Large Scale TIDs climatology over Europe using HF Interferometry method

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Outline

- **Traveling Ionospheric Disturbaces**
- **TechTIDE & MIRA projects**
- **HF Interferomtry method to detect LSTIDs**
- **Results: Climatology** of LSTIDs for 2014-2019
  - Seasonal & diurnal **Occurrence.**
  - Seasonal & diurnal **Activity**.
  - **Prevailing** direction of **propagation.**
- **Summary & Conclusions.**

TIDs

Travelling Ionospheric Disturbances (TIDs) are plasma density fluctuations that propagate as waves through the ionosphere at a wide range of velocities and frequencies.

TIDs constitute a threat for operational systems using predictable ionospheric characteristics as they can impose significant disturbances in the ambient electron density and Doppler frequency shifts on HF signals.

Systems and services that can be affected by TIDs:

- European Geostationary Navigation Overlay Service (EGNOS)
- Network Real-Time Kinematic (N-RTK)
- High Frequency (HF) communications
- Radio reconnaissance operations
- Very High Frequency – Ultra High Frequency (VHF-UHF) radiowave propagation.

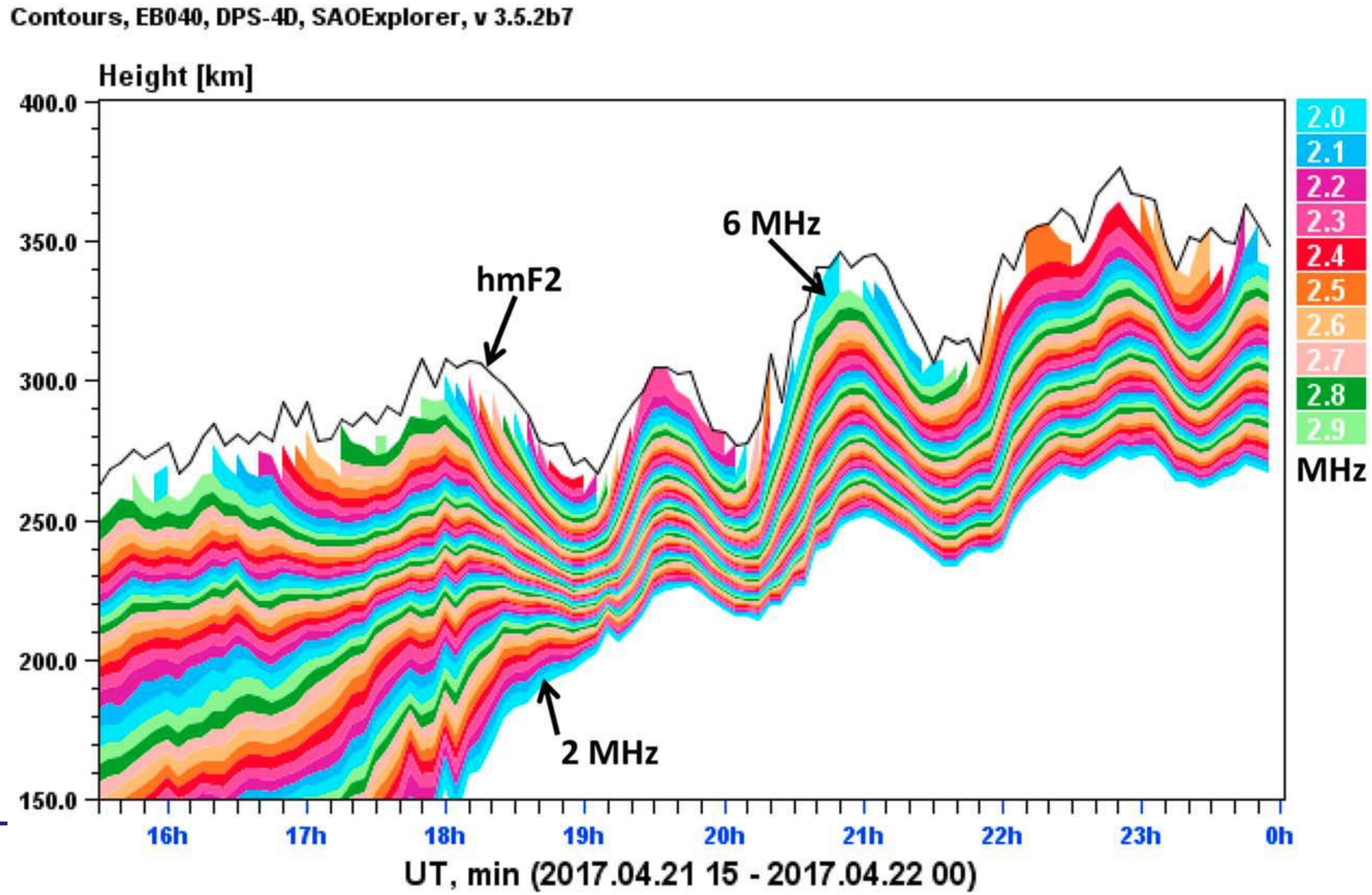

Figure: TID signature in the electron isodensity contours observed by the EB040 Digisonde (Spain) during 21–22 April 2017 as the result of moderate auroral activity.

TechTIDE & MIRA projects

TechTIDE project

Objective: To design and test new viable TID impact mitigation strategies for the technologies affected and in close collaboration with operators of these technologies.

Our Tasks: Development of new methodology (HF Interferometry method) to detect LSTIDs in near real time using ionospheric characteristics from dense enough networks of digisondes (e.g. Europe and South Africa).

TechTIDE

GA-776011

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techtide.project@gmail.com
https://twitter.com/Tech_TIDE

MIRA project

Objective: To provide new knowledge and applicability on the climatological behavior of the ionosphere and, specially, on the short term ionospheric disturbances or irregularities.

Our Tasks: Improvement of the functionality and application of the HF Interferometry method (developed under TechTIDE project) to perform climatological analysis and characterization of LSTIDs with the aim to obtain an activity index of LSTIDs.

MIRA

detection, Monitoring and modelling of Ionospheric irRegulArities
PGC2018-096774-B-I00 (MCIU, AEI, FEDER)

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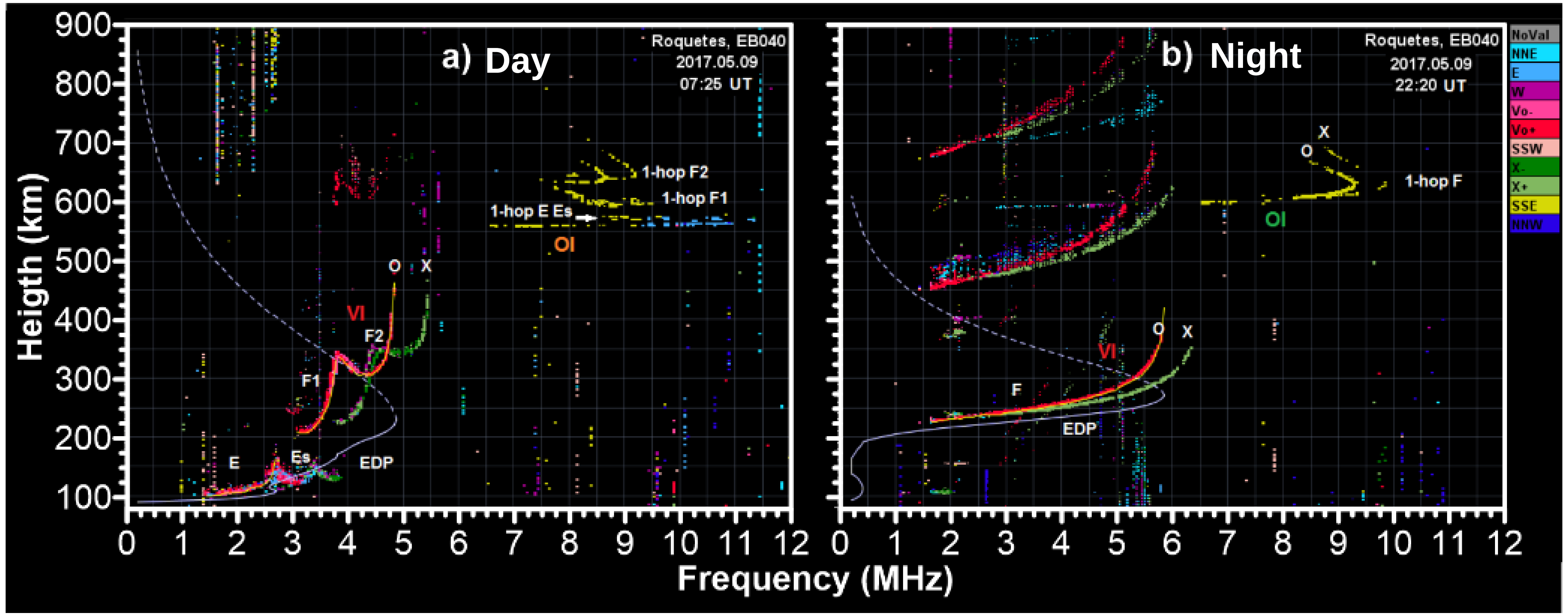
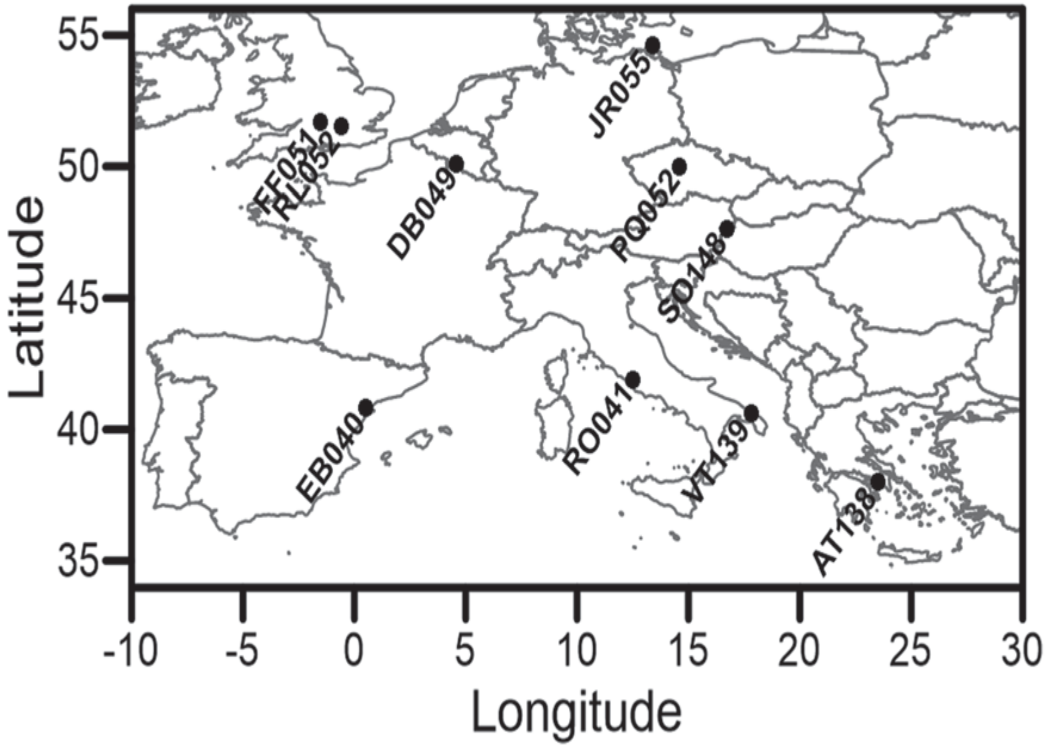
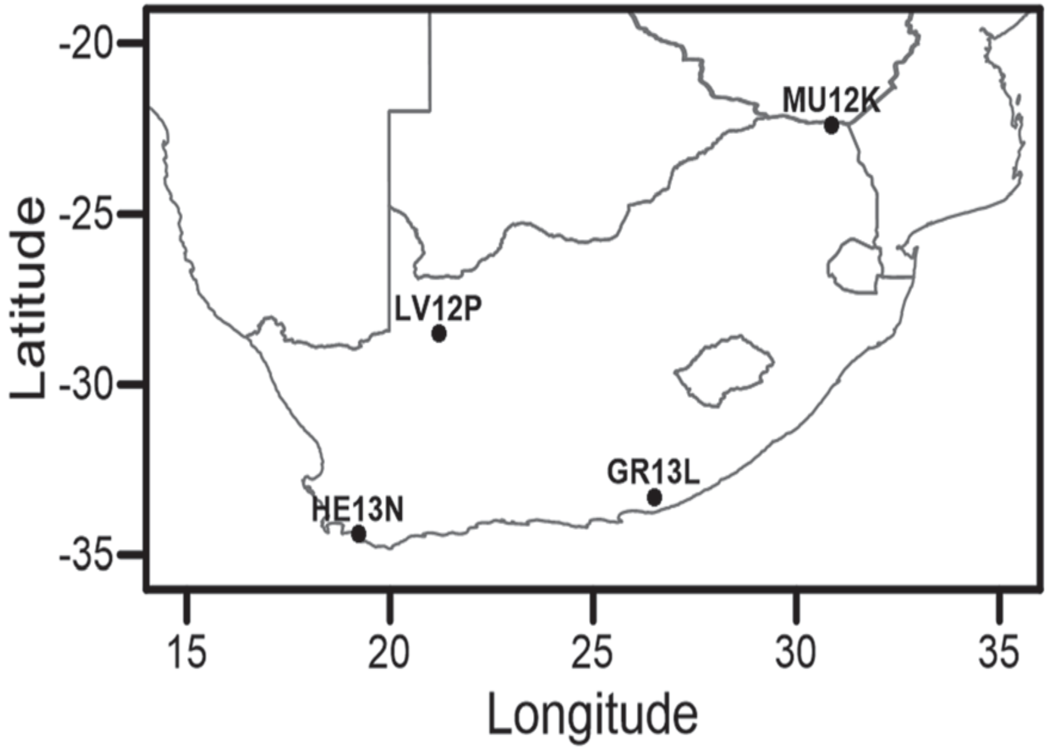
Data and Network

