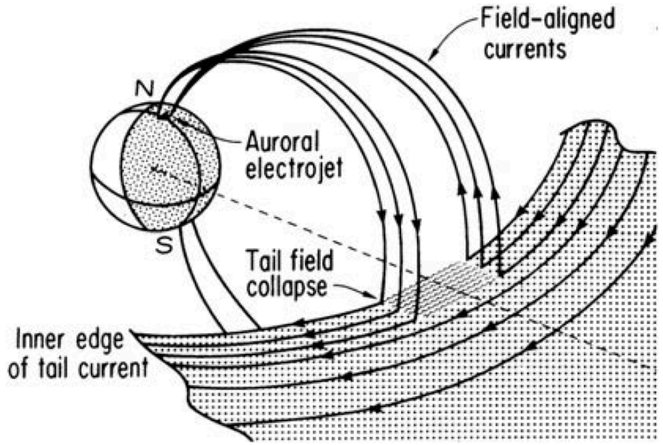
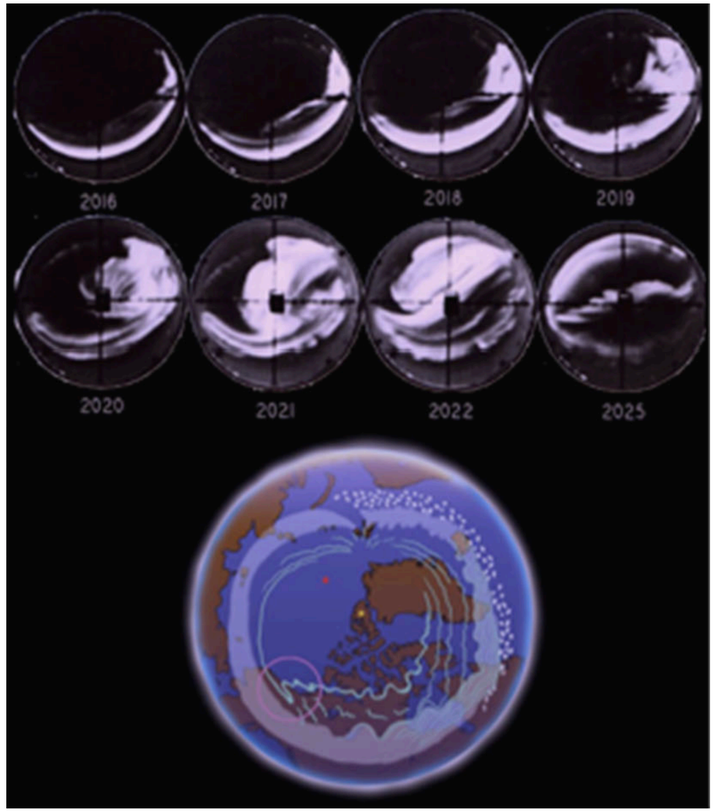
AKR Observations From All Local Times Indicate Substorm Activity

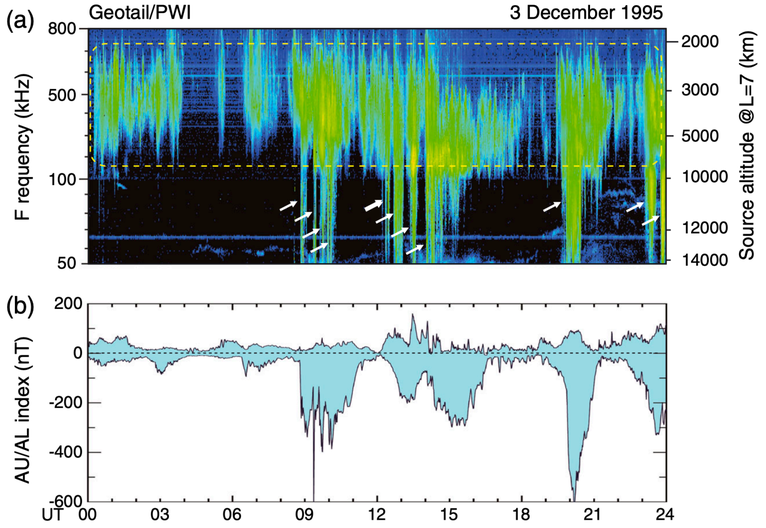
J. E. Waters, L. Lamy, J. C. Coxon, C. M. Jackman, C. J. Lao, C. Forsyth, A. R. Fogg



