Automatic detection of polar cap patches in SuperDARN observations

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Project science objective and goals (ONR N000142312161)

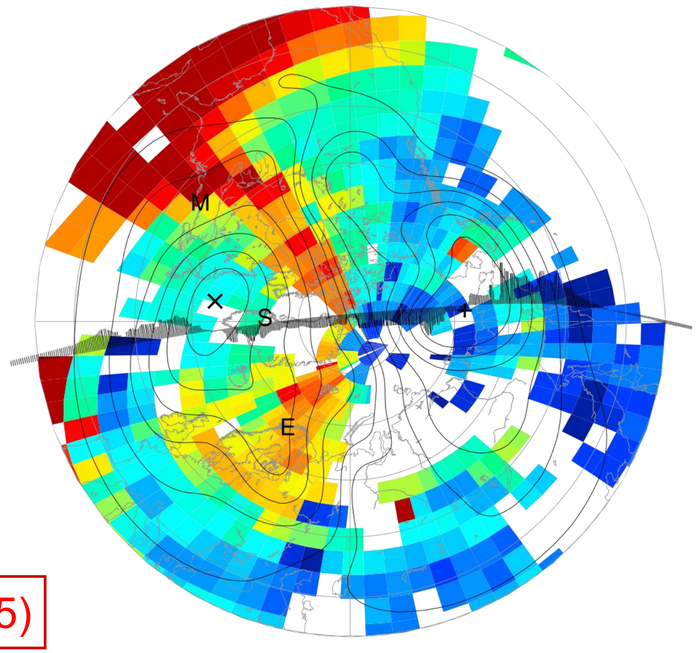
- Objective: Advance the development of a polar cap patch detection algorithm for Over-The-Horizon Radars (OTHRs).
  - This will generate new knowledge to improve understanding of space weather processes and open up the possibility for real-time operations and forecasting of ionospheric irregularities.

- Goal 1: Establish a set of criteria that reliably detect polar cap patches using OTHR backscatter characteristics.
- Goal 2: Develop a reliable, automated polar cap patch detection algorithm for OTHR backscatter.
- Goal 3: Advance the development of a near real-time OTHR patch detection algorithm.

Background - “polar-cap patches”

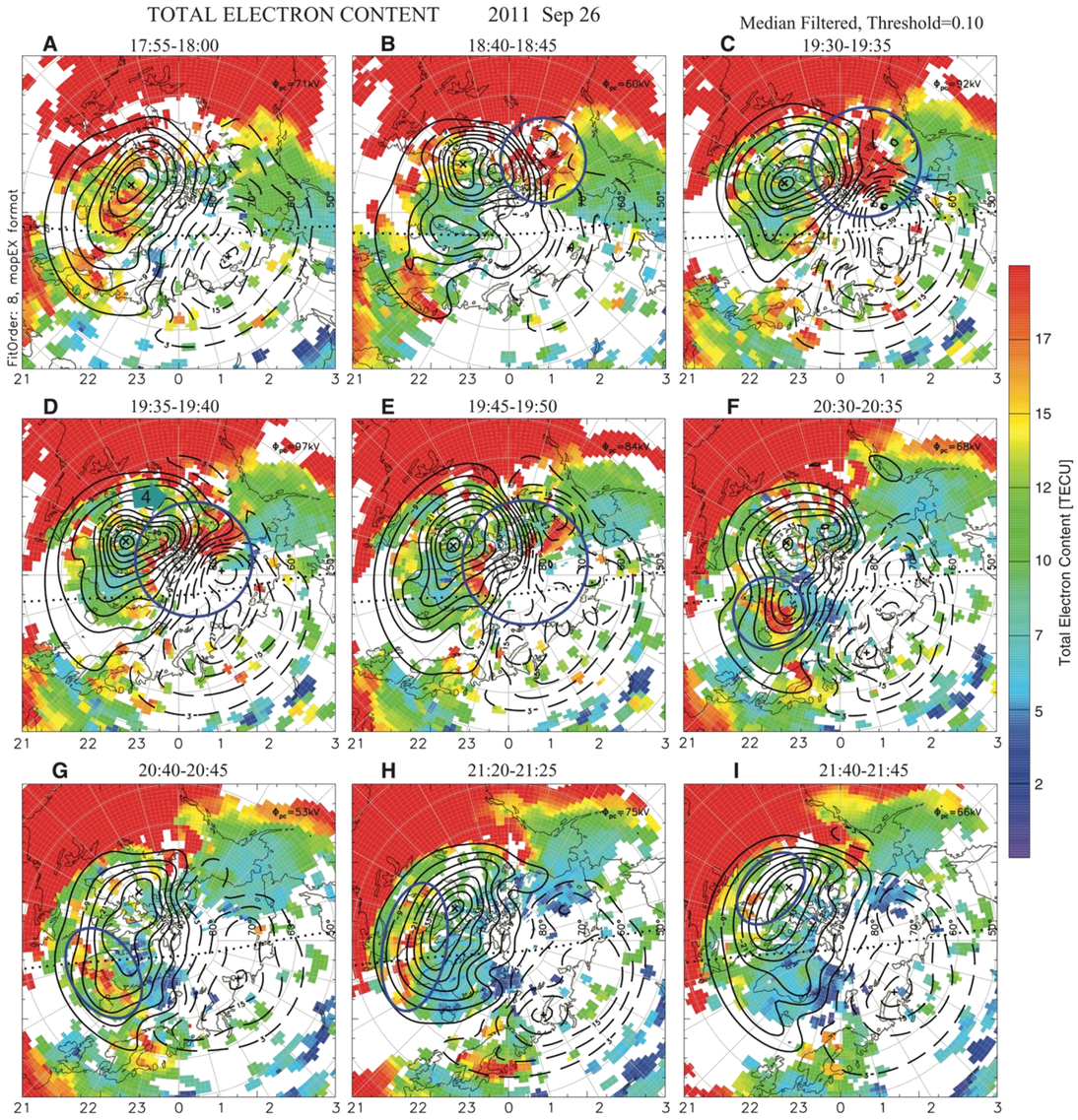
- “Polar-cap patches”
  - Operational definition (Crowley, 1996)*: “plasma-density enhancements (by a factor of two or more above the ambient) that have entered, or are about to enter the polar cap.”*
    - *“The term blob is reserved for plasma enhancements which have already passed through the polar cap, and are now located outside it.”*
  - In practice, patch definition tends to be a bit more relaxed. For example, (Perry & St.-Maurice, 2018) F-region plasma enhancement above the background with a spatial scale > 10 km and lifetime of > 30 minutes.
- Patches were first identified by Meek (1949).
  - *“Clouds of ionization”* identified in oblique ionogram traces as sporadic enhancements in the foF2.

