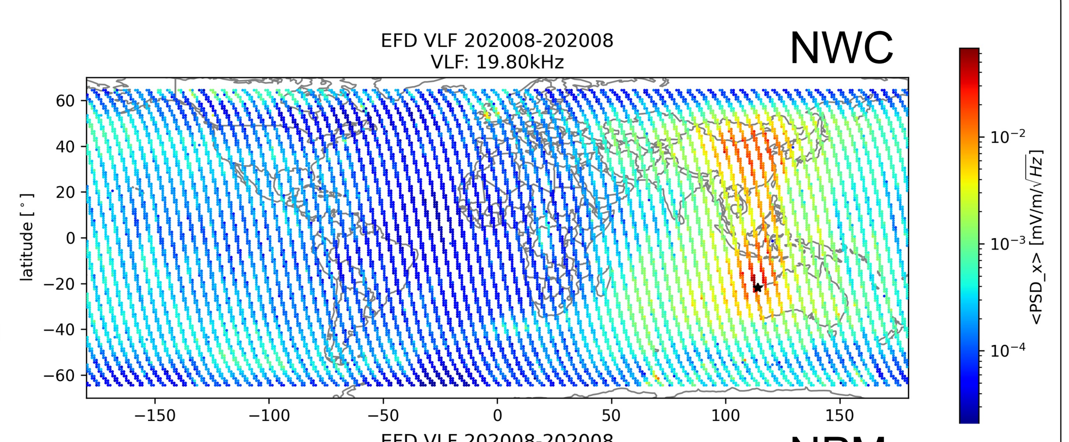
- Whisp strong on southern hemisphere (about -40º latitude)
- BLC wisp potentially associated with NPM transmitter, while DLC wisp connected to NWC

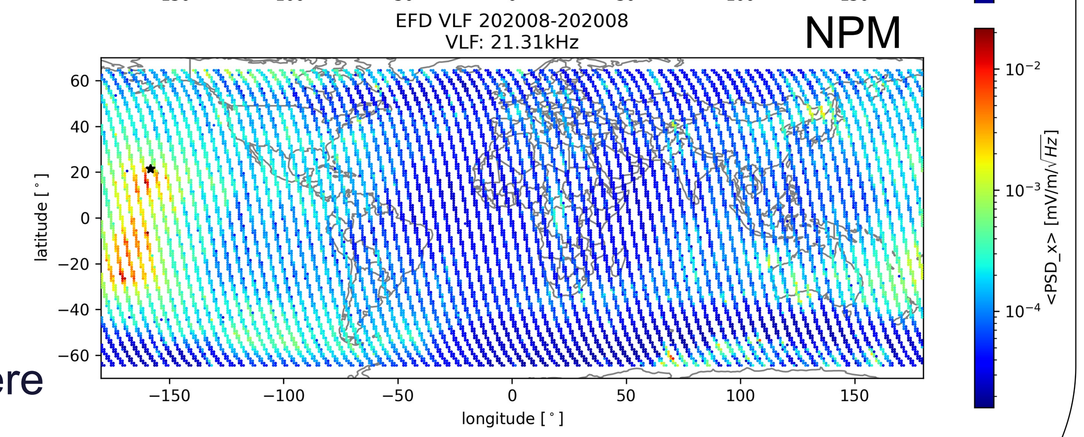
[Y. Shen et al. (2022). Inner belt wisp precipitation measured by ELFIN, doi:10.1029/2022JA030968]

Complementary measurements of EM waves with CSES-01 Electric Field Detector (EFD)

- Wave detection from few to 25kHz
- Allows monitoring of transmissions on daily basis

→ Plan to evaluate electron flux enhancements and wisp events in on/off periods





Conclusions

- CSES-01 HEPP-L has unique ability to measure particle precipitation at multiple pitch angles at the same time
- BLC wisp precipitation event detected in northern hemisphere between 1.45 ≤ L < 1.6 and electron energies (200 – 400)keV

NEXT:
- Statistical analysis of occurrence of whisp precipitation events
- Search for whisp precipitation events of other VLF transmitters
- Calculation of pitch angle diffusion coefficients