Clauer & McPherron+ 1974



Akasofu 2017



Morioka+ 2013

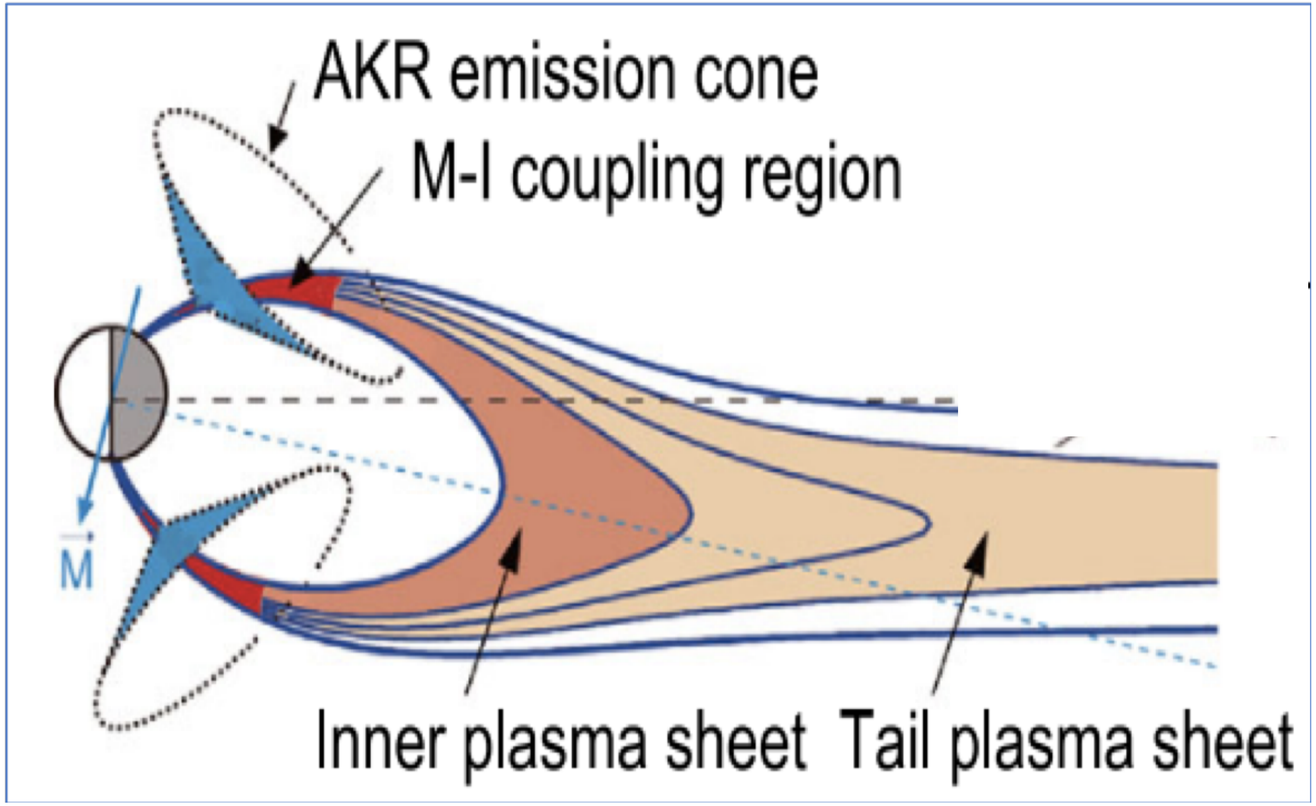
PRE X 2025
12 June, Marseille, France

j.e.waters.space@gmail.com

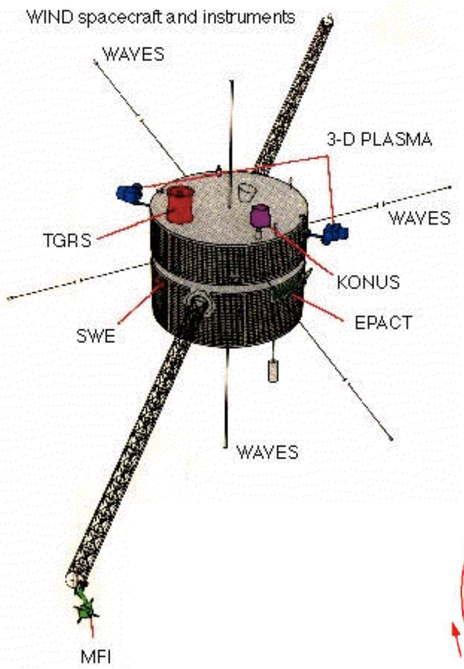
cnes

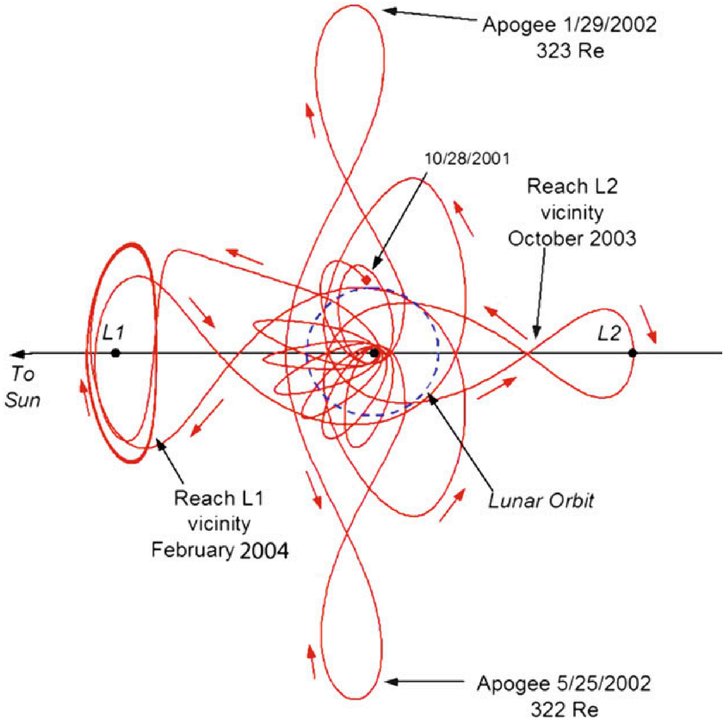
LAM
LABORATOIRE D'ASTROPHYSIQUE DE MARSEILLE

Auroral kilometric radiation (AKR) - remotely observing the auroral acceleration region



