Exploration on the Impact of Solar Variabilities on TID Occurrence Characteristics using Ionospheric Tilt Measurements (ExSoTIDs)

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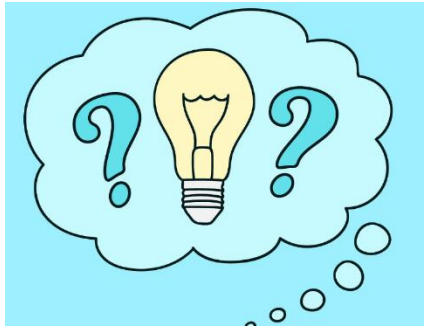
Outline

- Introduction and motivation
- Methodology
- Results
- Discussion
- Summary and conclusion

Introduction and motivation

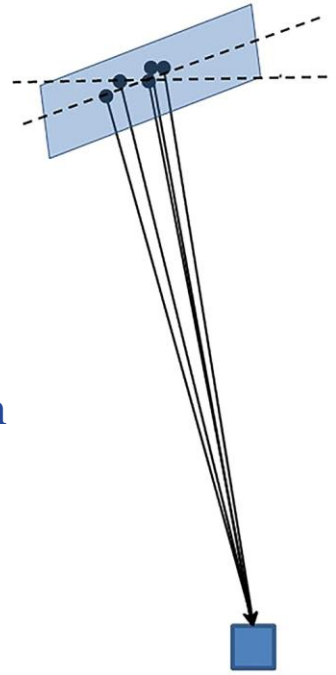
- Traveling ionospheric disturbances (TIDs) are wave like fluctuations of the electron density induced by gravity waves in the neutral atmosphere (Hines, 1960; Francis, 1974).

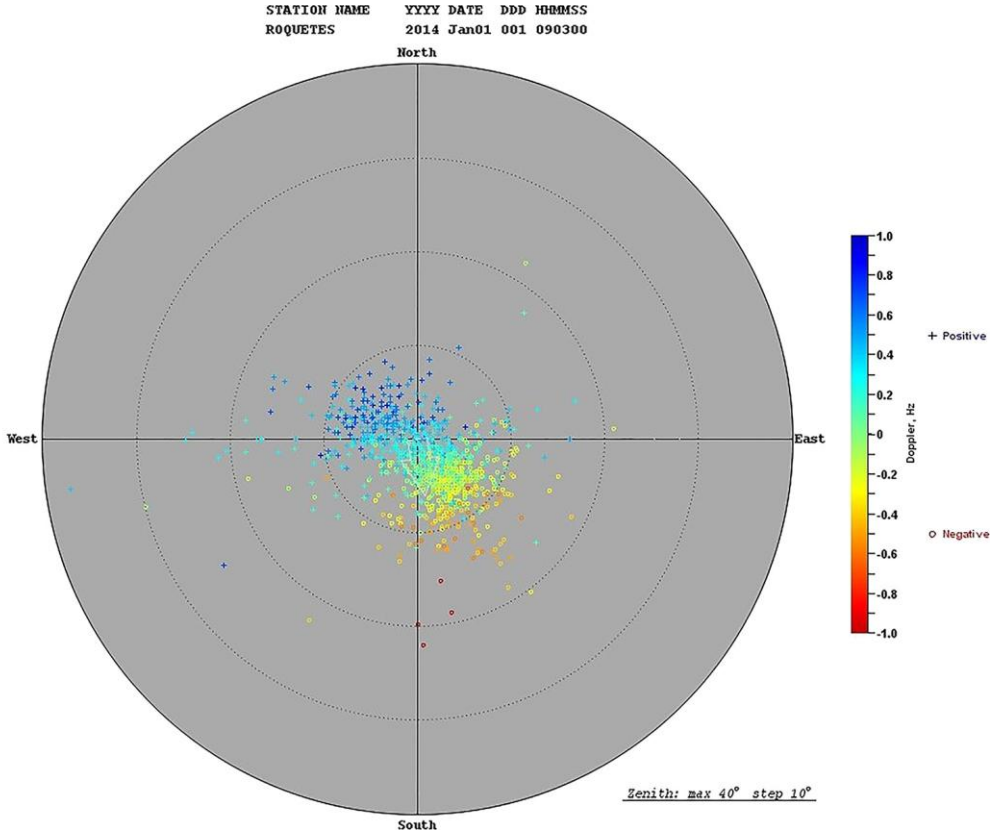
- Motivation of this work comes from a previous study by Dima on 2020 (Paznukhov et al., 2020). So, one of our previous TNA, we have compared the tilt angle with the detrended total electron content (dTEC) estimated MSTIDs and independent ionogram features (which represents MSTIDs). We found that the comparison show good agreement. **Now we have a full solar cycle of tilt data compared with the HWM14 and TIE-GCM, and we can compare also d-TEC fluctuations as indication of MSTIDs.** This motivated us to utilize the ionosonde tilt measurement to investigate the diurnal, seasonal, interannual and solar activity dependency of the MSTIDs occurrences.