- Data from Vertical Incidence Ionospheric sounding (**MUF(3000)F2**). **NRT**
- Network of DPS4D with **TechTIDE** stations working **synchronized**. European and South Africa networks.
- **South Africa**: Limitation by small number of stations. **Not** all operate in **NRT**



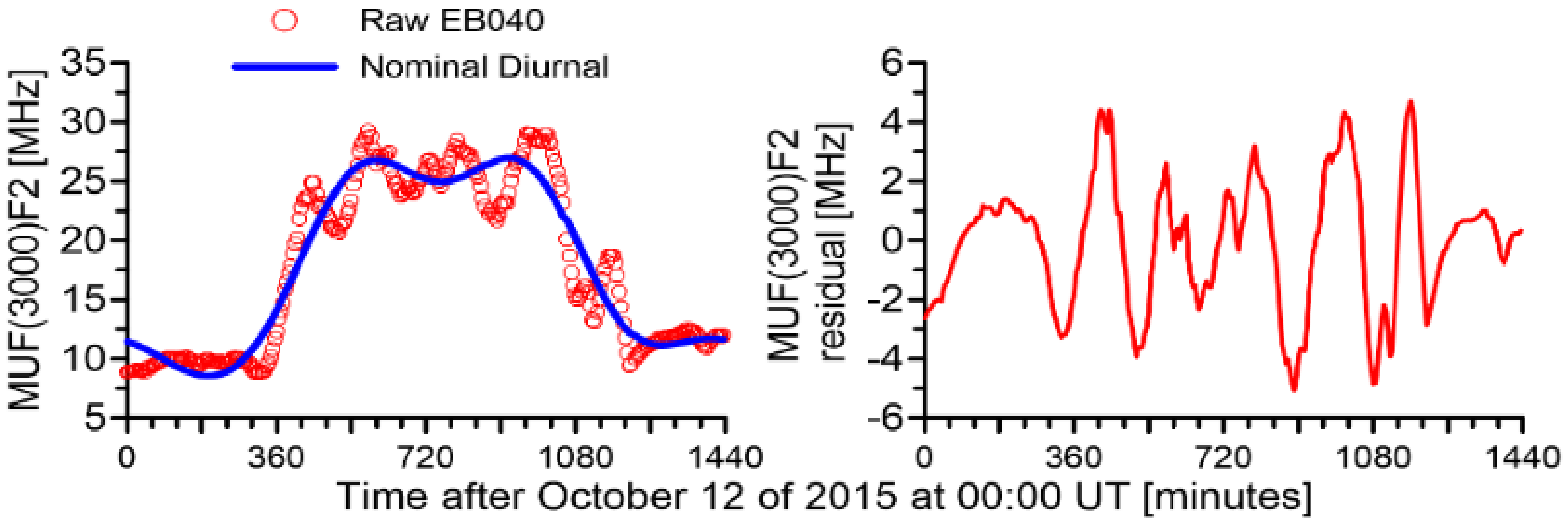




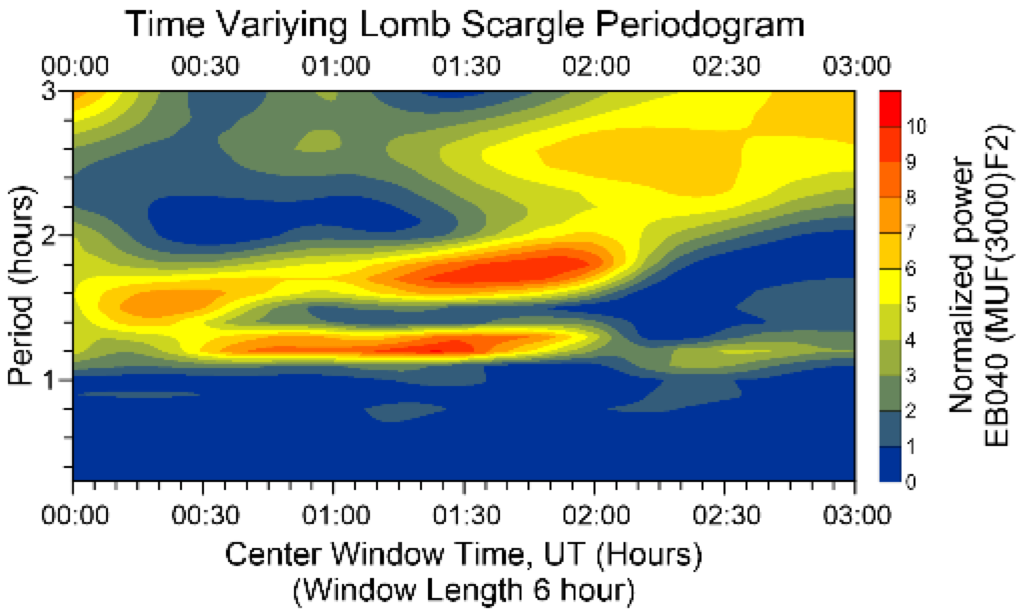
HF Interferometry method

Method and Concept

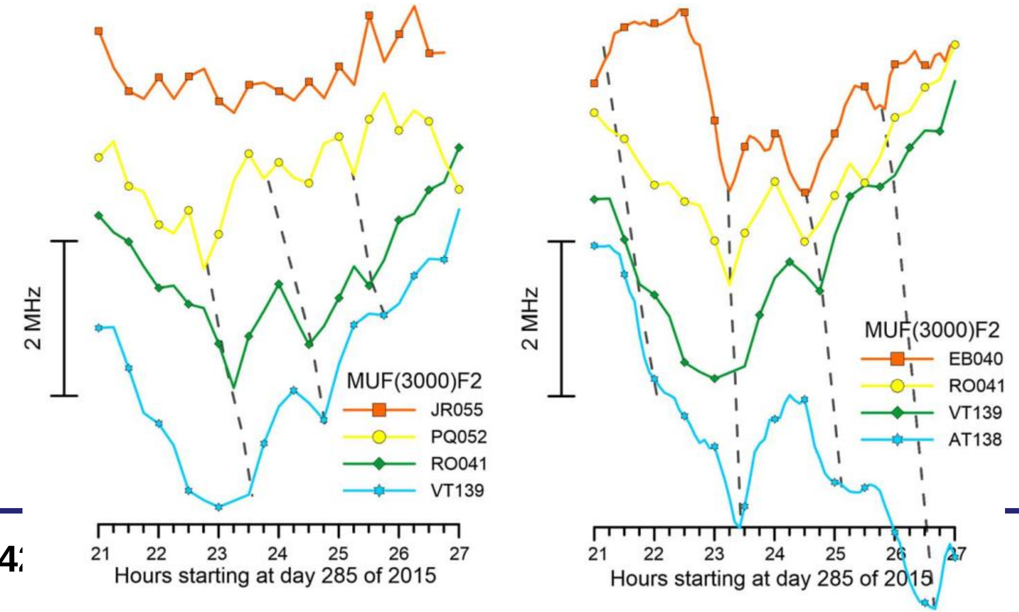
1.Obtain nominal daily variation and residuals at different sites.



2.Detect coherent TID-like variations by spectral analysis



3.Estimate time delays for different sites by cross-correlation.



4.Estimate propagation velocity of irregularities $\vec{v}$ by time delays of maximum correlation ΔTM.

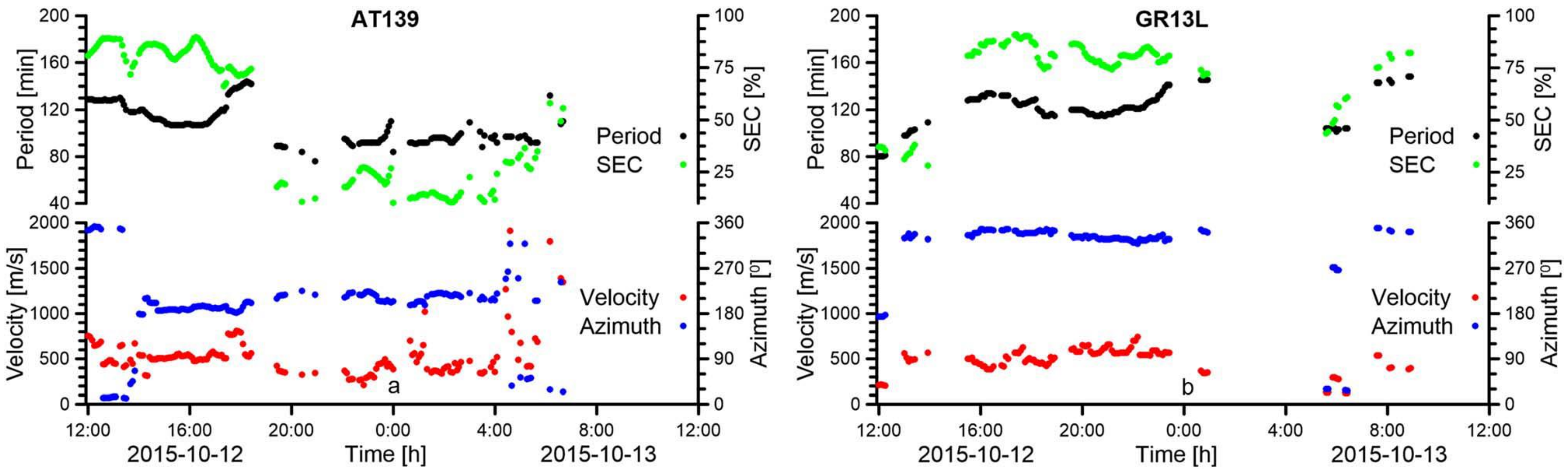
$$\Delta TM_i - \vec{s} \cdot \Delta \vec{r}_i = 0 \ ; \ \vec{v} = \frac{\vec{s}}{s^2}$$

It provides: TID occurrence, amplitude, period, spectral contribution, propagation velocity (speed and azimuth)

HF Interferometry method

Performance for 12-13 Oct 2015

Figure: Results of detection of the LSTID activity by the HF-Int over two stations located in Europe (left) and South Africa (right) for the time interval from 12UT on October 12 to 12UT on October 13 of 2015. Red dots show **velocity**, blue dots show **azimuth**, black dots show **period** and green dots show **spectral energy contribution** (SEC).