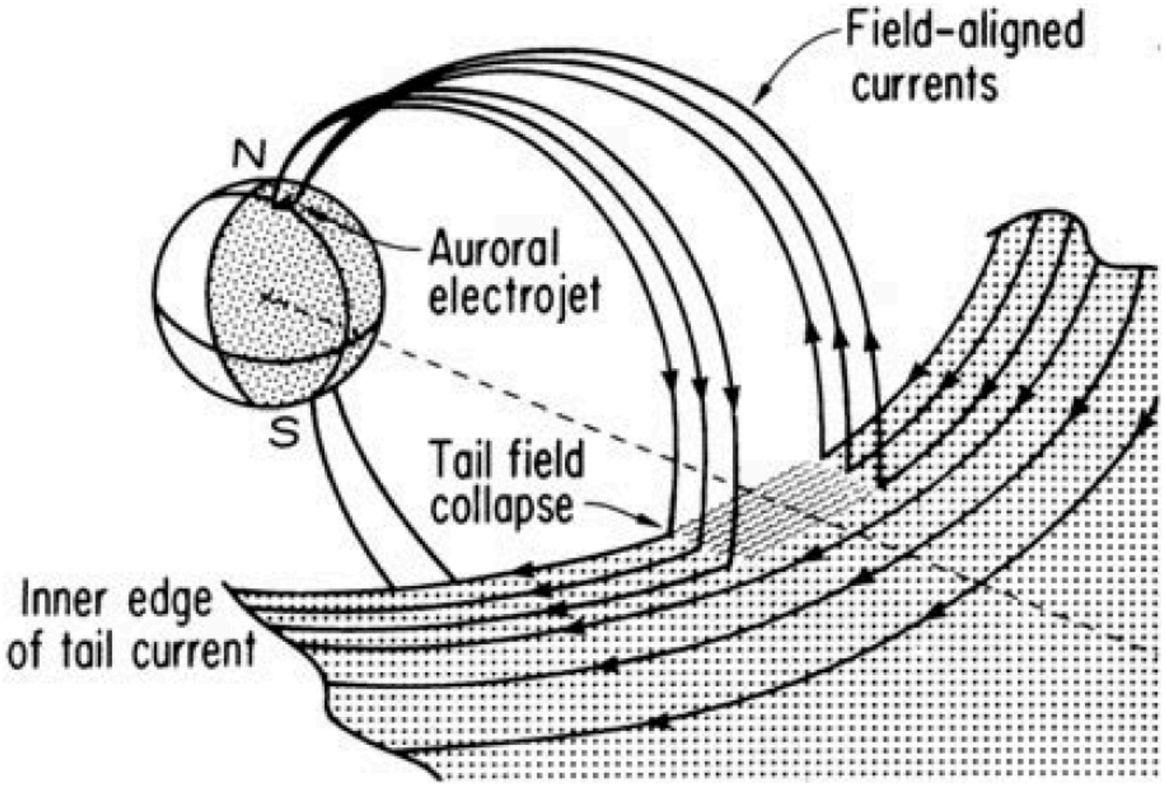
Morioka+ 2013





j.e.waters.space@gmail.com

Substorms

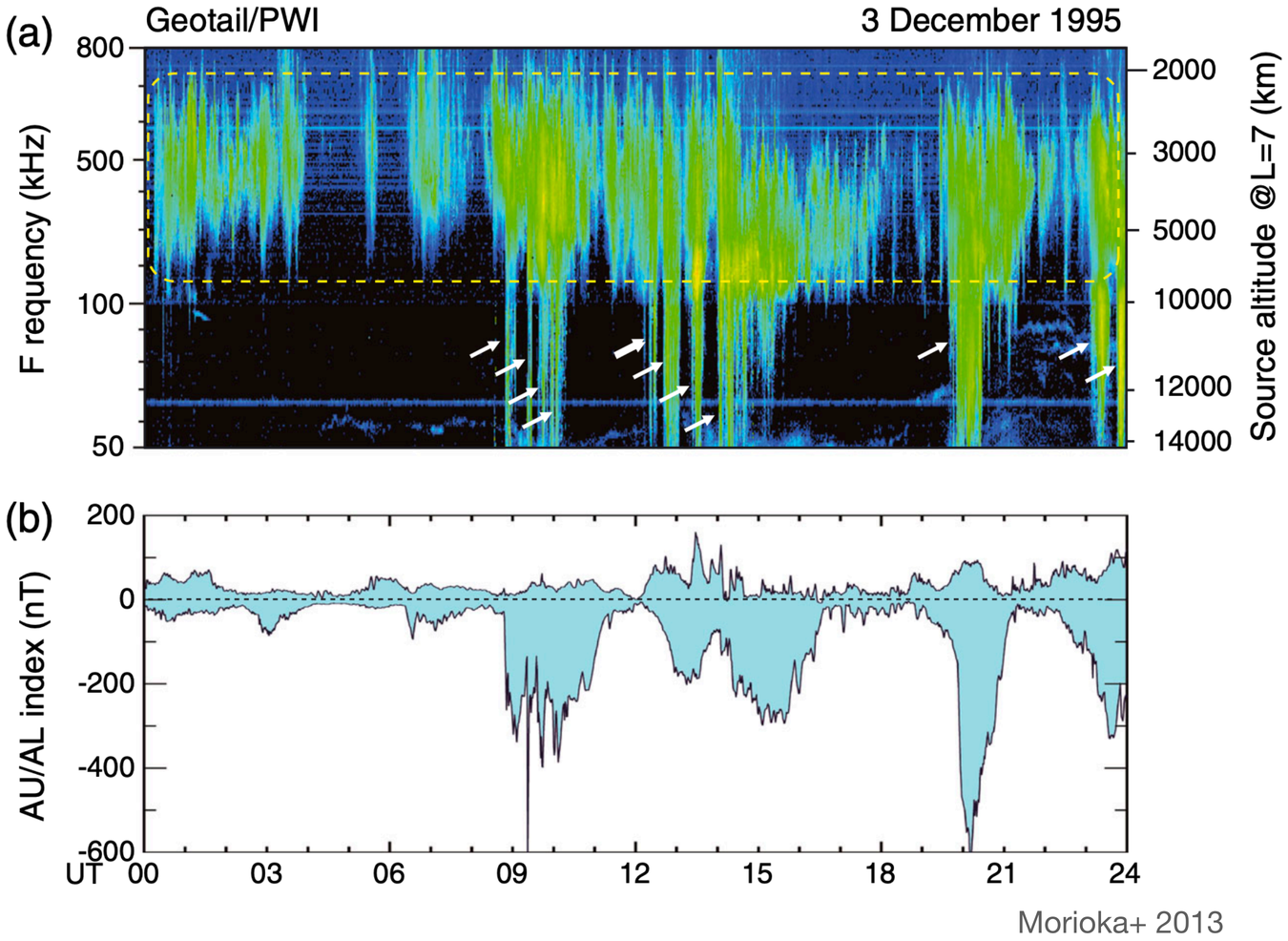


Clauer & McPherron+ 1974

- Magnetic reconnection in the nightside magnetotail follows dayside reconnection (~2.5 hr quasiperiodicity)
- Current is diverted from the plasma sheet to the auroral electrojet in ionosphere