Data and Methodology

- 1. Ionosonde tilt measurement
  - 30° x 1hour binned azimuth angles





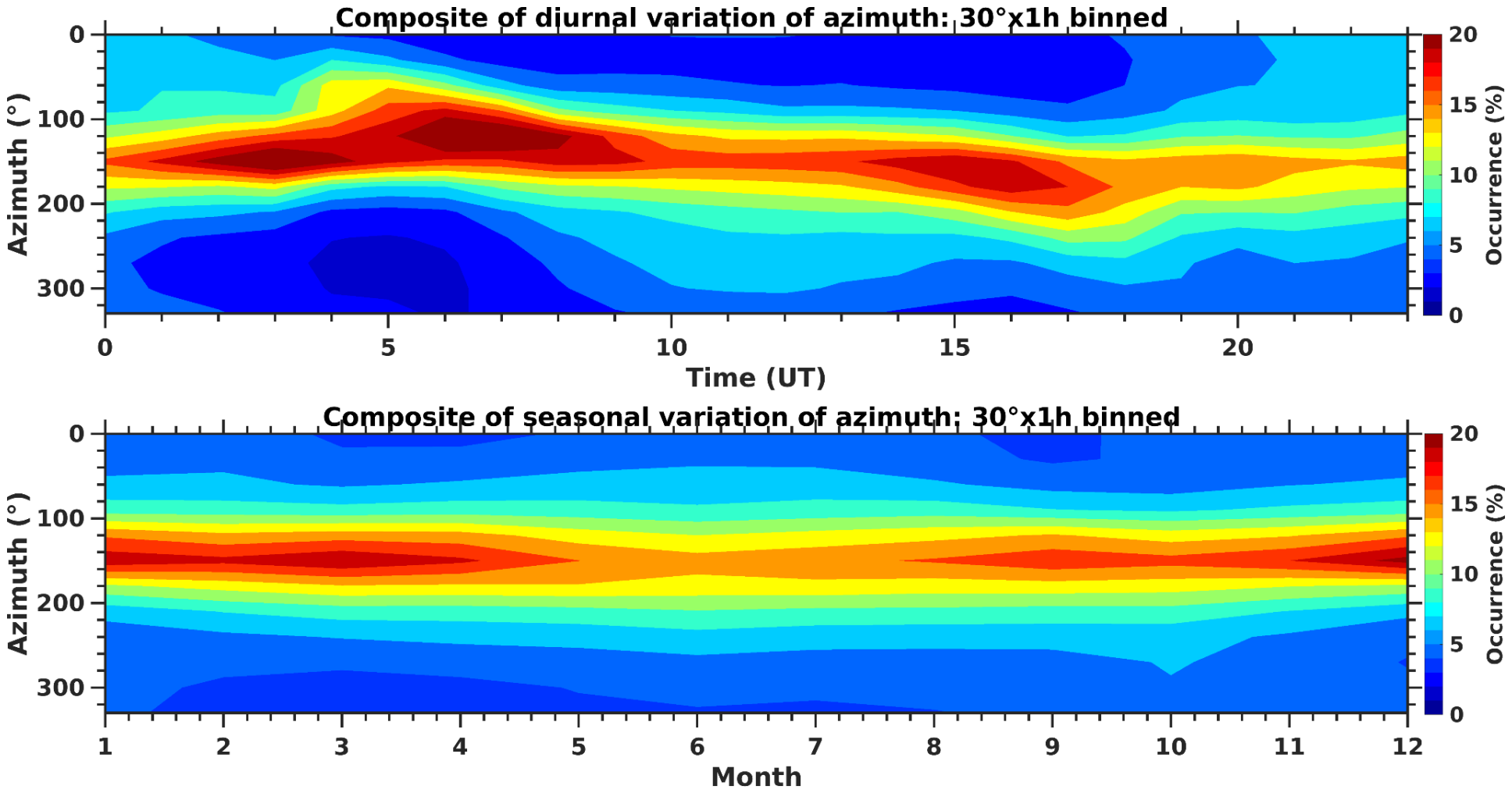
- 2. Horizontal wind model (HWM)
  - Empirical model
  - Surface to 450 km
  - We used the HMW14,
  - wind profiles calculated from 100 to 250km
  - height in 5 km steps for the central day of each month, from January to December.