Background - “polar-cap patches”



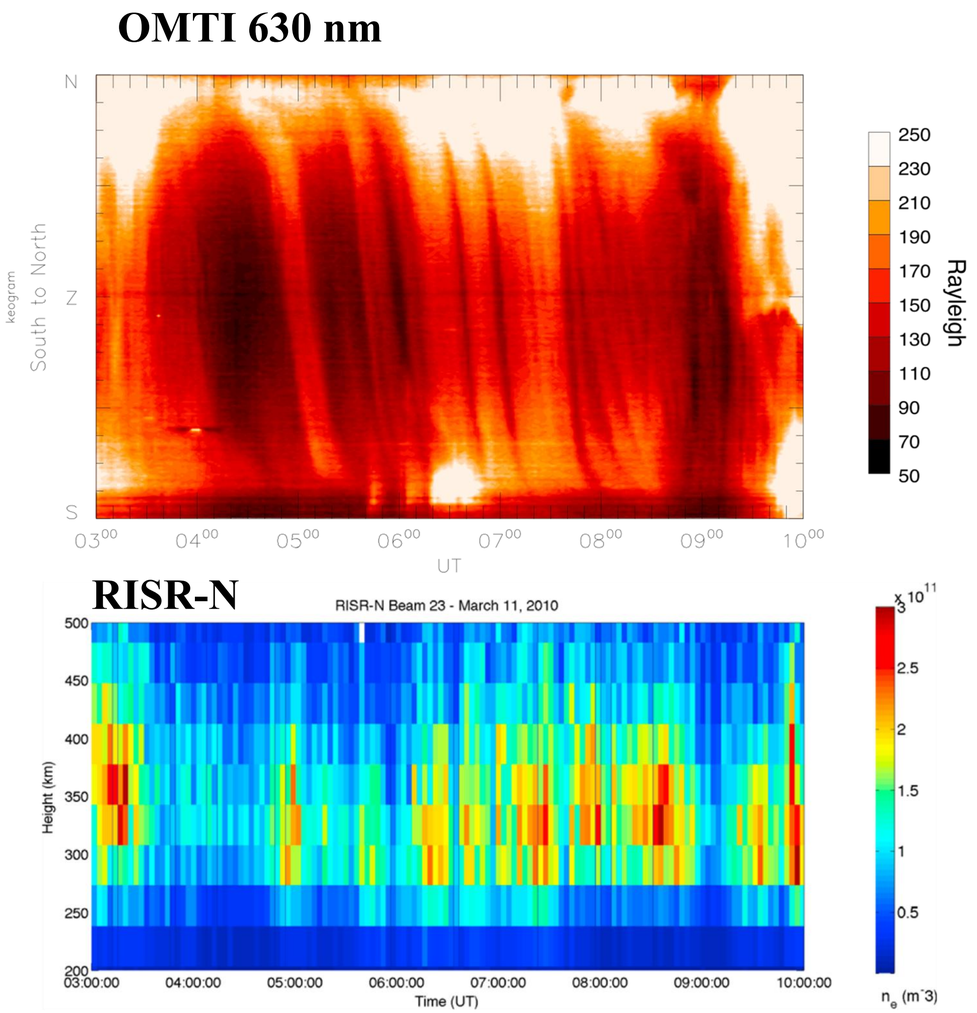
(Foster et al., 2005)

- The dayside ionosphere is often identified as a source of patches.
  - Photoionized plasma is convected into and through the polar-cap.
- Particle precipitation has also been identified as a patch generator, although it’s relative contribution is not well understood.

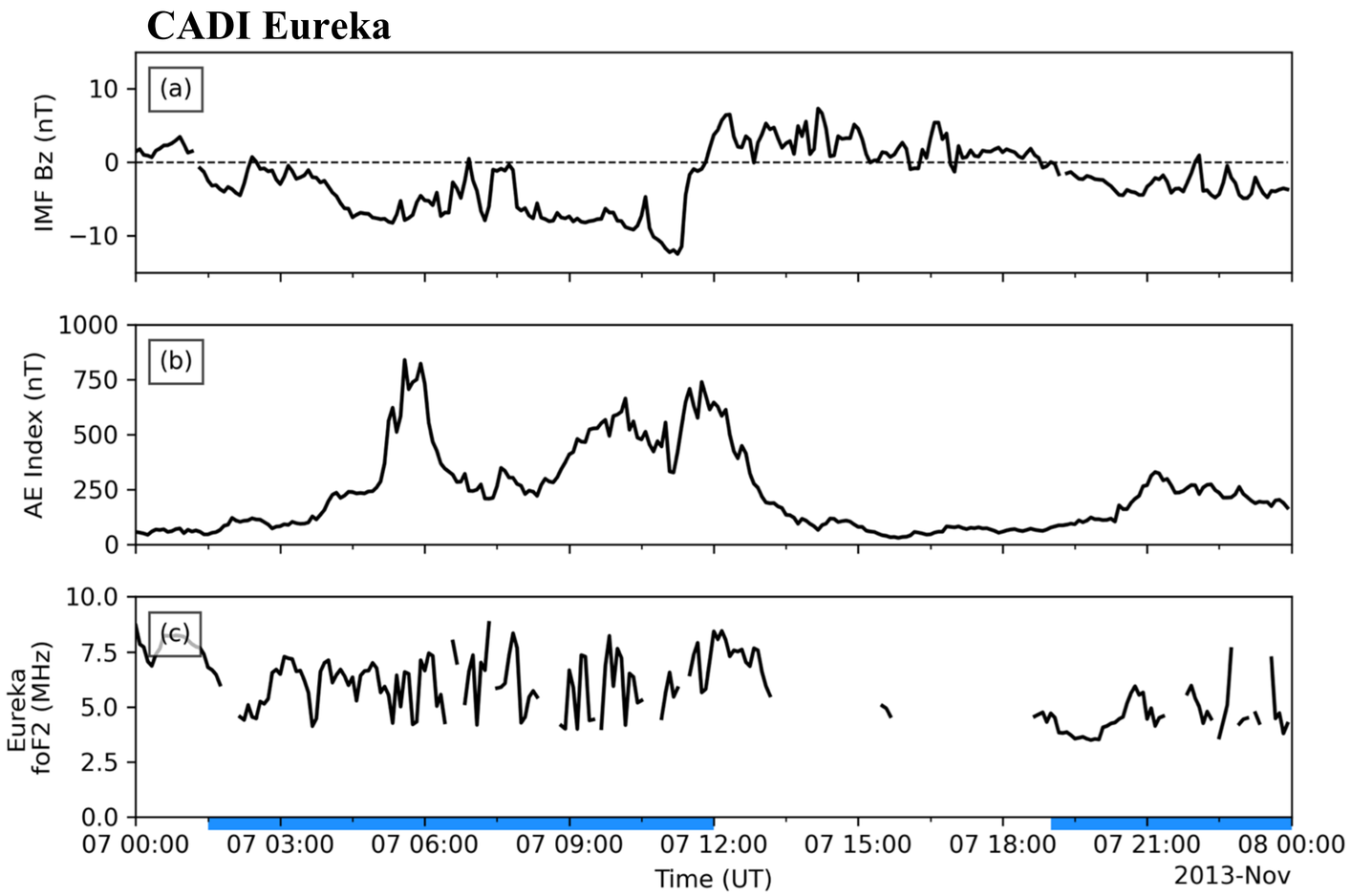


(Zhang et al., 2013)