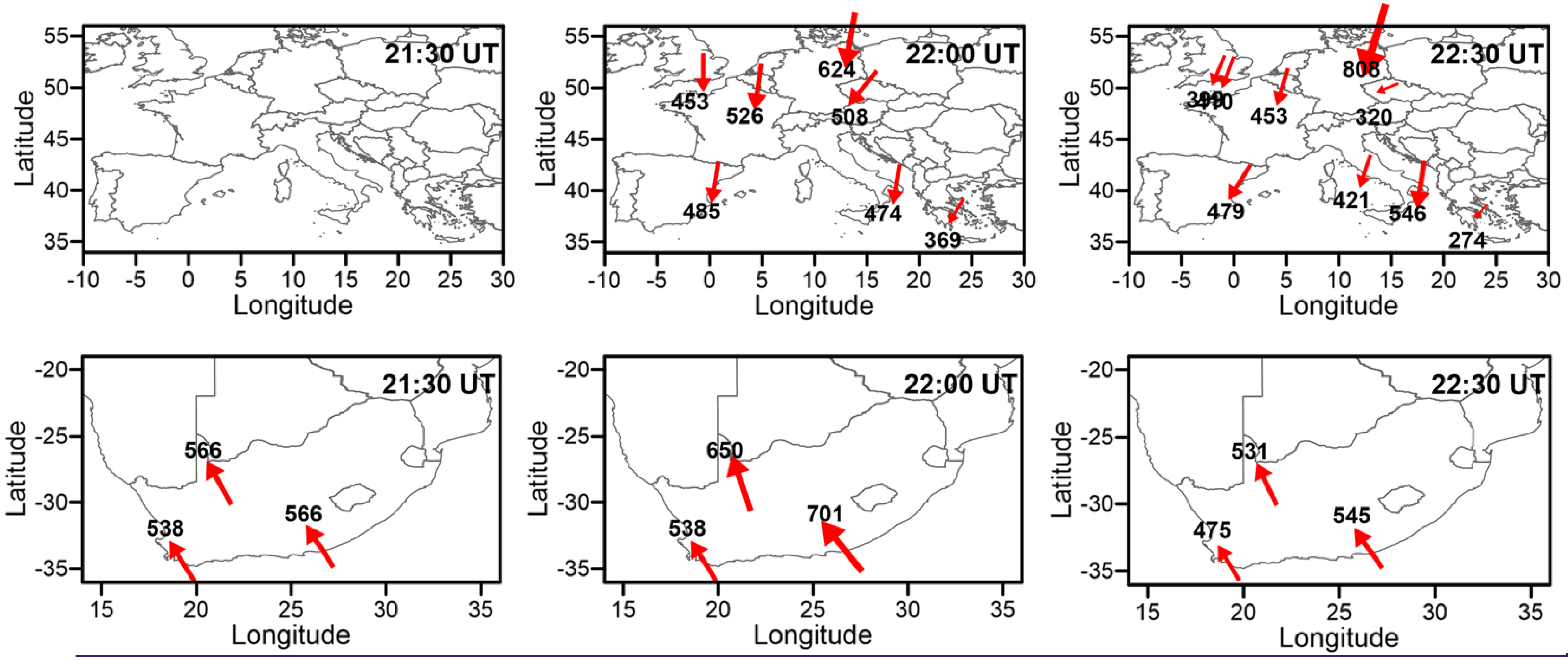
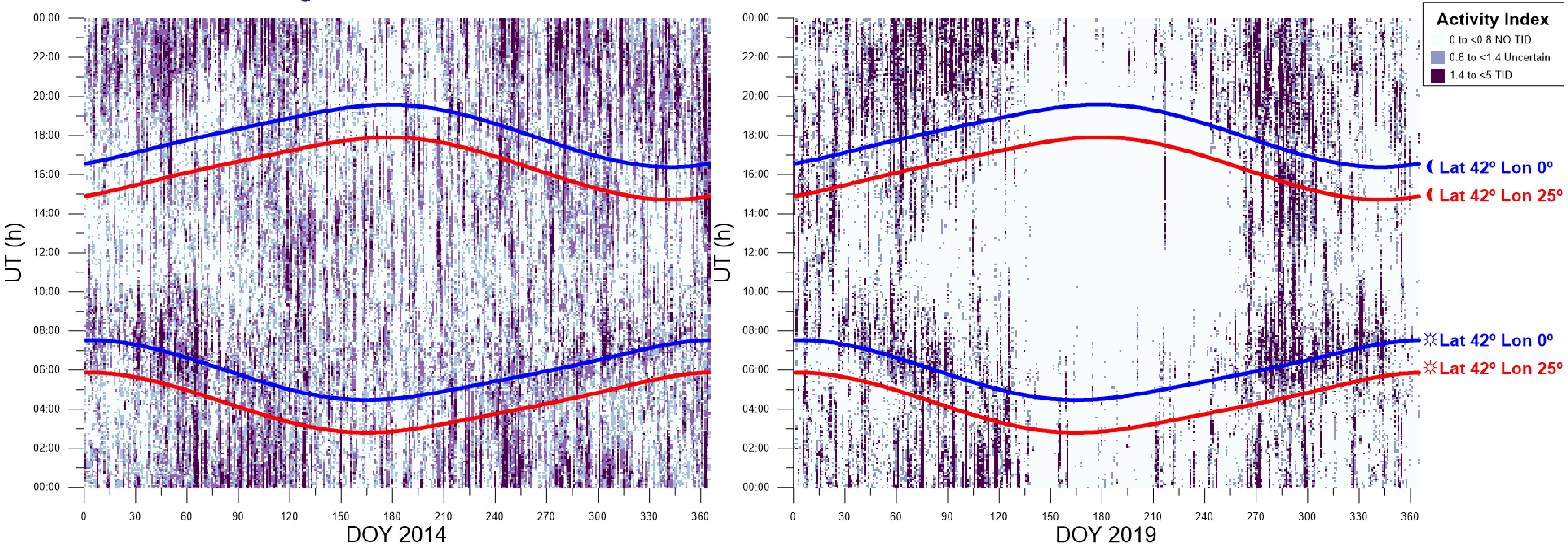


Figure: Maps of the **estimated velocity vectors** of the LSTID event detected over Europe (up) and South Africa (down) on 12 October 2015 for the indicated times. Length of arrows is proportional to the velocity values which is show in the labels.

Altadill et al., 2020. J. Space Weather Space Clim., https://doi.org/10.1051/swsc/2019042

LSTIDs Climatology

Solar activity & Seasonal & Diurnal LSTIDs occurrence



Poor data availability for summer at low solar activity due to **Es** layer **screening**.

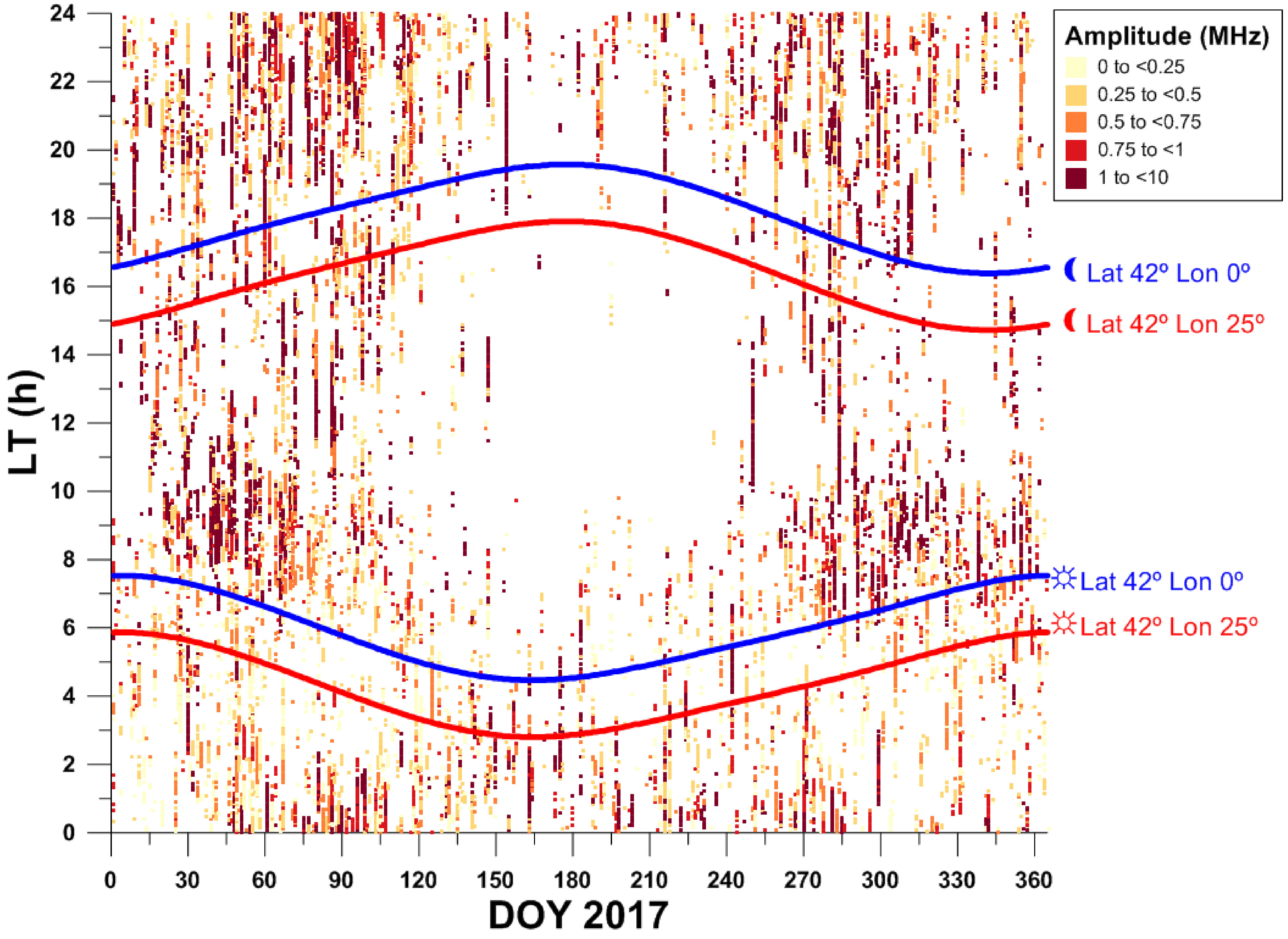
Larger occurrence during nighttime and near solar terminator.