(https://ccmc.gsfc.nasa.gov/models/TIE-GCM~2.0/)

- 3. TIE-GCM
  - Thermosphere-Ionosphere-Electrodynamics General Circulation model.
  - Spatial resolution 5° latitude x longitude
  - Range 97 to 500-700km

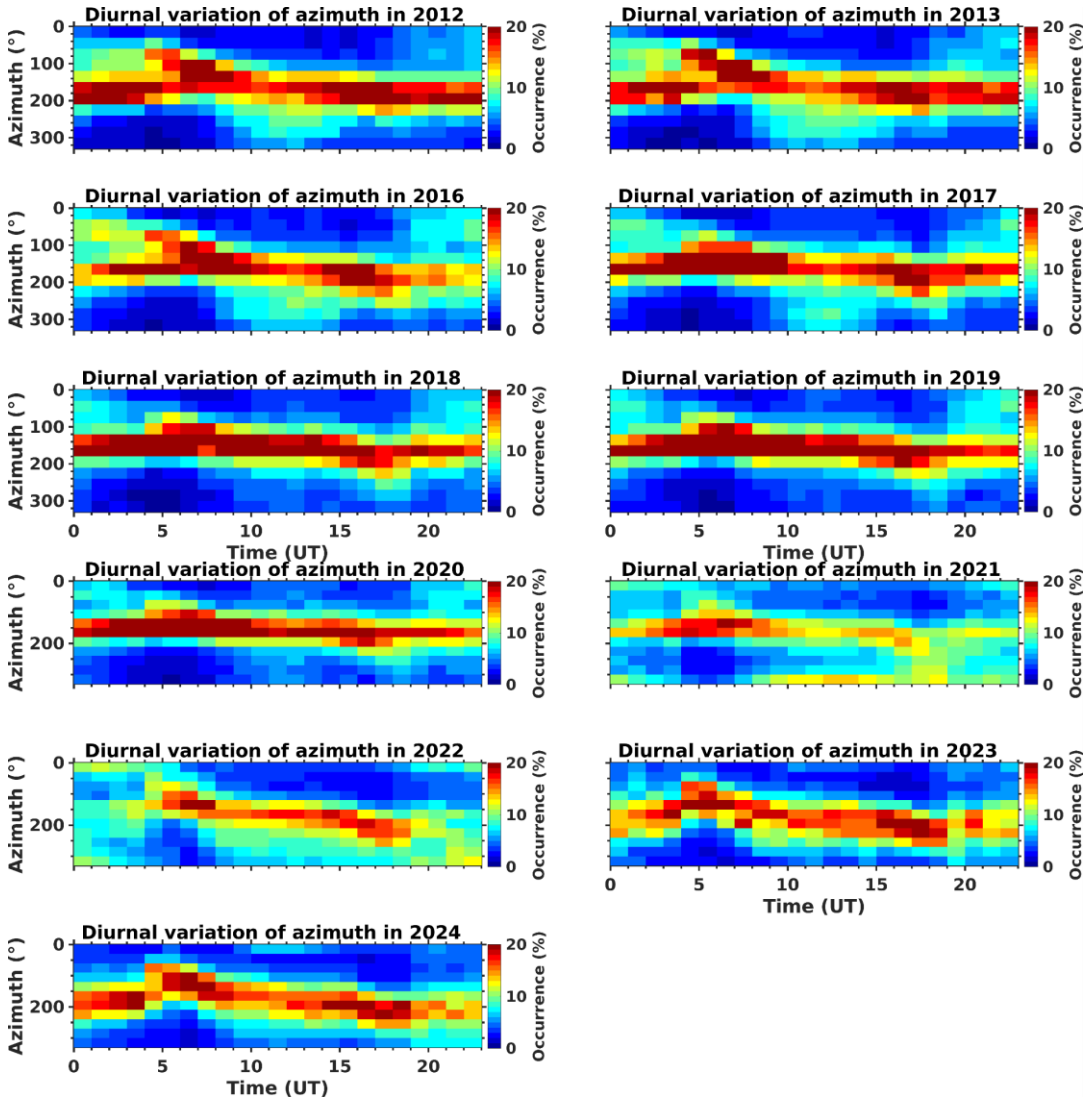
(https://ccmc.gsfc.nasa.gov/models/HWM14~2014/)