- Strengthened ionospheric currents measured with ground magnetometer networks

j.e.waters.space@gmail.com

AKR and Substorms

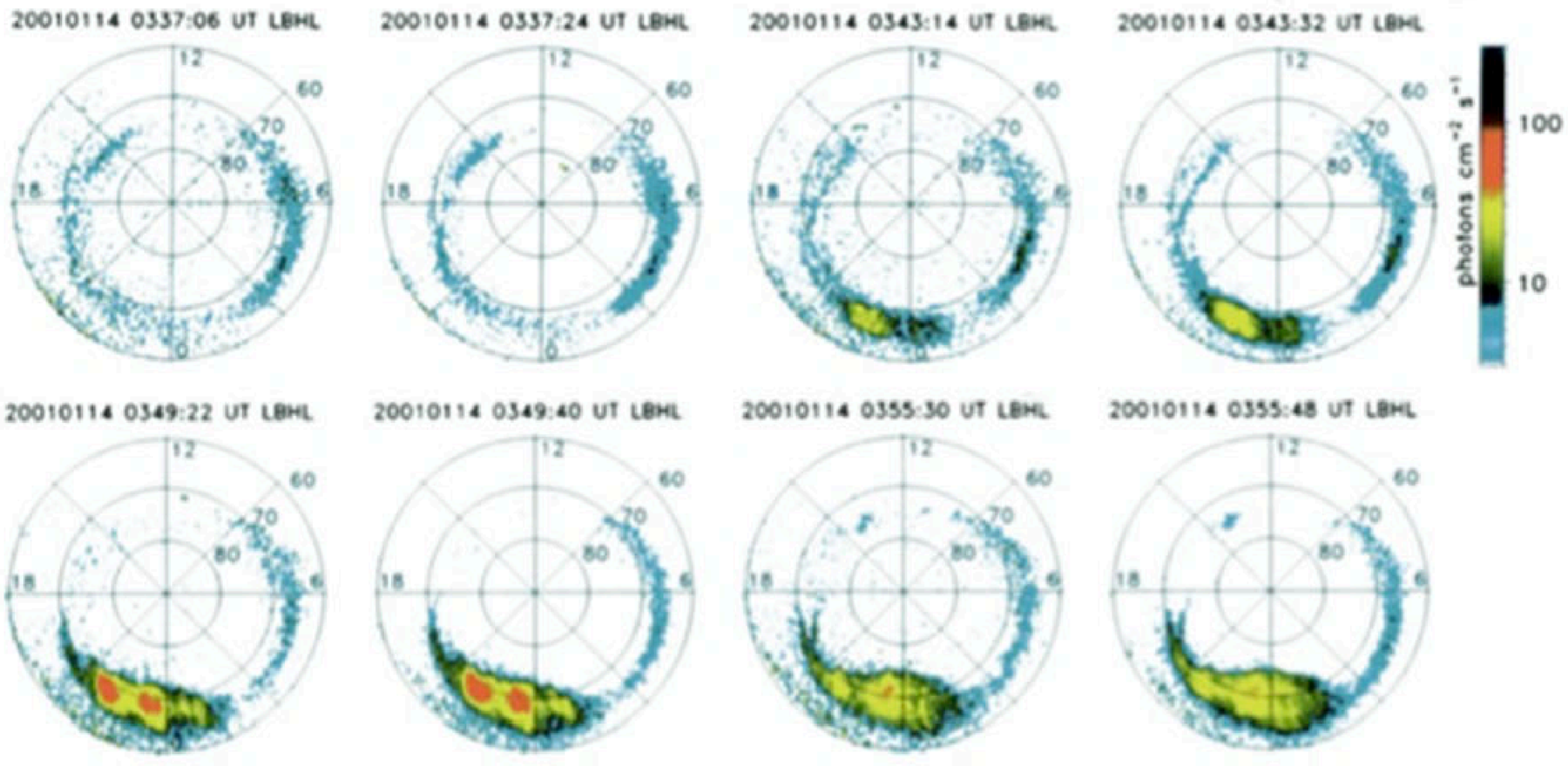


Morioka+ 2013

- AKR known to exhibit low frequency activity around substorm activity
- Showed statistically for first time with 10 years of Wind/Waves observations (Waters+ 2022)
- Strengthened ionospheric currents measured with ground magnetometer networks