Enhanced nigh-time occurrence for equinoxes.

LSTIDs Climatology

Seasonal & diurnal occurrence

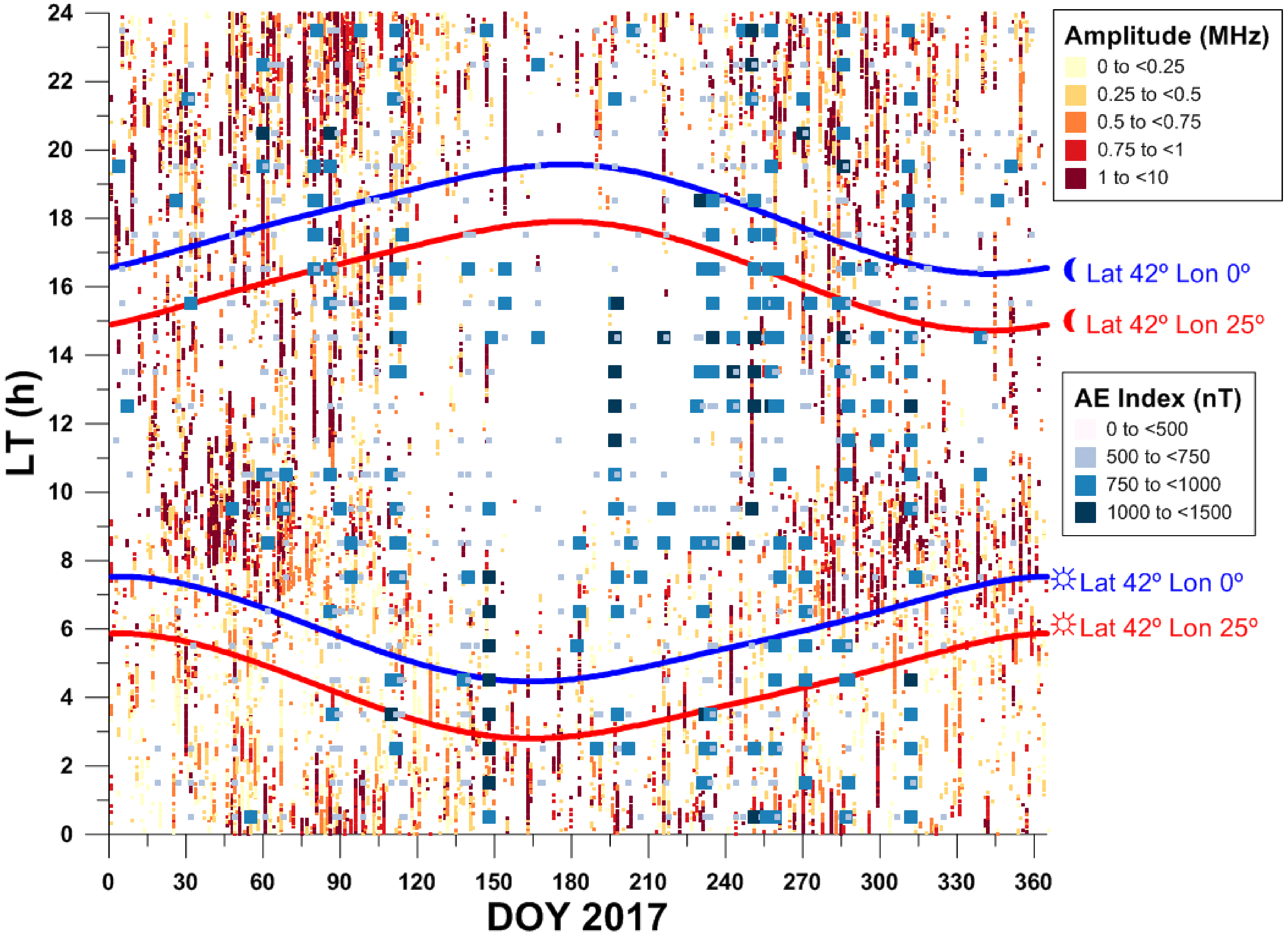
- Poor data availability for summer: **Es** layer **screening**.
- Larger occurrence near solar terminator and night-time.
- Enhanced nigh-time occurrence for equinoxes.



LSTIDs Climatology

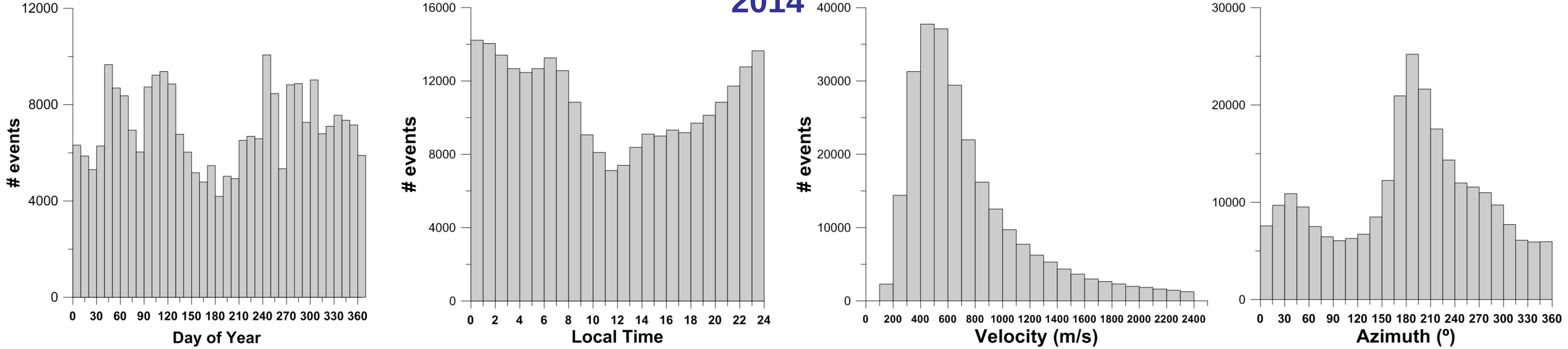
Seasonal & diurnal occurrence

- Poor data availability for summer: **Es** layer **screening**.
- Larger occurrence near solar terminator and night-time.
- Enhanced nigh-time occurrence for equinoxes.
- **Equinoctial occurrence of LSTIDs correlates with Auroral activity.**