Results: Composite of diurnal and seasonal variation of azimuth



- ✓ The maximum occurrence is noted during the early morning and afternoon
- ✓ Overall, the southward propagation is dominant
- ✓ Occurrence is more during winter and equinoxes than in summer

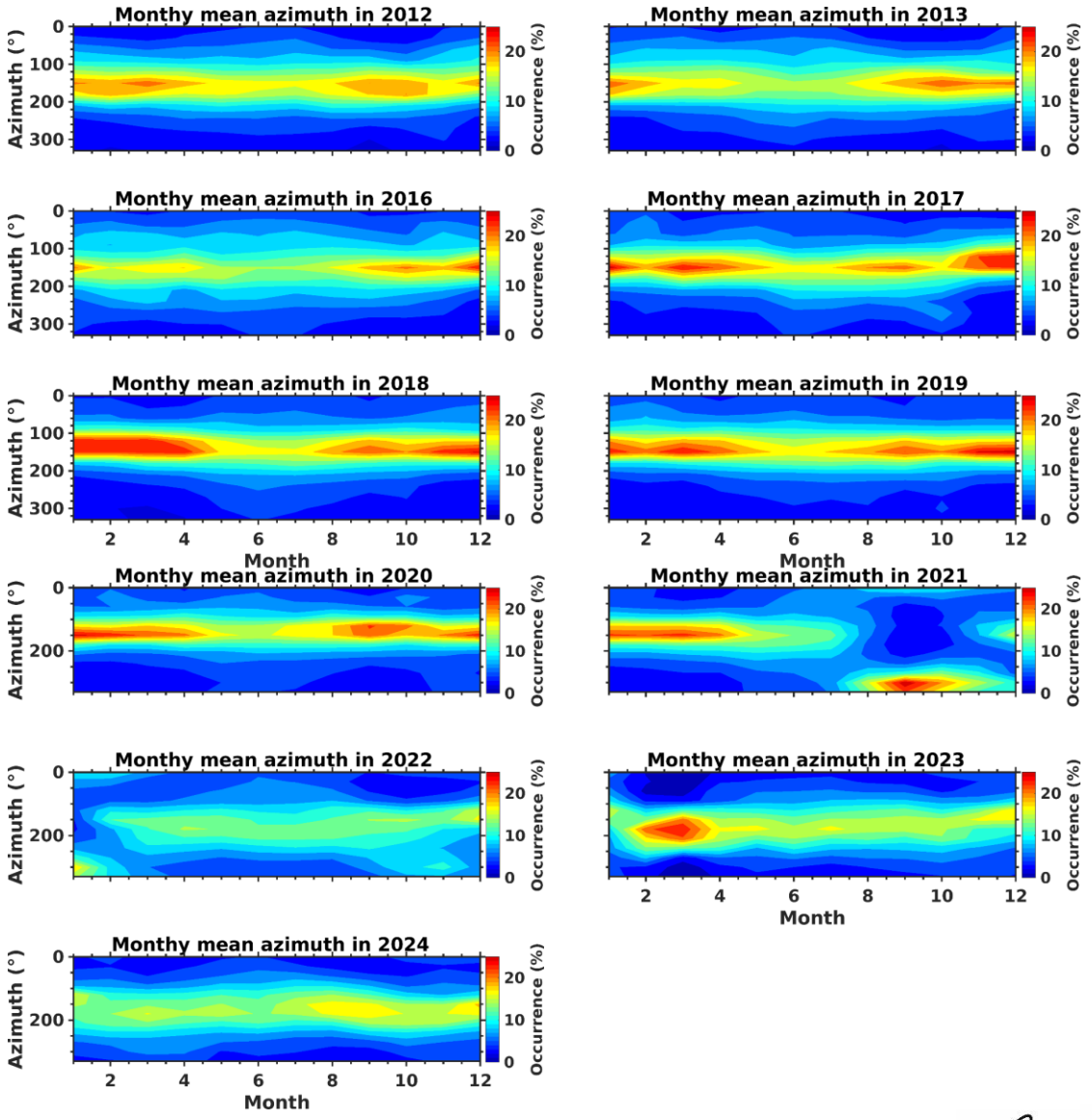
Interannual variation of the azimuth angle diurnal pattern