Background - “polar-cap patches”

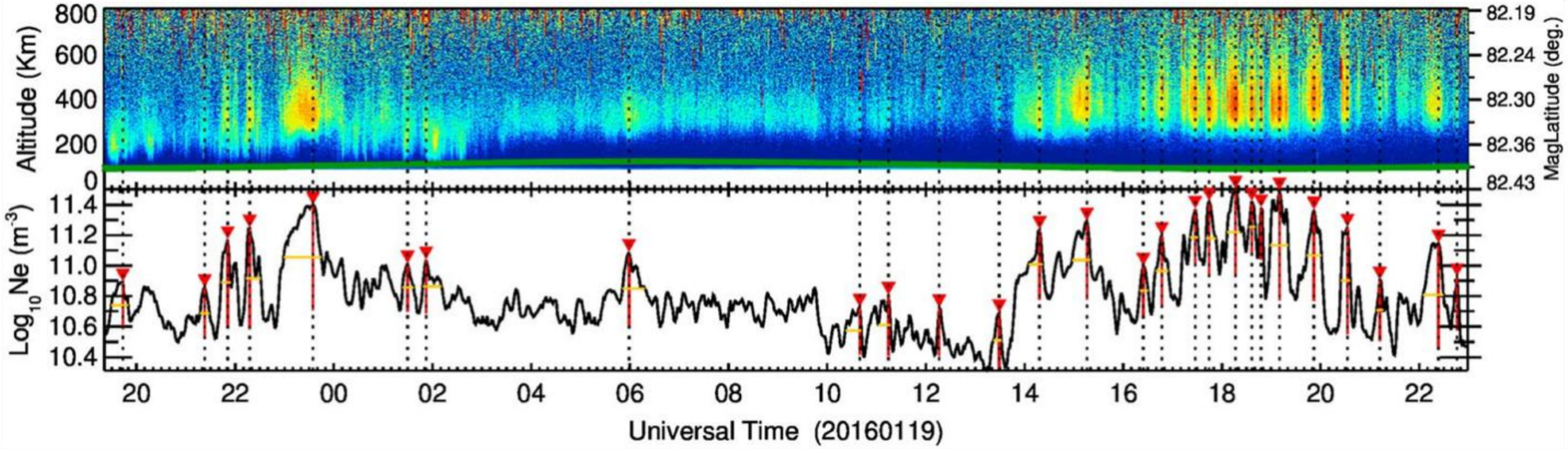


(Perry & St. Maurice, 2018)

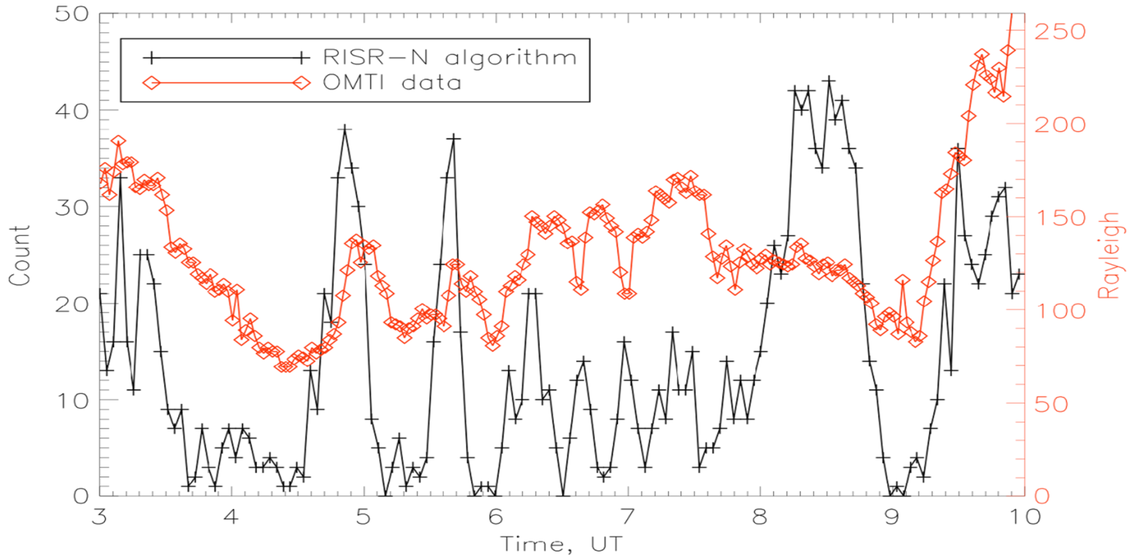


(Cameron et al., 2024)

Background - patch detection techniques



(Ren et al., 2018)