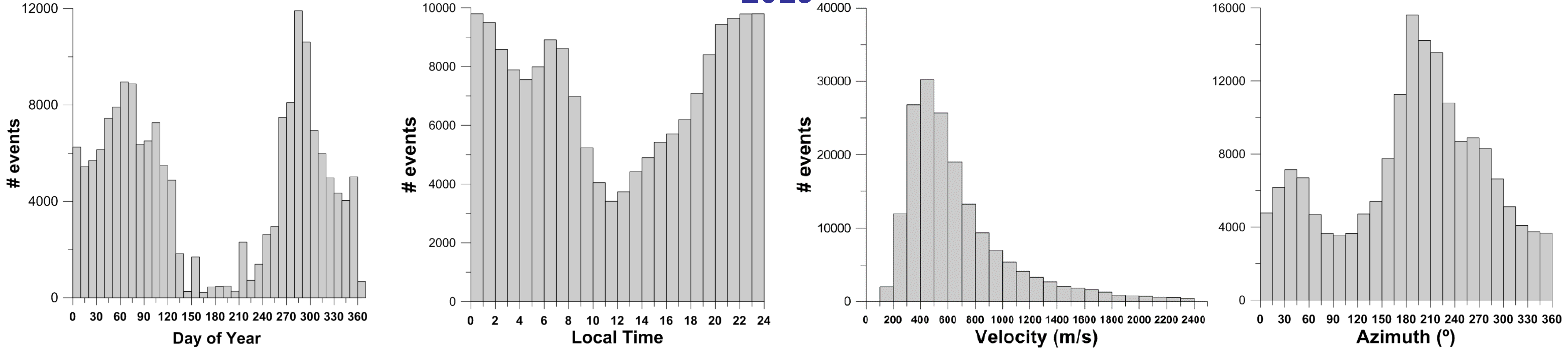


LSTIDs Climatology

2014



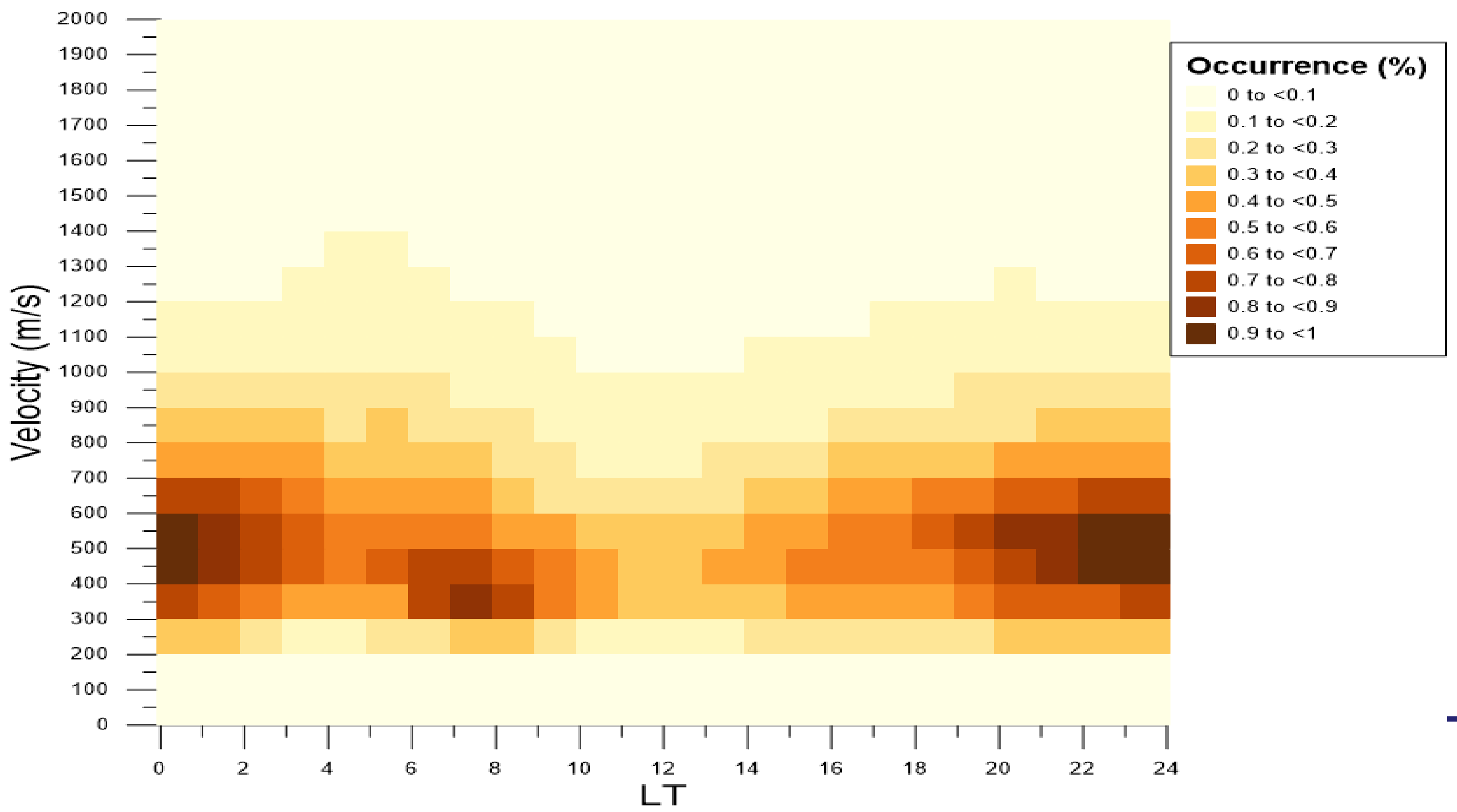
2019



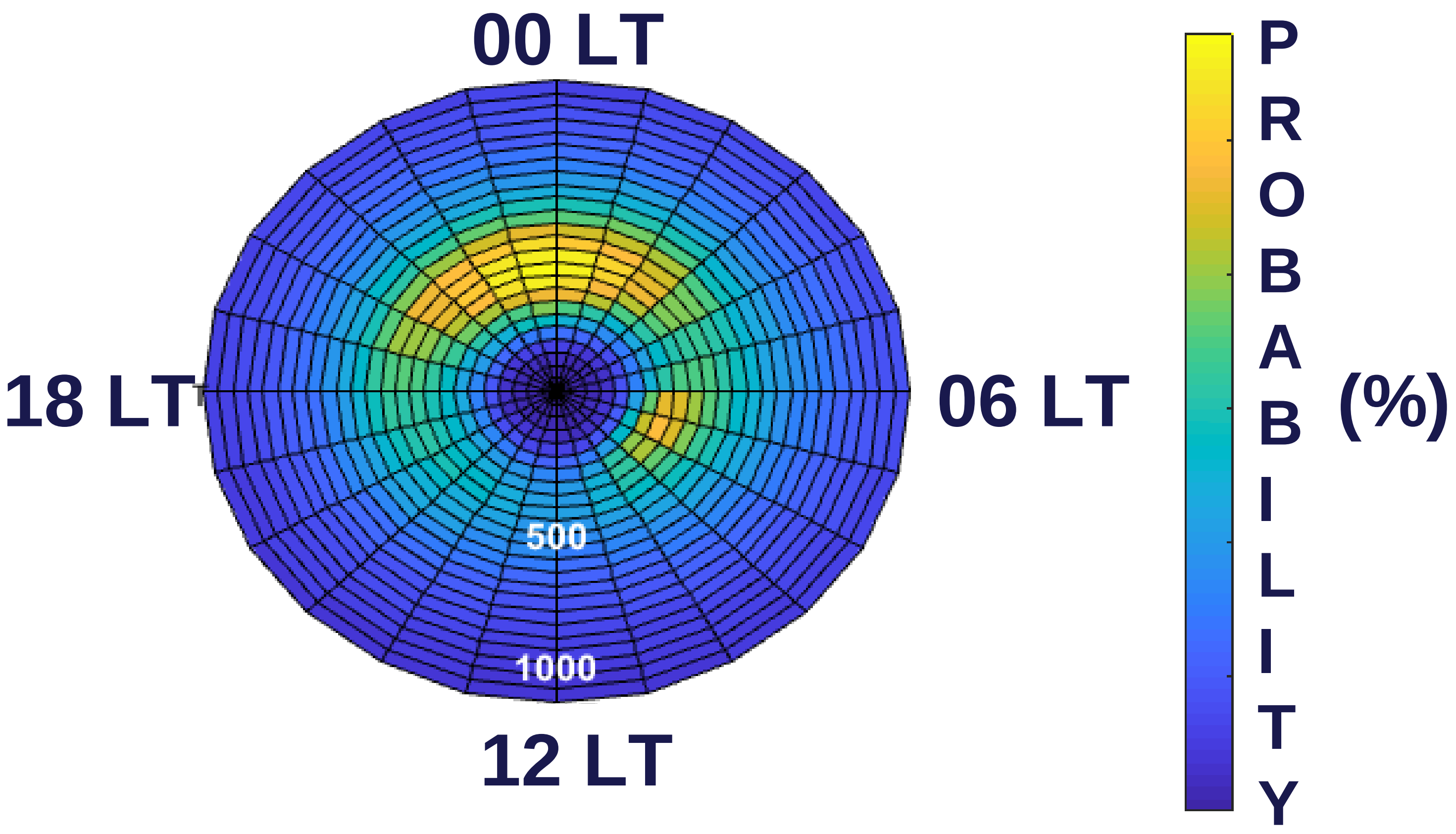
LSTIDs Climatology

Diurnal Velocity & LT analysis

- Activity tend to concentrate during night time and near Sun Rise (**SR**).
- Results suggest **origin** of the **LSTIDs** by the **solar terminator** and **auroral activity**.
- Nighttime events related with auroral activity reach larger velocities.



Velocity & LT of LSTIDs (all scenarios)

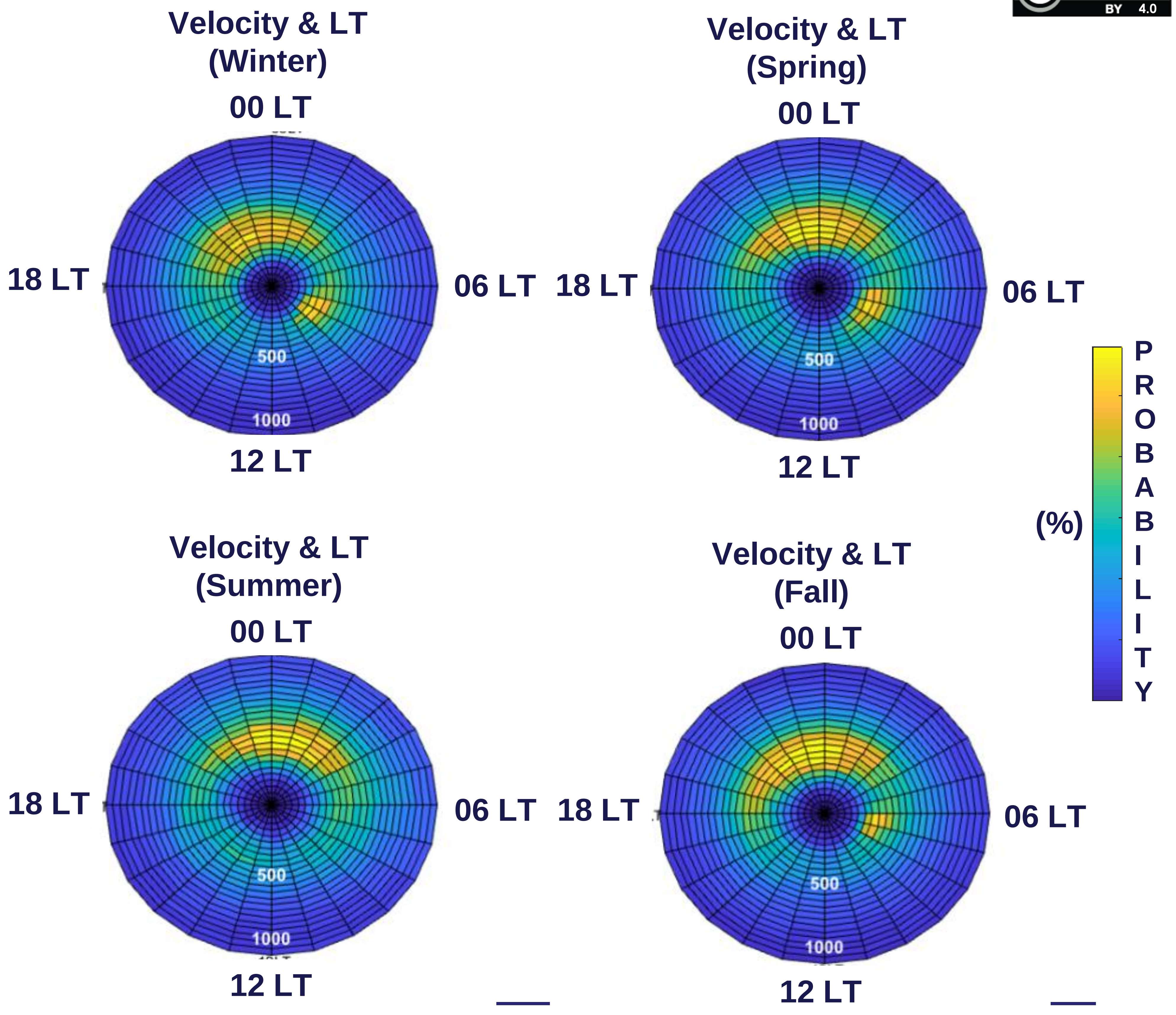


LSTIDs Climatology

Seasonal & Diurnal Velocity & LT analysis

Similar behavior for all seasons except for summer:

- Activity tend to concentrate during night time and near Sun Rise (**SR**) with larger velocities during nighttime.
- Different behavior for summer can be due to Es layer screening.