- ✓ There is a consistent diurnal pattern similar to the composite mean except 2021 and 2022
- ✓ Significant northward propagating daytime MSTIDs are observed for the years 2012, 2013, 2016 and 2017
- ✓ All these years the northeast propagation is dominant during the early morning hours.

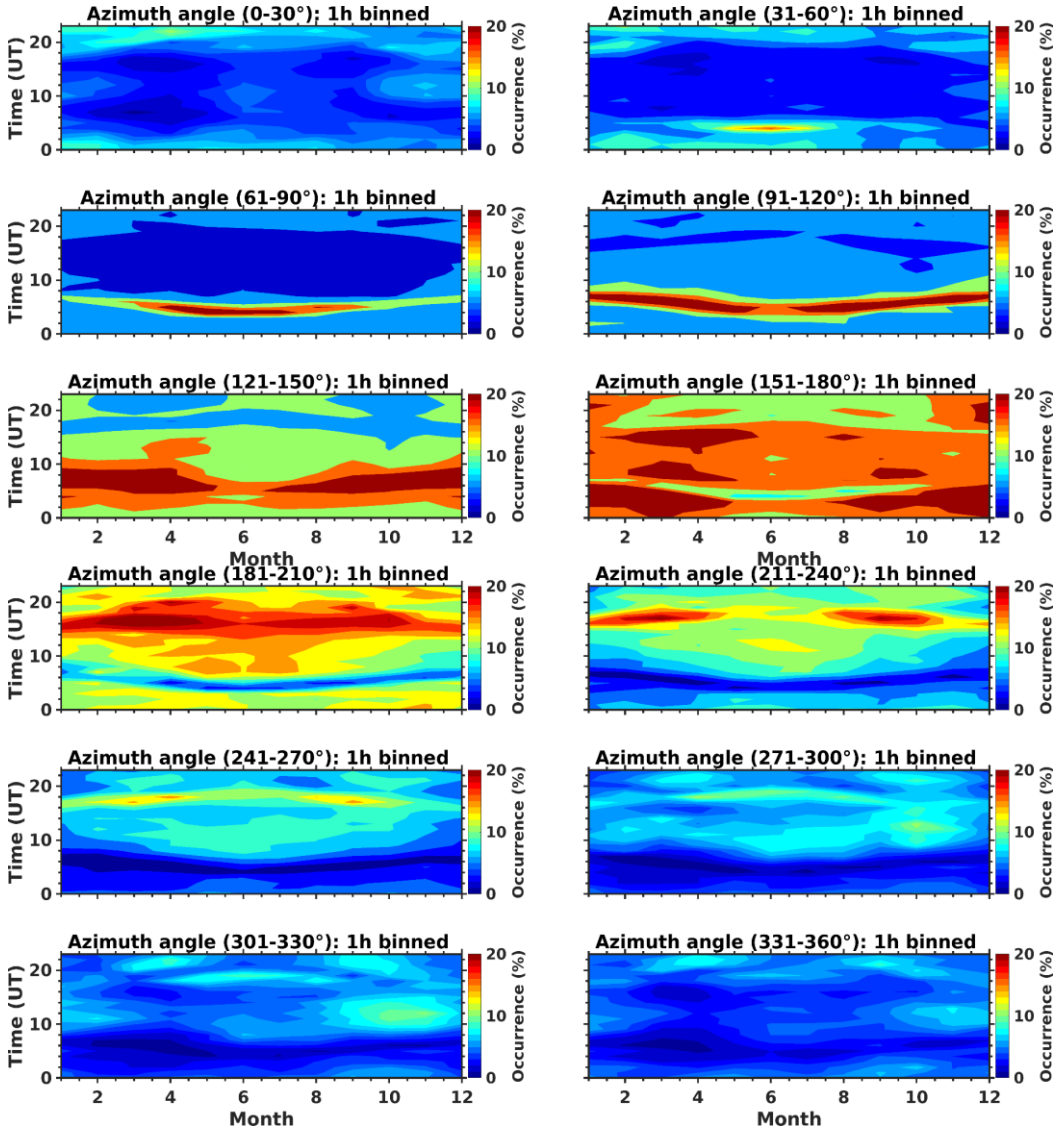
Interannual variation of seasonal pattern