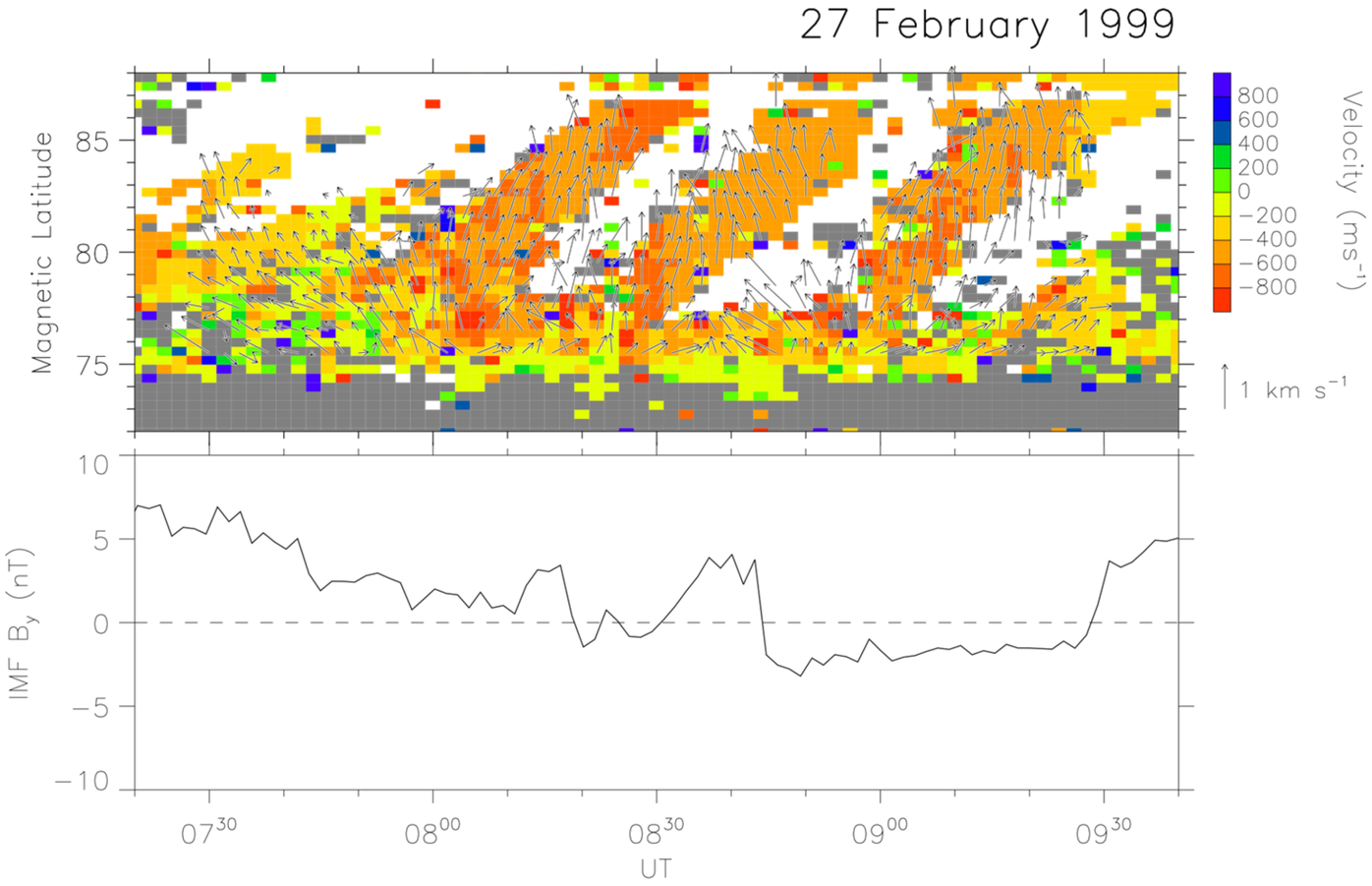


(Perry & St. Maurice, 2018)

- At least two techniques have been developed independently to detect patches in incoherent scatter radar data.
  - Based on plasma density measurements.
- In situ (LEO spacecraft) techniques have also been used.

Supervised classification

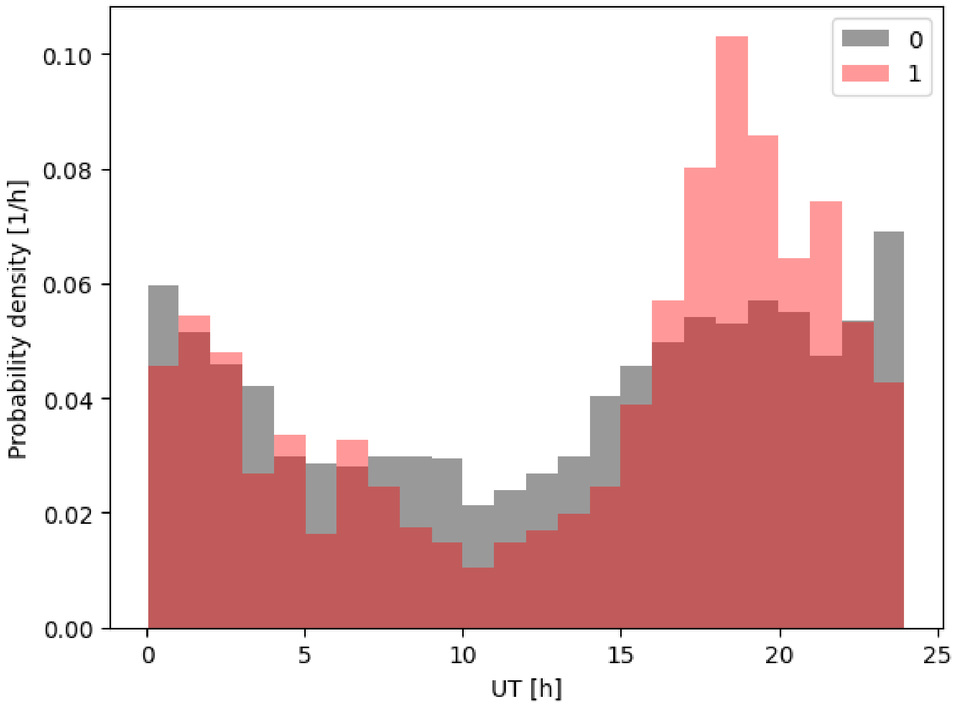
- We used patches detections derived from Ren et al. (2018) algorithm applied to RISR-N/C data
- For these time windows, we extracted the SuperDARN backscatter properties from the collocated beam/range cell of the CLY radar and assigned them a value of 1, corresponding to patch detection, otherwise 0- input for classification