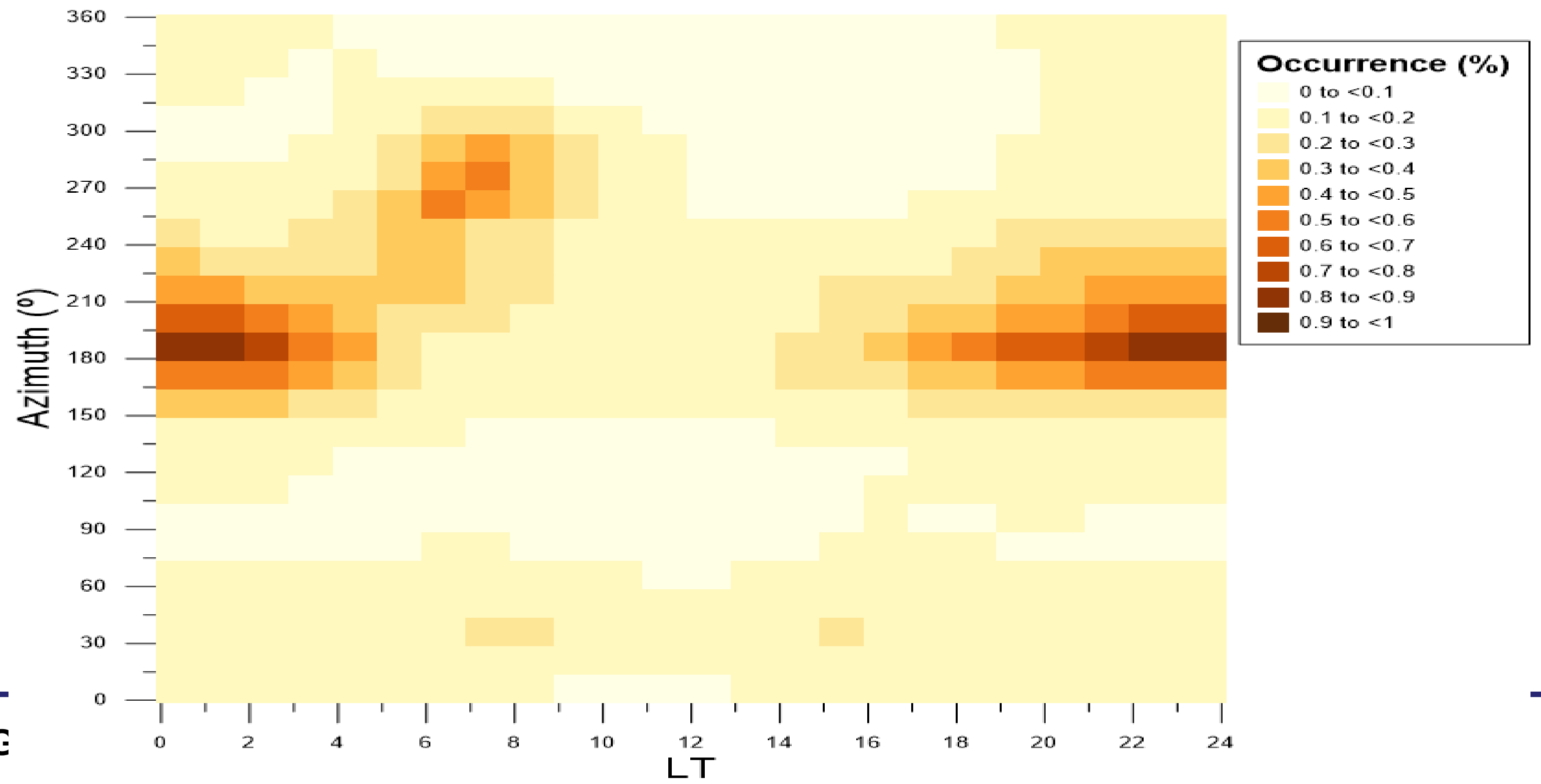


LSTIDs Climatology

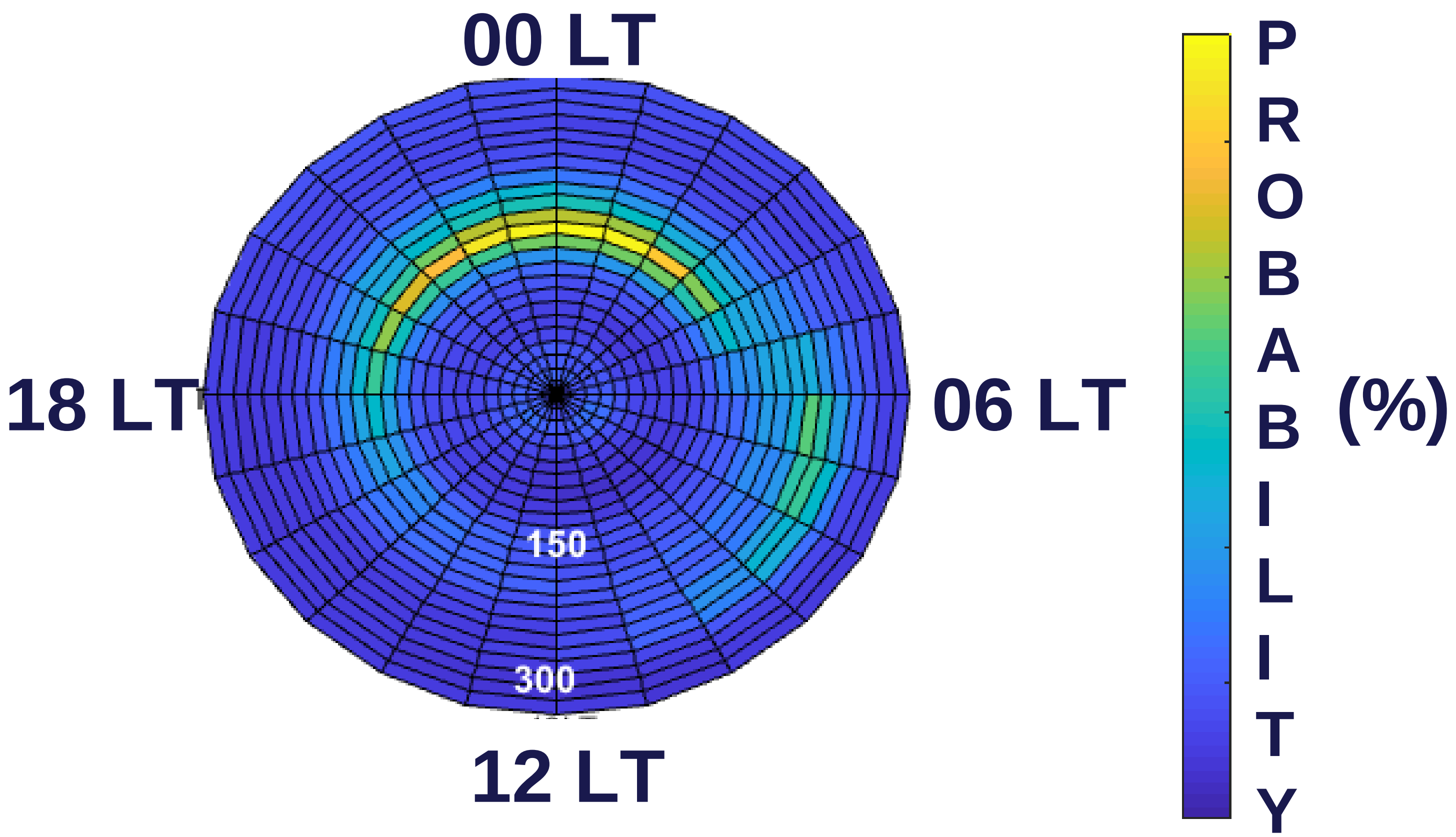
Diurnal Azimuth & LT analysis

- Most of the events present southward propagation (180º) suggesting origin of the LSTIDs by **auroral activity.**

- Westward propagation (270º) during morning time suggesting origin of LSTIDs by **sunrise** effect.



Azimuth & LT of LSTIDs (all scenarios)

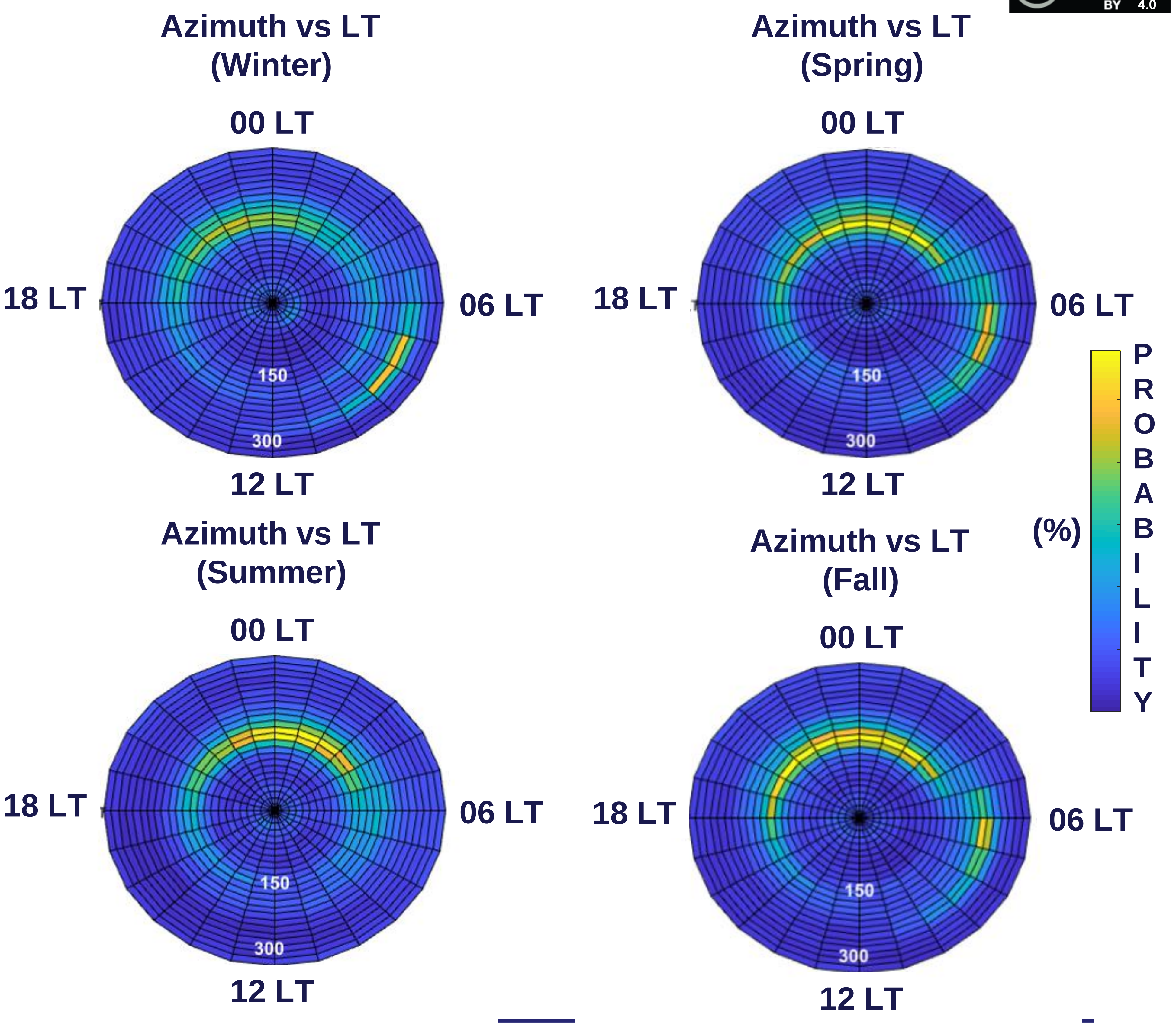


LSTIDs Climatology

Seasonal & Diurnal Azimuth & LT analysis

- Activity tend to concentrate during nigh time and near Sun Rise. This behavior is not observed during summer due to Es layer screening effect.

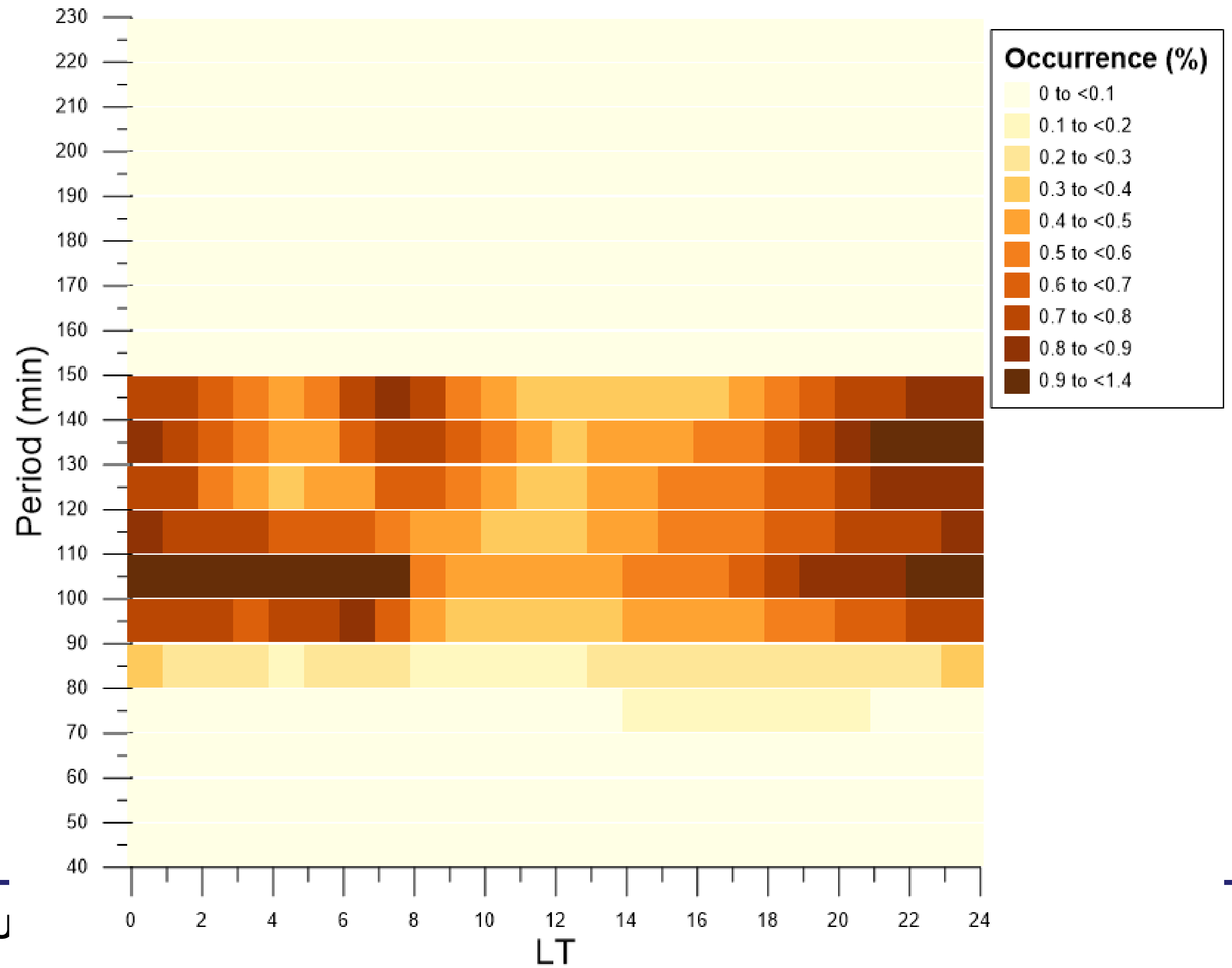
- We observe southward propagation at nighttime and westward propagation during morning time.