- ✓ Similar to the diurnal variations, overall seasonal variation is also persistent with the composite mean i.e. the occurrence is more during winter and equinoctial months.
- ✓ Notable year to year variation in the occurrence amplitude also observed
- ✓ Occurrence is high during the year 2017 to 2022 in comparison with other years.
- ✓ The minimum occurrence is observed in 2022
- ✓ In 2012 and 2013 equinoctial months MSTIDs occurrence is higher than the winter and summer months.

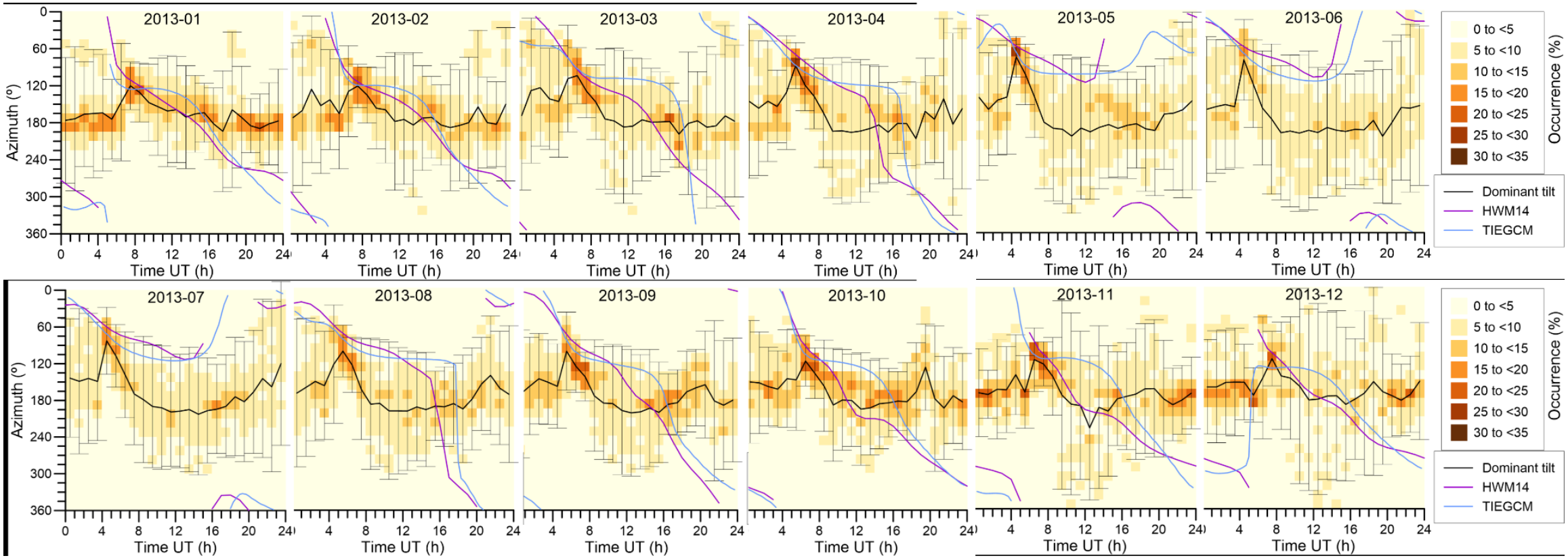


Seasonal variations of the propagation direction

- ✓ We have observed a clear diurnal and seasonal variation in the propagation direction of the MSTIDs
- ✓ Northeast (31-60°) propagation is high during the summer early morning hours.
- ✓ Eastward (northeast →61-90° and southeast→ 91-120°; 121-150°) propagation is also dominant during the summer and throughout the year in early morning hours, respectively.