j.e.waters.space@gmail.com

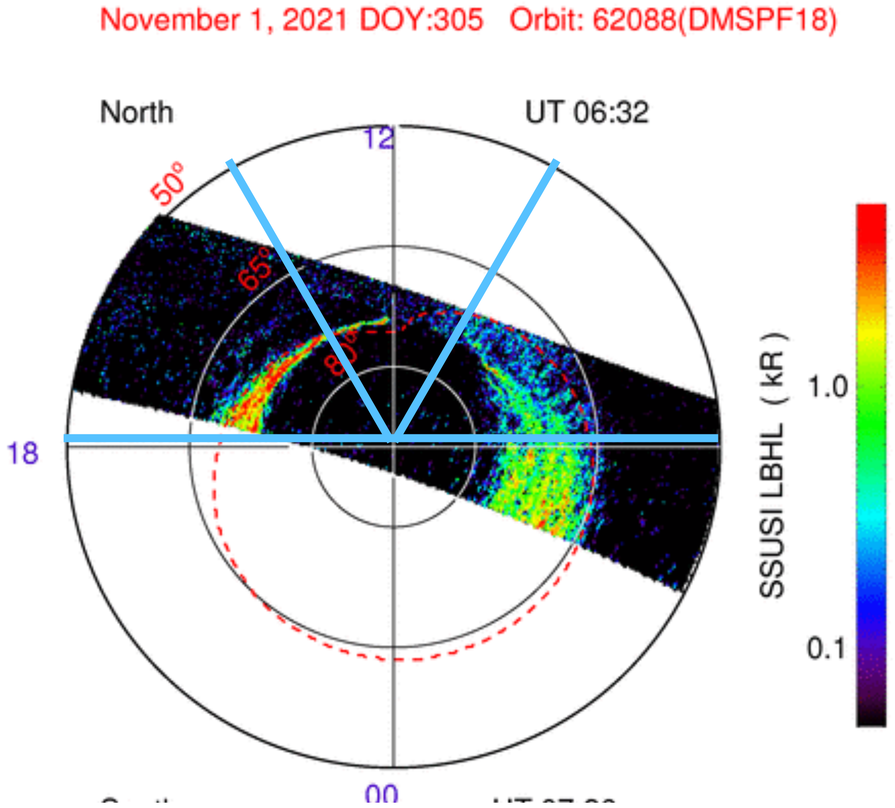
Substorms - auroral morphology

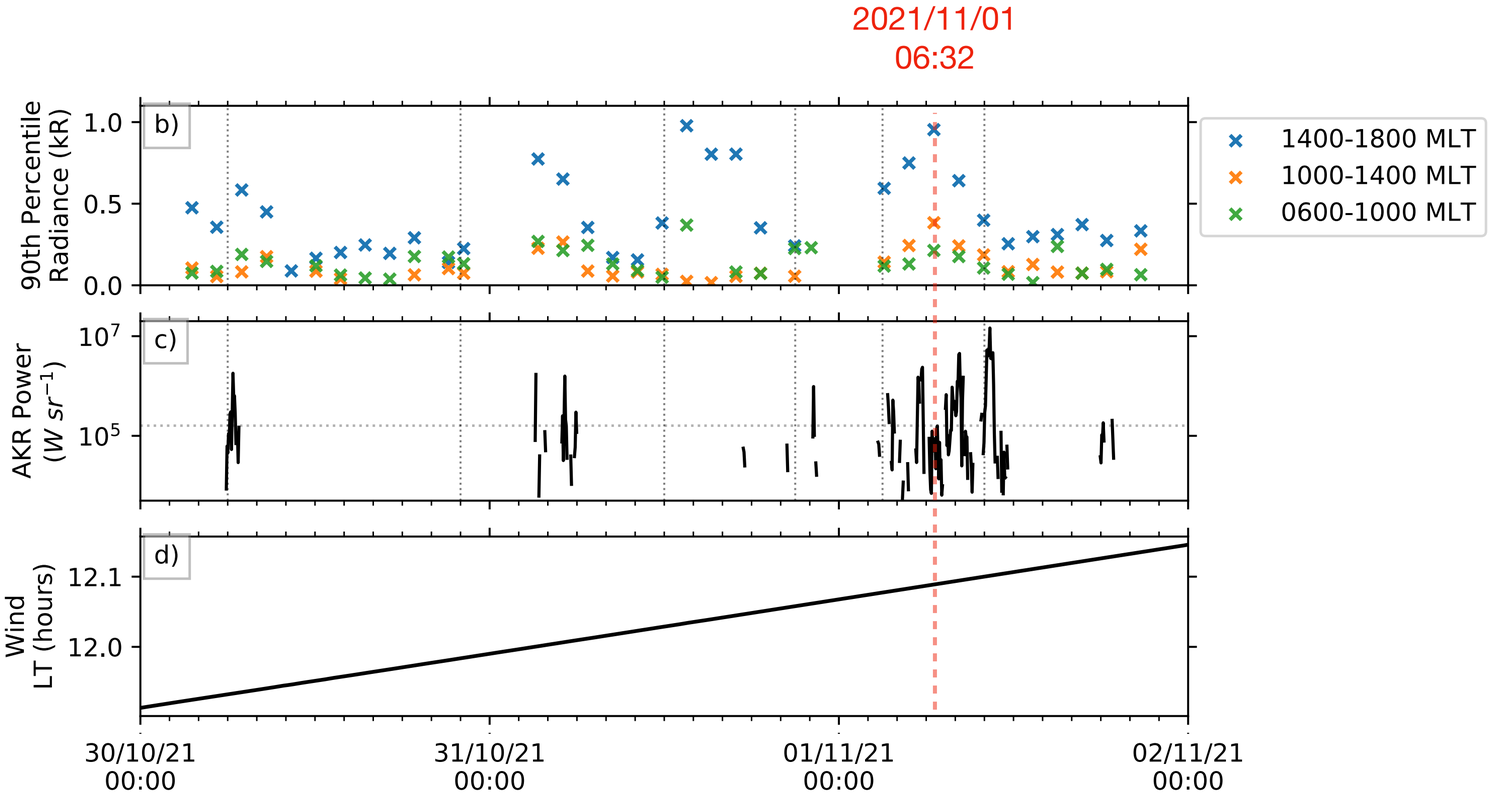


- Polar UVI Observations during substorm onset (Akasofu 2017)

j.e.waters.space@gmail.com

AKR and Substorms

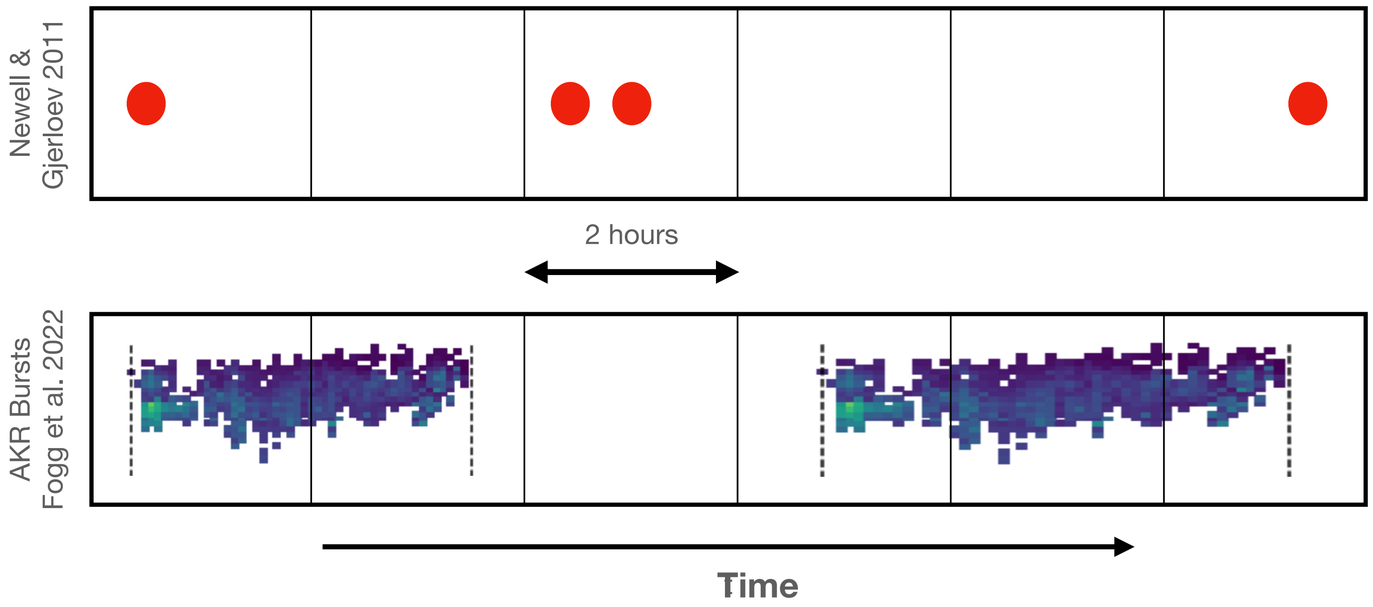




Waters+ 2023

j.e.waters.space@gmail.com

Binary classification of substorms with remote AKR observations



- Using substorm event lists with appropriate coverage:
  - SuperMAG SML index; Newell & Gjerloev 2011
  - Mid-latitude positive bay index, derived from SuperMAG; Chu et al., 2015
  - SuperMAG derived, with greater constraints; Ohtani et al., 2020
  - IMAGE/WIC UV observations of substorm auroral features; Frey 2004 (not shown)