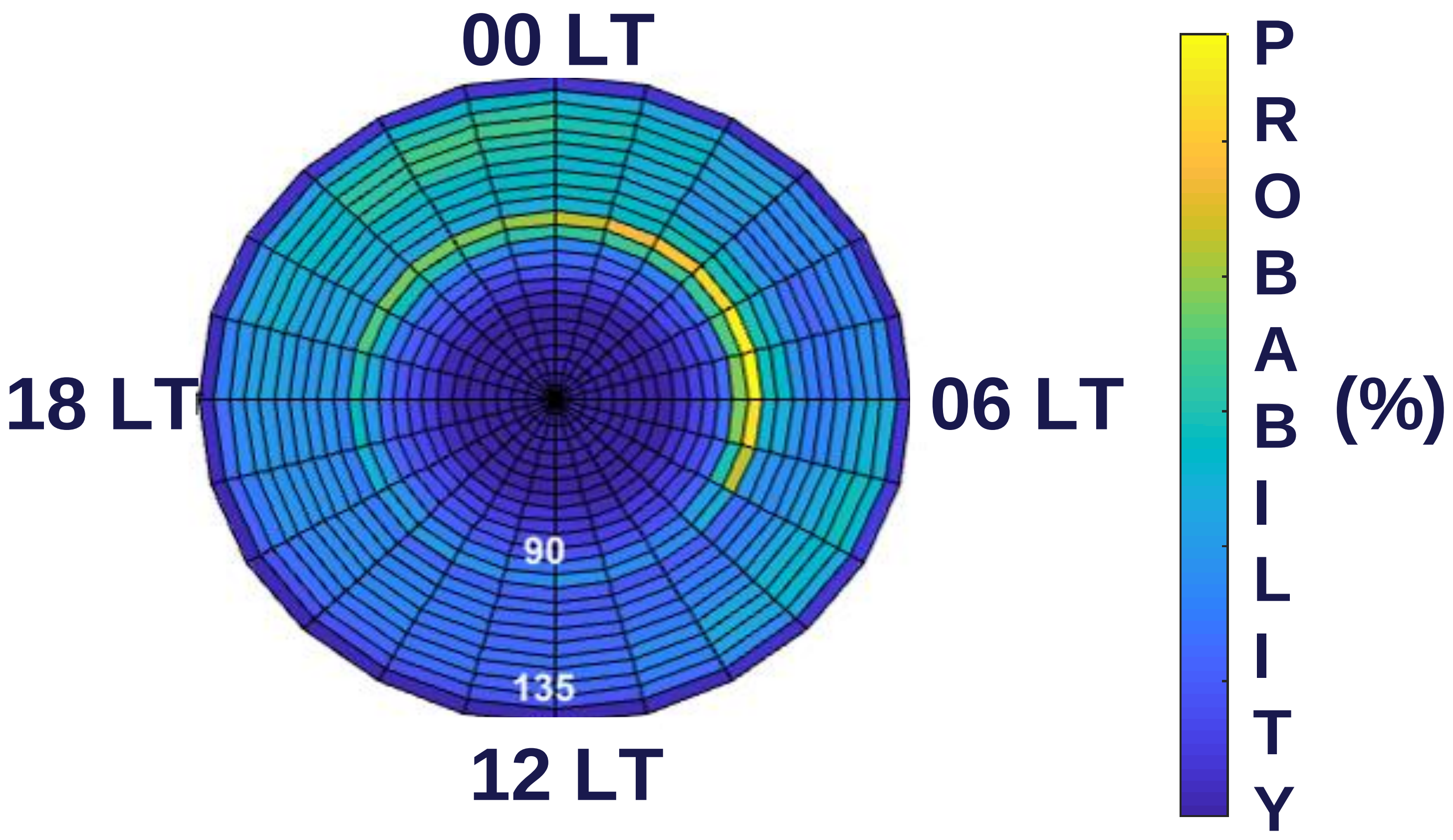
LSTIDs Climatology

Diurnal Period & LT analysis

Detected LSTIDs present coherent periods from 80 to 140 min, prevailing those cases with 100-130 min during the night.



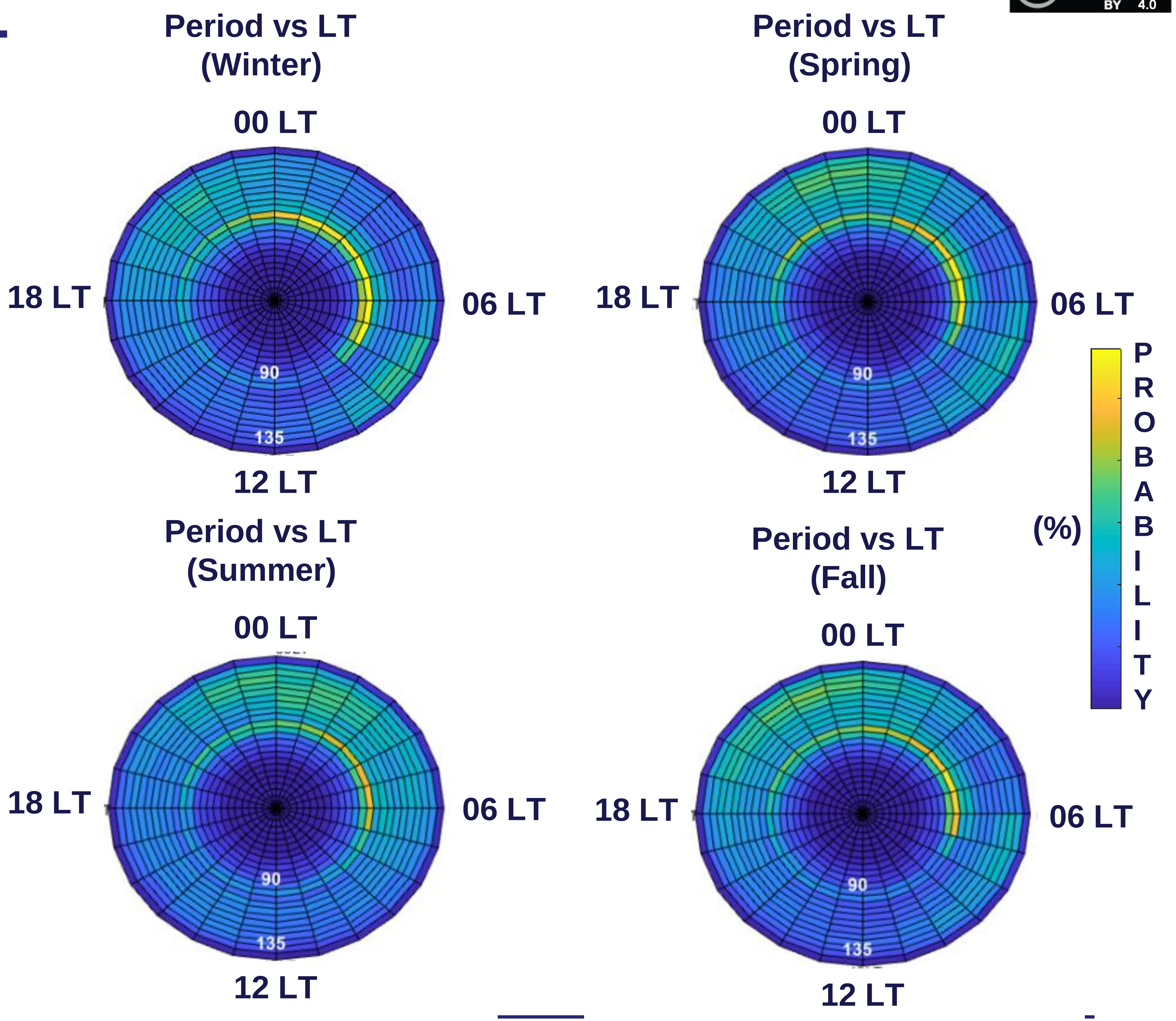
Period & LT of LSTIDs (all scenarios)



LSTIDs Climatology

Seasonal & Diurnal Period & LT analysis

Detected LSTIDs tend to have a period of 90-120 min, specially when they occur from midnight to sunrise. Larger periods occur before midnight.