- ✓ Southward (preferable southeast- 151-180°) propagation is significant during the post midnight and daytime throughout the year
- ✓ Southward (preferable southwest- 181-210°) propagation is significant during the afternoon hours throughout the year
- ✓ Southwest (211-240°) propagation is dominant during the sunset hours of equinox months
- ✓ Westward (241-270°) propagation is high during the sunset hours



Relation between background wind and propagation direction



- ✓ Seasonal variation in the wind direction are clearly observed
- ✓ Northeast and southwest propagation of the daytime MSTIDs during the winter seasons are in opposite to the wind direction

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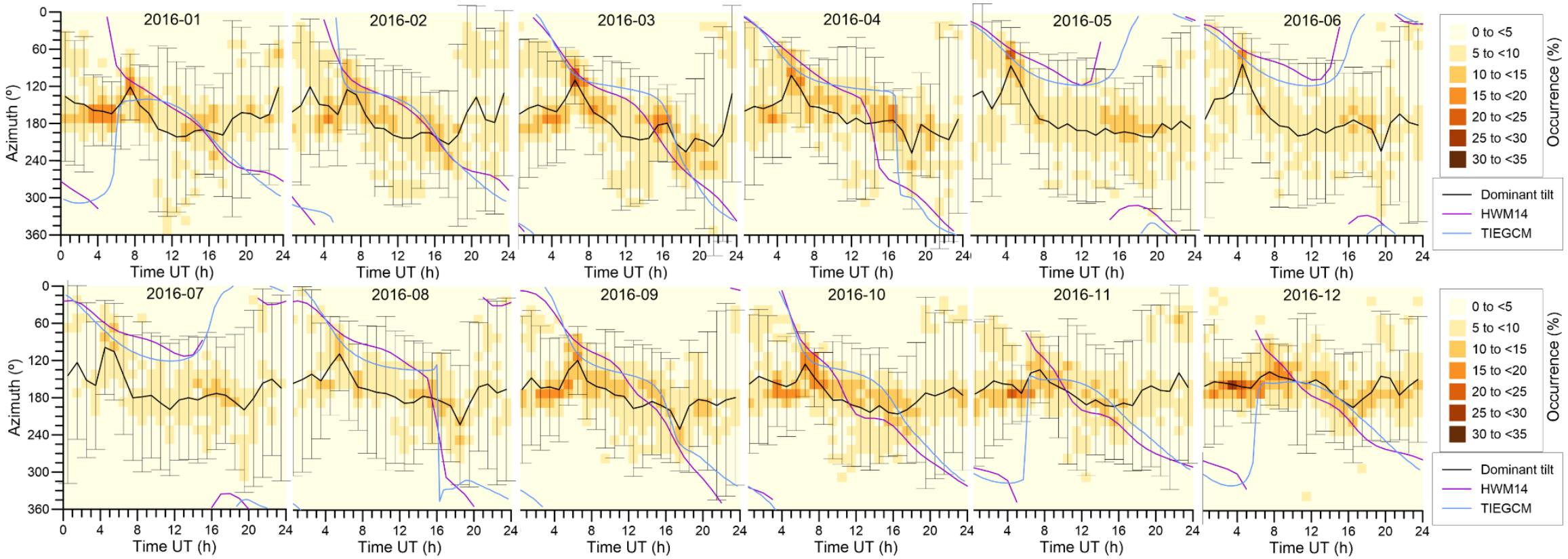

- ✓ Seasonal variation in the wind direction are clearly observed. There is a notable difference in the nighttime winds HWM and TIE-GCM during January and December
- ✓ Northeast and southwest propagation of the daytime MSTIDs during the winter seasons are in opposite to the wind direction