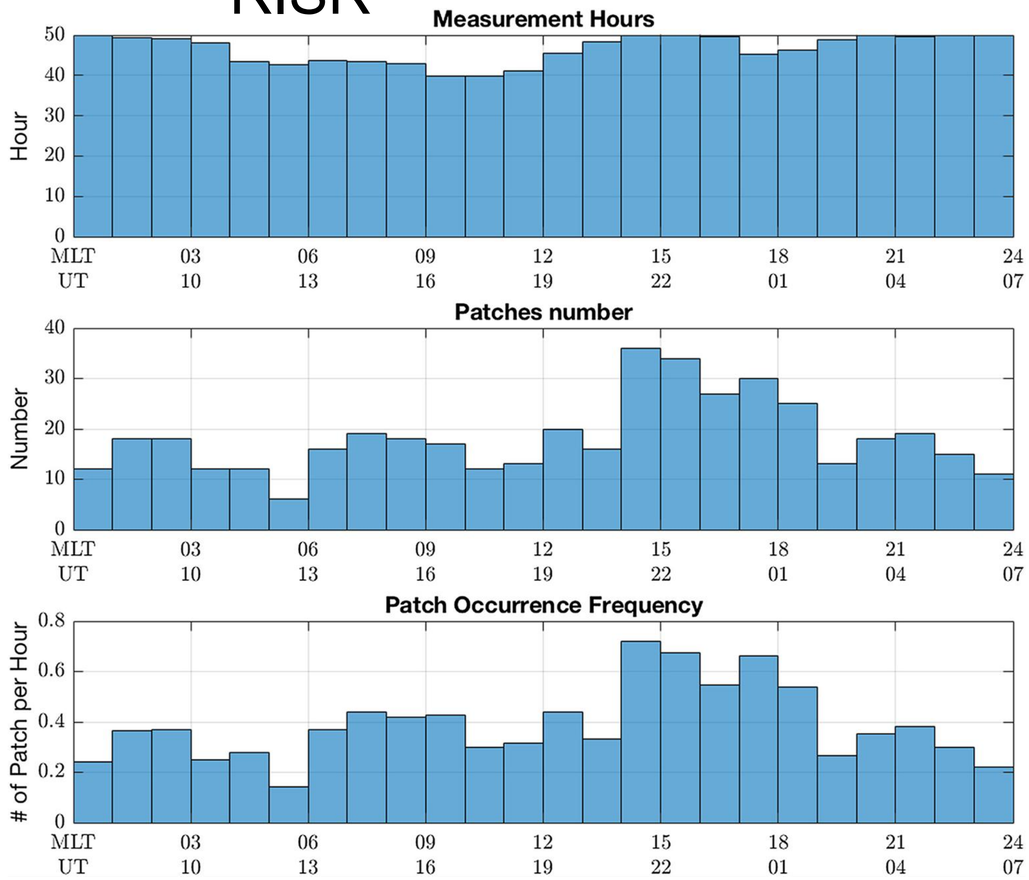
(Milan et al., 2002)

Input for classification

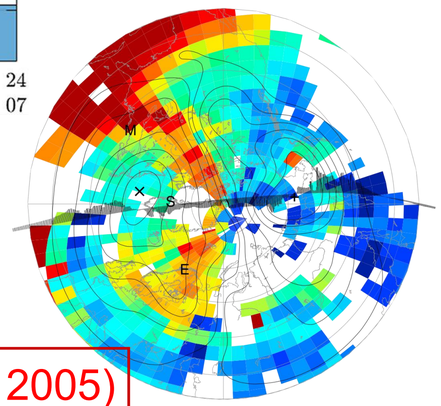
CLY



RISR



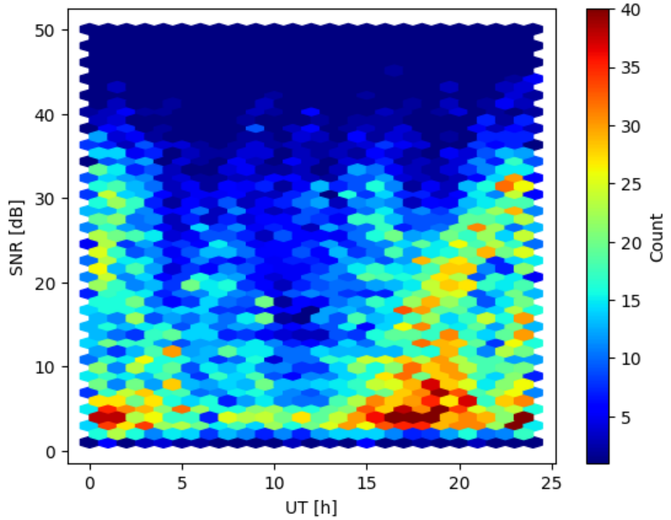
(Ren et al.,2018)

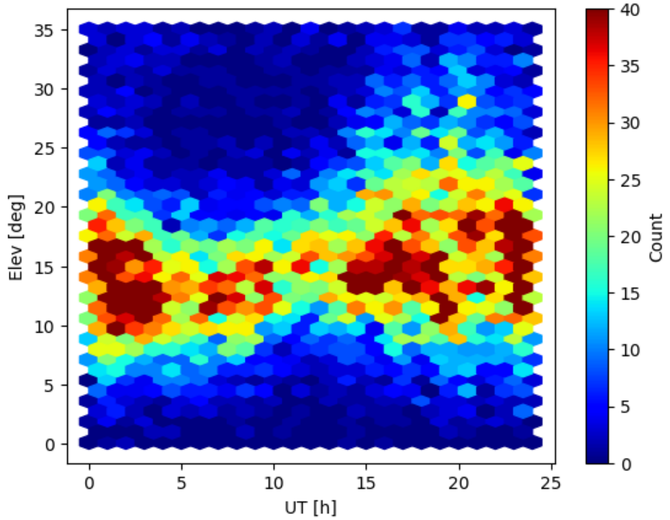


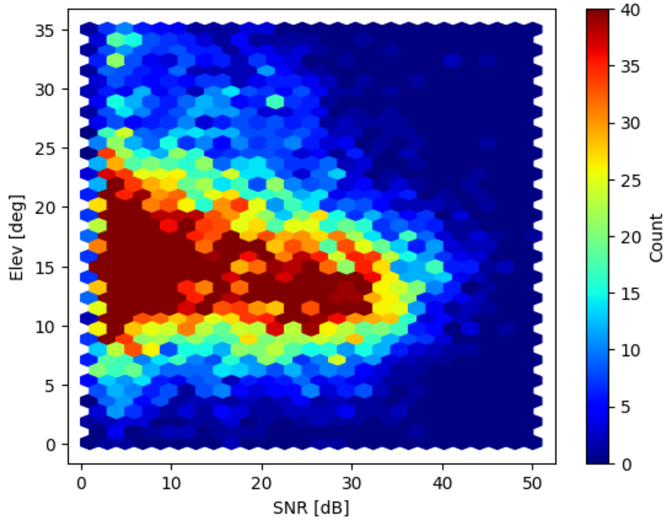
(Foster et al., 2005)

- Occurrence rate higher in the afternoon MLT sector
- Distributions different if no backscatter found during the patch detection

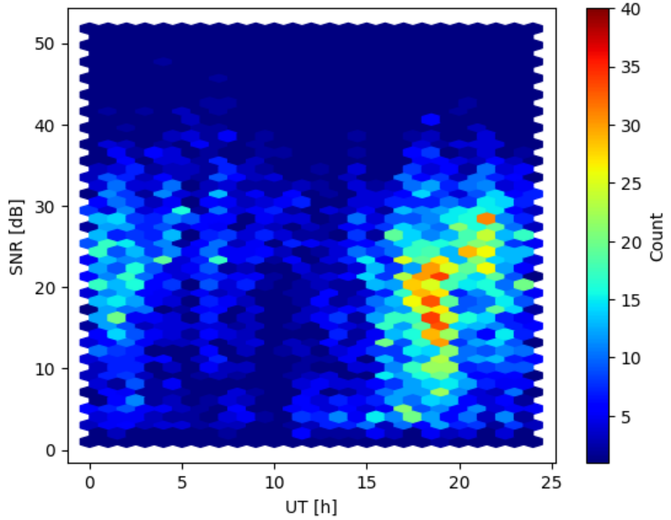
Input for classification- benchmark model