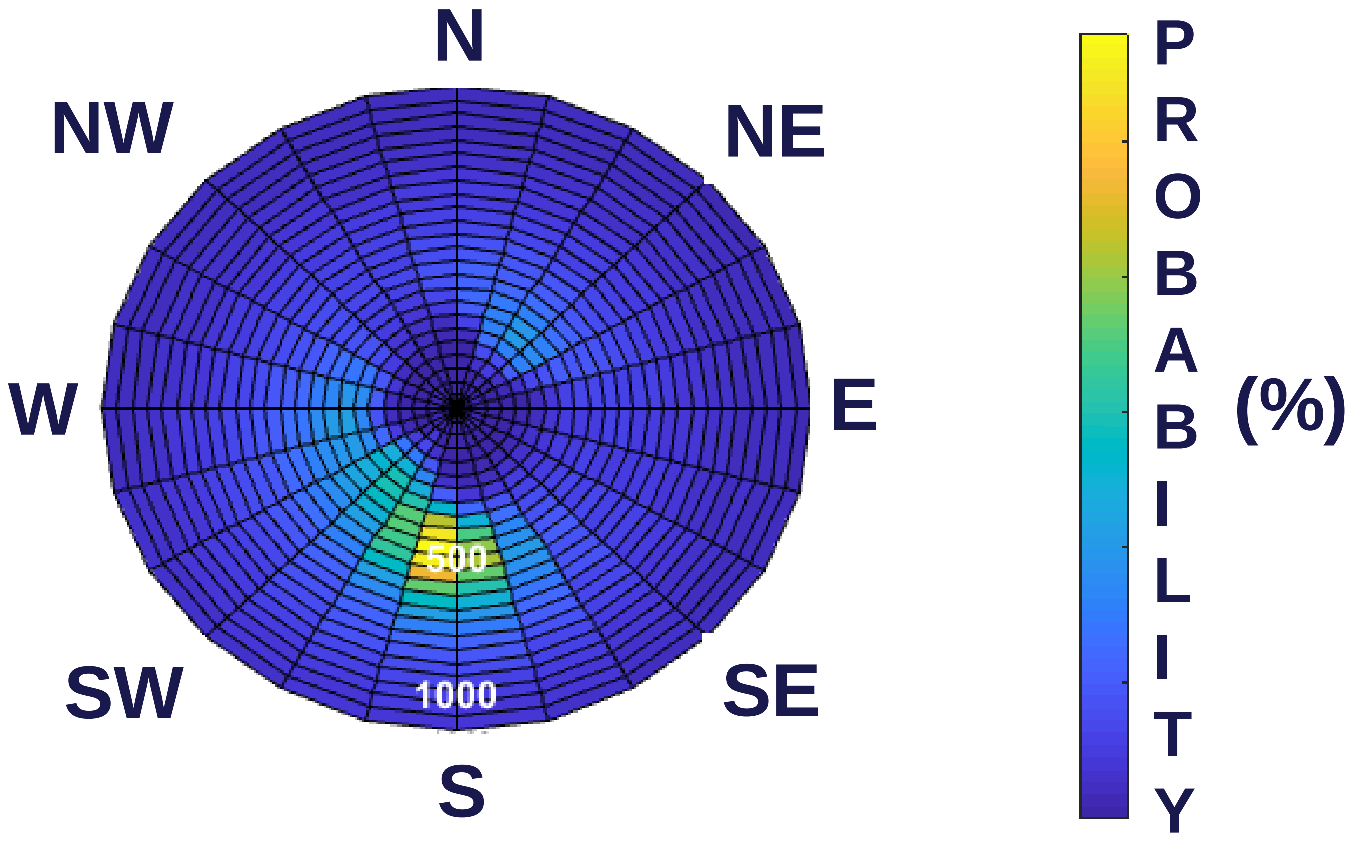
LSTIDs Climatology

Velocity & Azimuth analysis

- Most of the events present southward propagation (180º) suggesting origin of the LSTIDs by **auroral activity.**

- Fewer events are observed to occur to other directions, mostly from SW to NW suggesting origin of LSTIDs by **sunrise** effect.

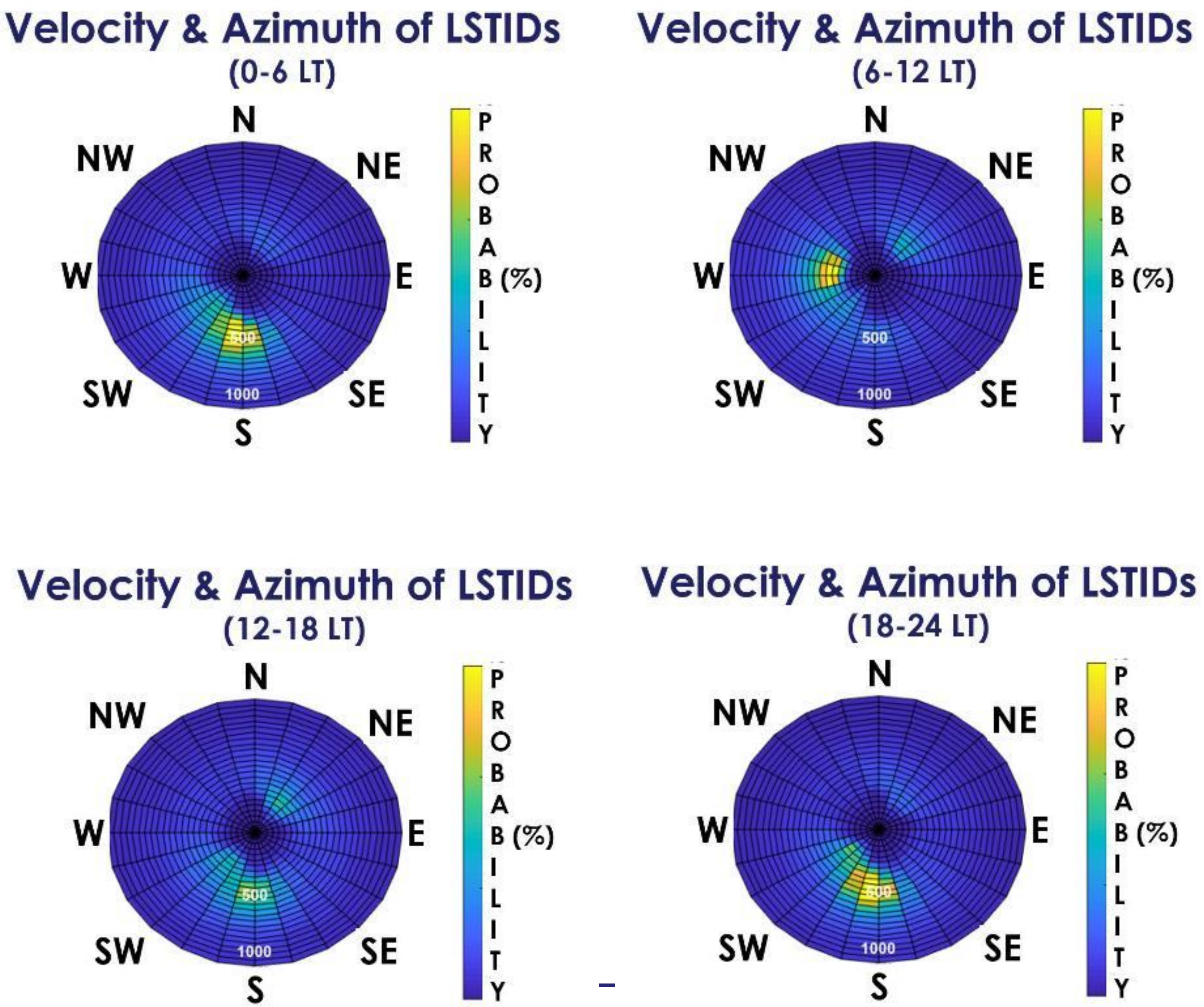
Velocity & Azimuth of LSTIDs (all scenarios)



Diurnal Velocity & Azimuth analysis

Propagation azimuth depends of the LT:

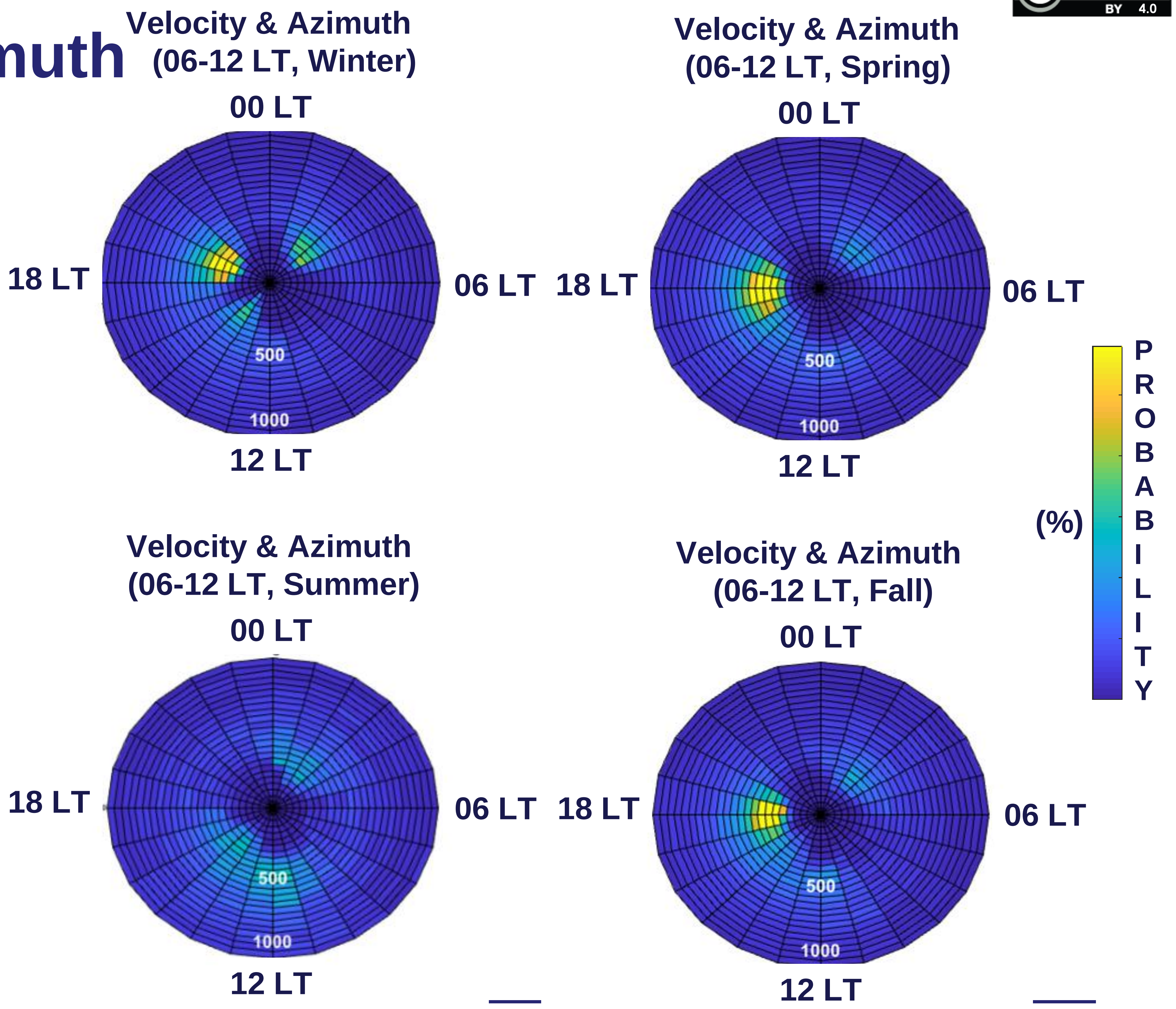
- **Night time (18-6h LT):** propagation is mostly southward that suggest origin of the LSTID by auroral activity.
- **Moring time (6-12h LT):** propagation is mostly westward that suggest origin of the LSTID by the solar terminator effect due to sunrise.
- **Afternoon time (12-18h LT):** Fewer number of events occur and dominant propagation direction is S-SW.



LSTIDs Climatology

Morning sector Velocity & Azimuth seasonal analysis

- **Northwestward** dominant propagation for **Winter**.
- **Westward** dominant propagation for **Equinoxes**.
- **Southwestward** dominant propagation for **Summer**.



Results suggest **Solar Terminator** and Prevailing **Thermospheric** wind influence.

Conclusions

- **LSTIDs** detection based **ionosonde data** work efficiently in **NRT** for European Region.
- The **method provides** dominant **Period**, **Amplitude** and vector **Velocity** of propagation.
- The **method** have been **tested** for geomagnetically **disturbed periods.**
- Presence of **distinct LSTID** signatures with dominant **periods** of **90-120 minutes** and southward **velocities** of **400 - 800 m/s.**
- **Climatology** observes **dominant activity** near Sun rise and at night. **Morning** sector observes prevailing **westward** propagation and **evening and nighttime** observe **southward.**
- Results suggest **origin** by the **solar terminator** and **auroral activity** and that **thermospheric** wind influence prevailing **propagation.**

This work has been partly developed under the TechTIDE project and MIRA project.

MIRA
detection, Monitoring and modelling of Ionospheric irRegulArities
PGC2018-096774-B-I00 (MCIU, AEI, FEDER)

TechTIDE
GA-776011

Thank you for you attention

Keep safe and see you in 2021!