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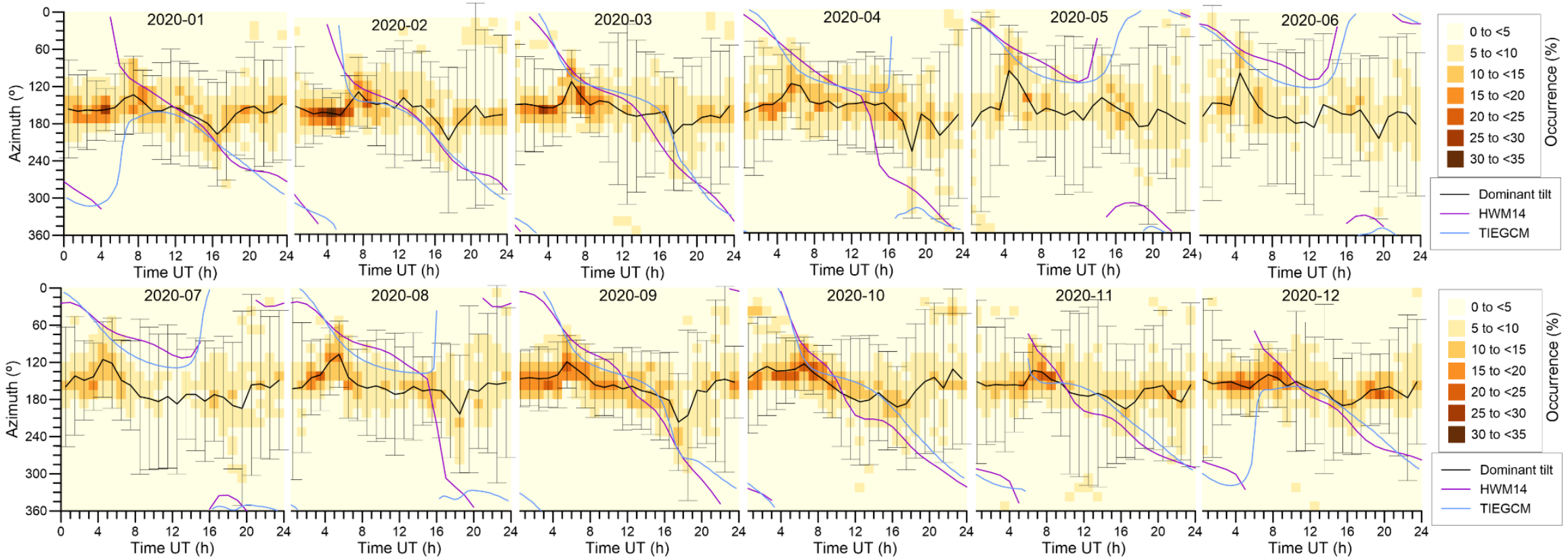
2020-01
2020-02
2020-03
2020-04
2020-05
2020-06
2020-07
2020-08
2020-09
2020-10
2020-11
2020-12
Azimuth (°)
Time UT (h)
0 to <5
5 to <10
10 to <15
15 to <20
20 to <25
25 to <30
30 to <35
Occurrence (%)
Dominant tilt
HWM14
TIEGCM

Summary and conclusion

- **Assuming that the ionosonde tilt angle might be considered as an indication of propagation direction of MSTIDs; We draw the following conclusions:**

  - ✓ the daytime TIDs likely have tropospheric/mesospheric AGWs as the source, while the nighttime TIDs can be due to equatorward propagating TIDs originating in the auroral region

  - ✓ the wind-filtering mechanism is likely a dominant factor in the propagations of MSTIDs at the mid-latitude location of Ebro Observatory during the daytime

  - ✓ c) the lower occurrence of the measured tilt azimuth in the summer months might be considered as an indication of lower activity of the MSTIDs in summer compared to winter and equinoxes.

- Diurnal, seasonal interannual variation in the occurrence of MSTIDs is observed.

Thank you for your kind attention!

Acknowledgement

Ebro observatory team members for their wonderful hospitality and the scientific discussion HWM14

TIE-GCM

- Wenbin Wang, UCAR (Model Developer)
- Jack Wang, NASA/GSFC (CCMC Model Host)
- Jia Yue, NASA/GSFC (CCMC Model Host)

HWM14

Douglas P. Drob

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