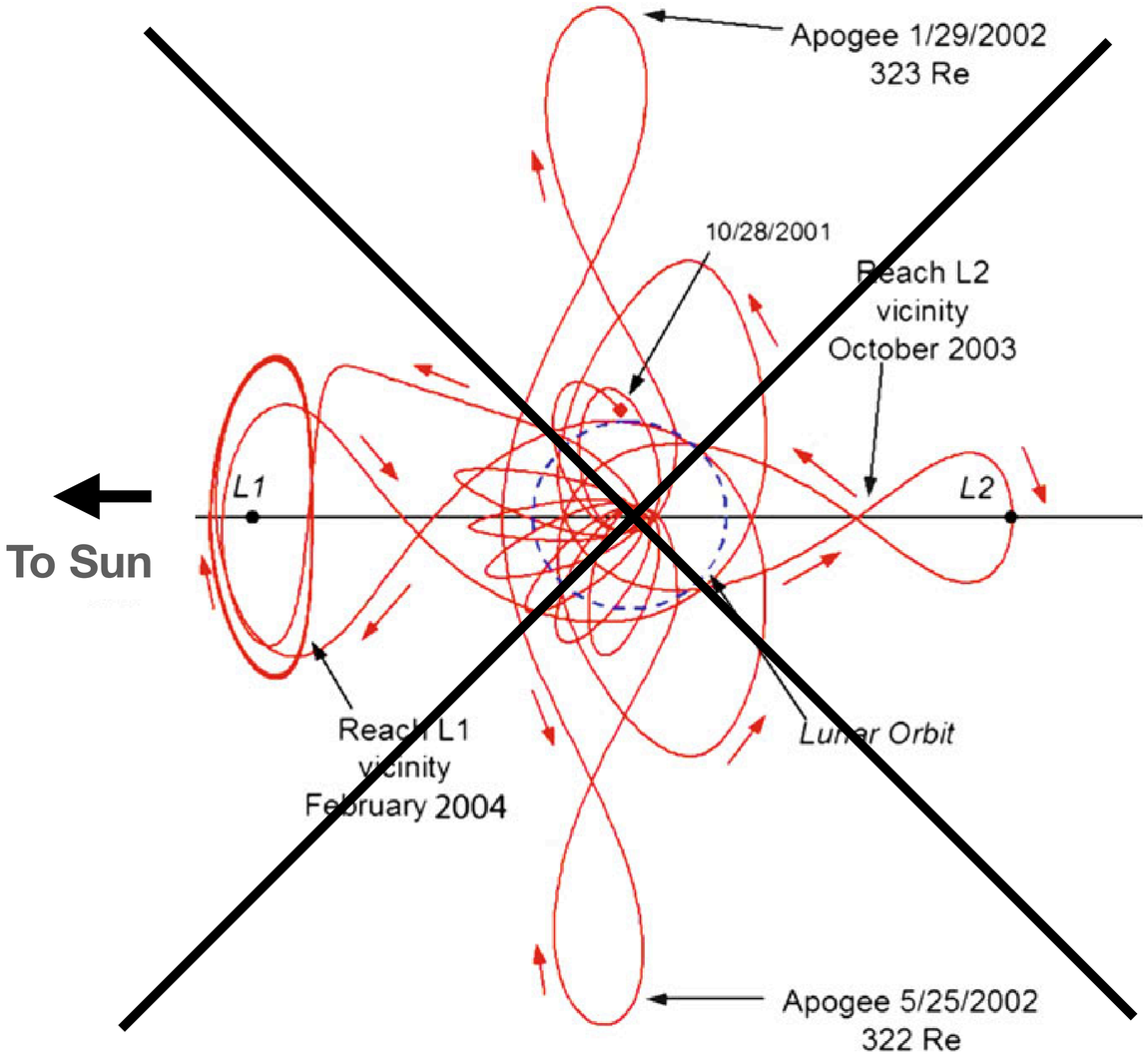
- **Treat AKR in context of binary classification to assess remote observations as a "forecast proxy" for substorm onset**

Wind AKR bursts

Substorm List (SuperMAG)	Predicted positive	Predicted negative
Real positive	4599	8958
Real negative	5566	24701