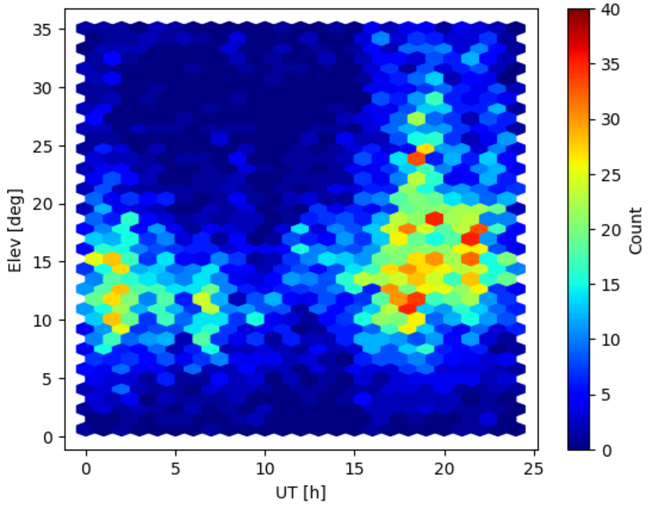


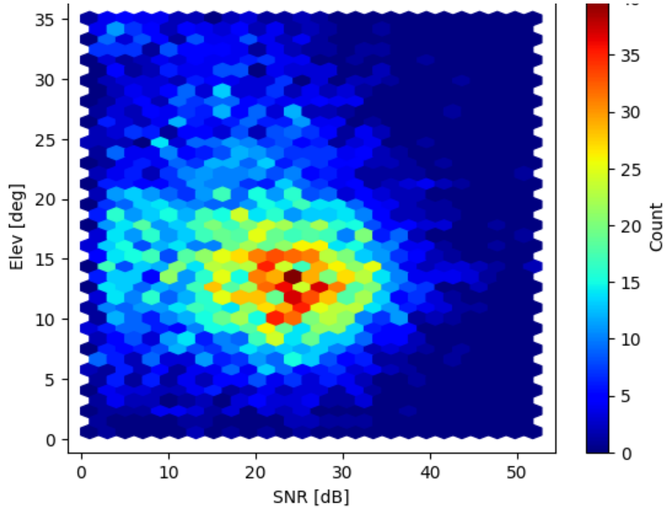




no patches



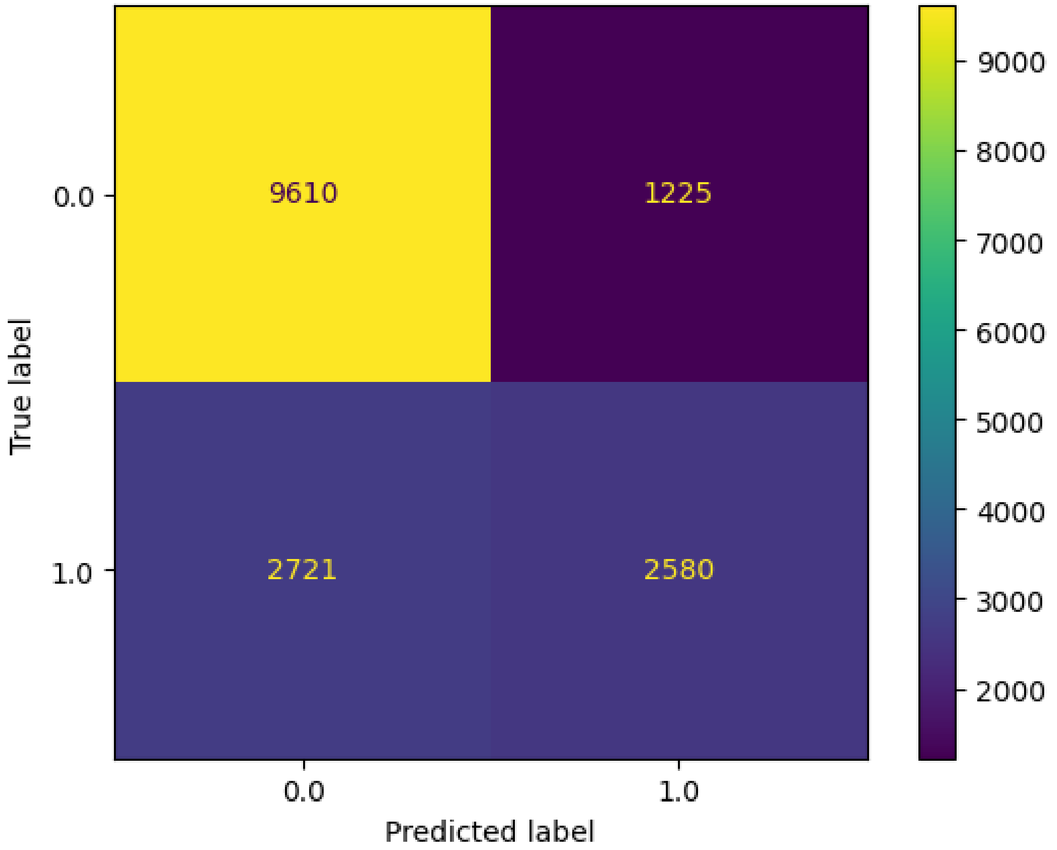




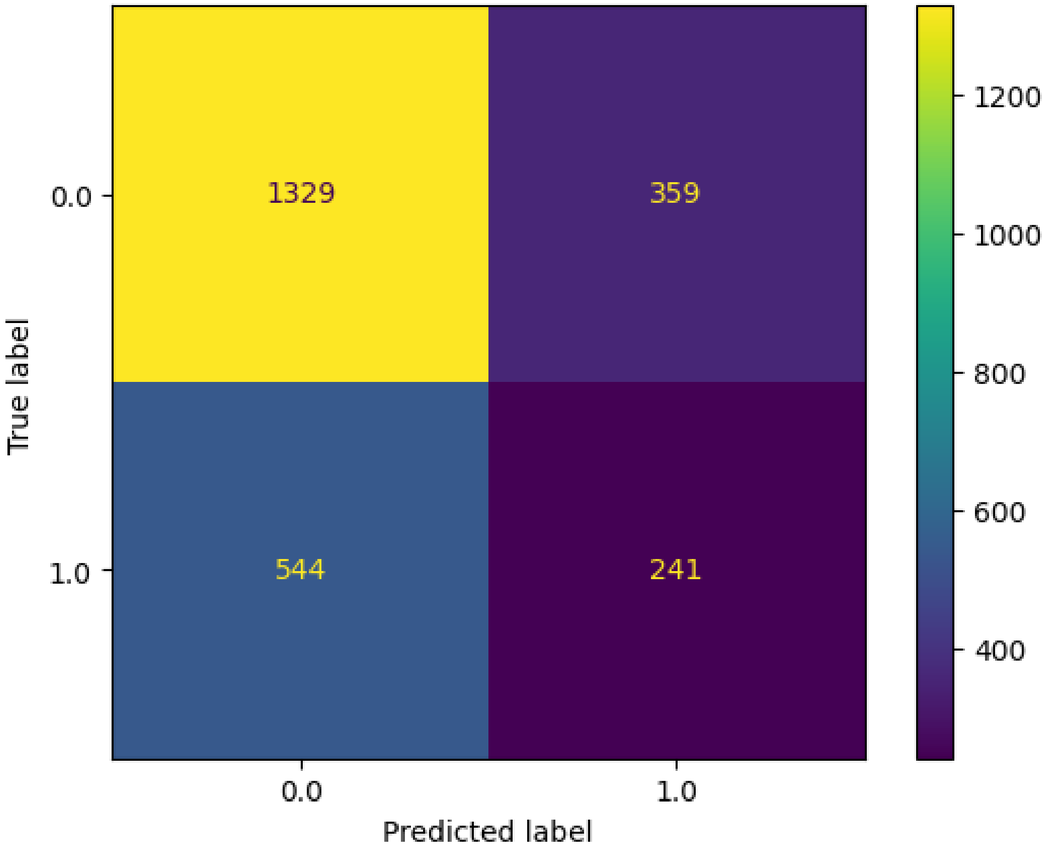
patches

Results- benchmark model

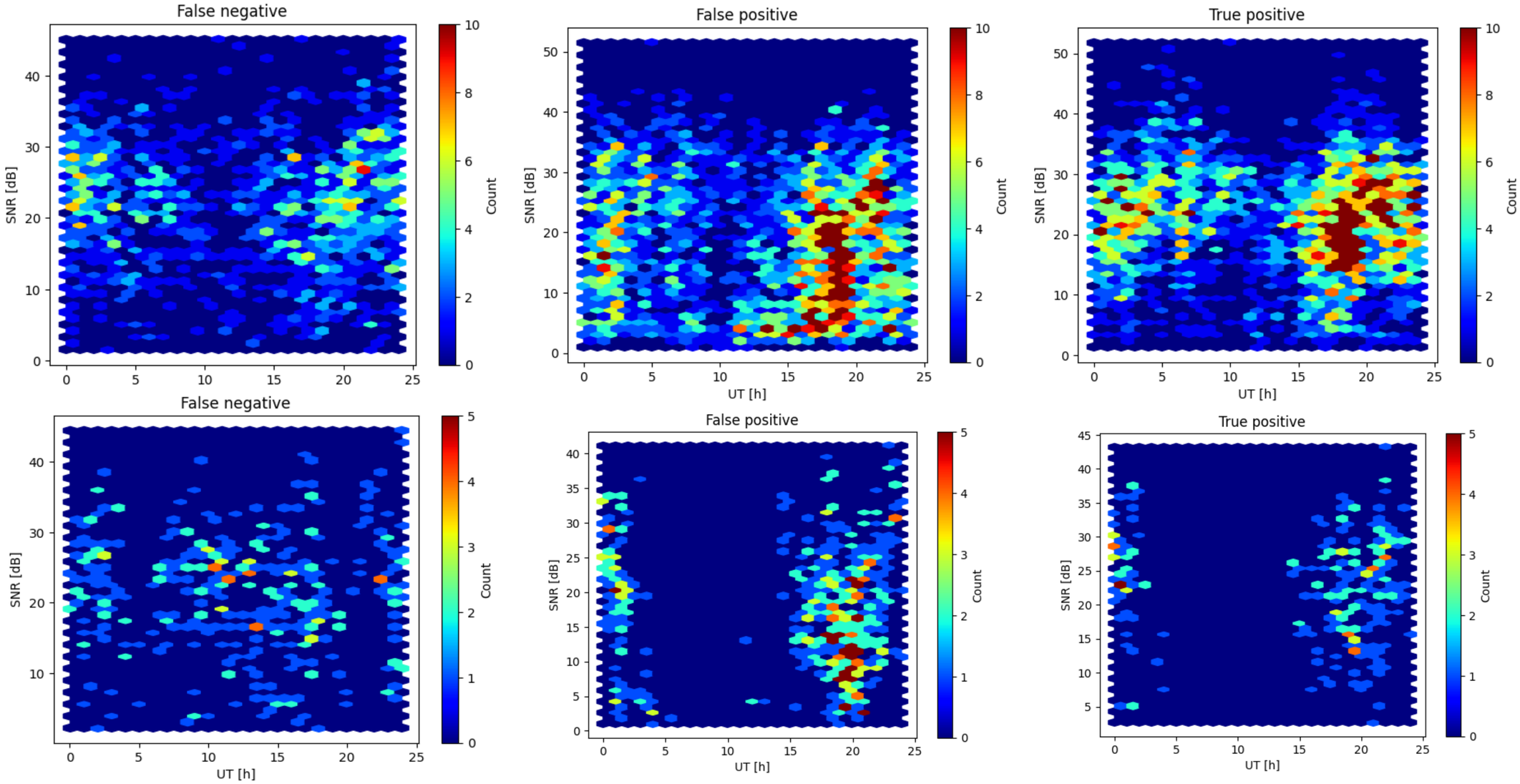
training set



test set



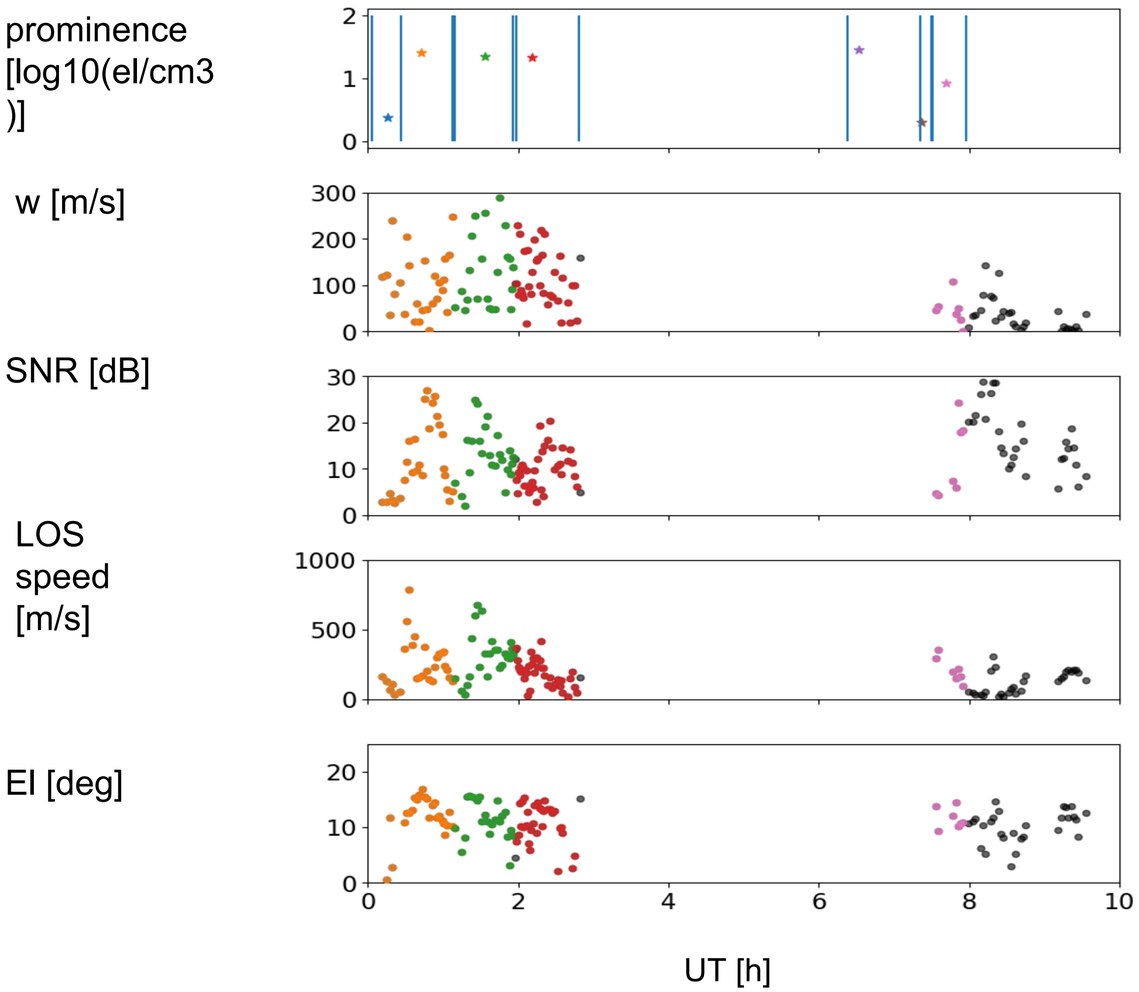
Results- benchmark model



training set

test set

Search for the next model: work in progress



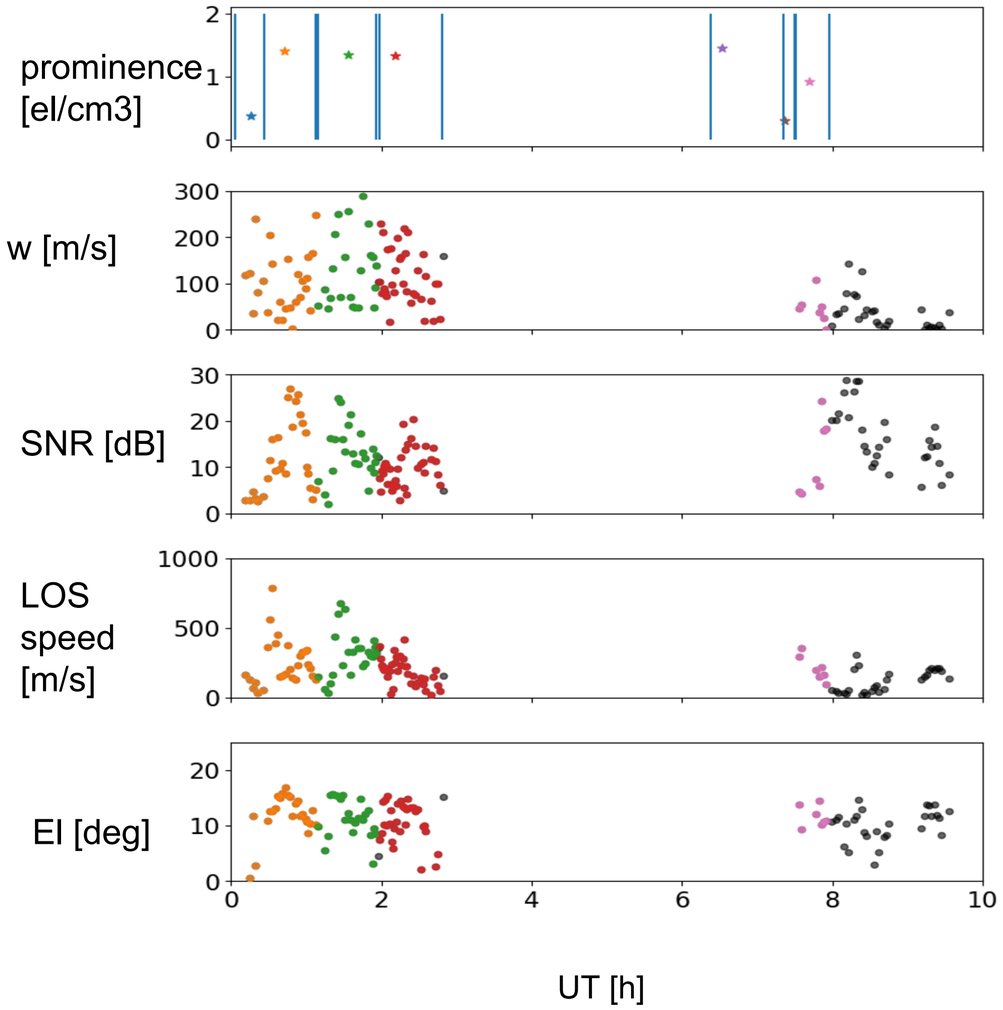
Model that is more aligned with the patches' definition- values relative to the background levels

Challenges:

- non-uniform measurements and lack of backscatter for patches events
- various durations of patches detection events

Conclusions

- The uniqueness of detected patches properties derived from SuperDARN using the benchmark model reflects their higher occurrence rate at specific MLT times (entrance and exit from the polar cap)
- The patches are not always associated with measured SuperDARN signals
- The benchmark model has low accuracy, but this could be something we are fine with for operational purposes
- **Where do we go from here?**
  - Test a model that incorporates temporal evolution of the signal, which is a consequence of the patches' characteristic spatial scales
  - Compare to the Perry and St. Maurice, (2018) detection algorithm



References and Acknowledgements

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