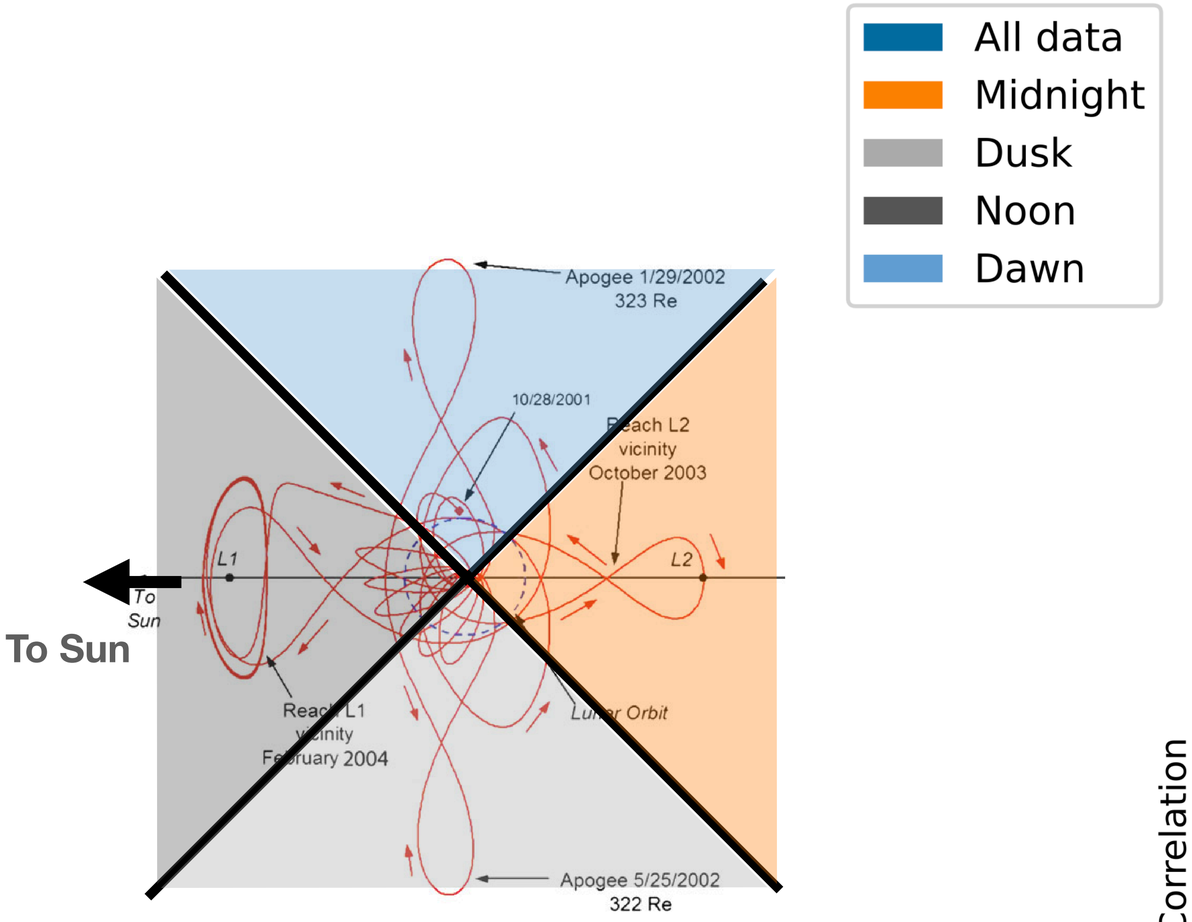
j.e.waters.space@gmail.com

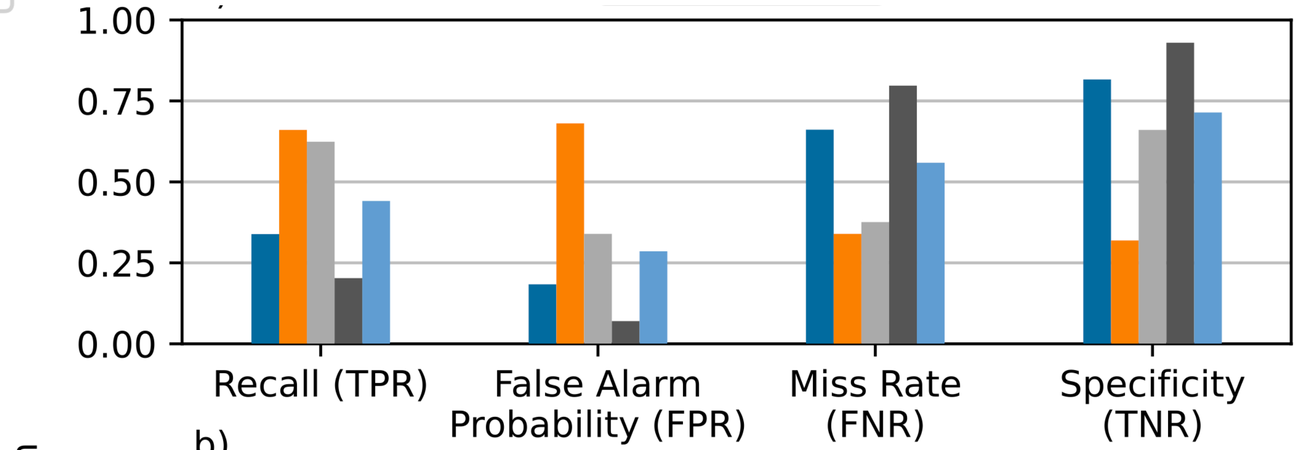
Binary classification of substorms with remote AKR observations

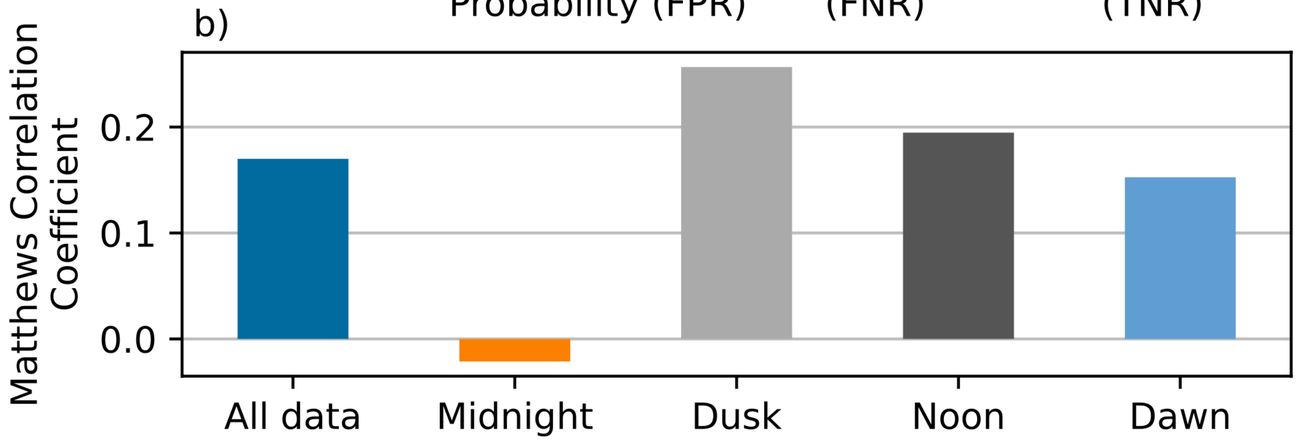


j.e.waters.space@gmail.com

Binary classification of substorms with remote AKR observations





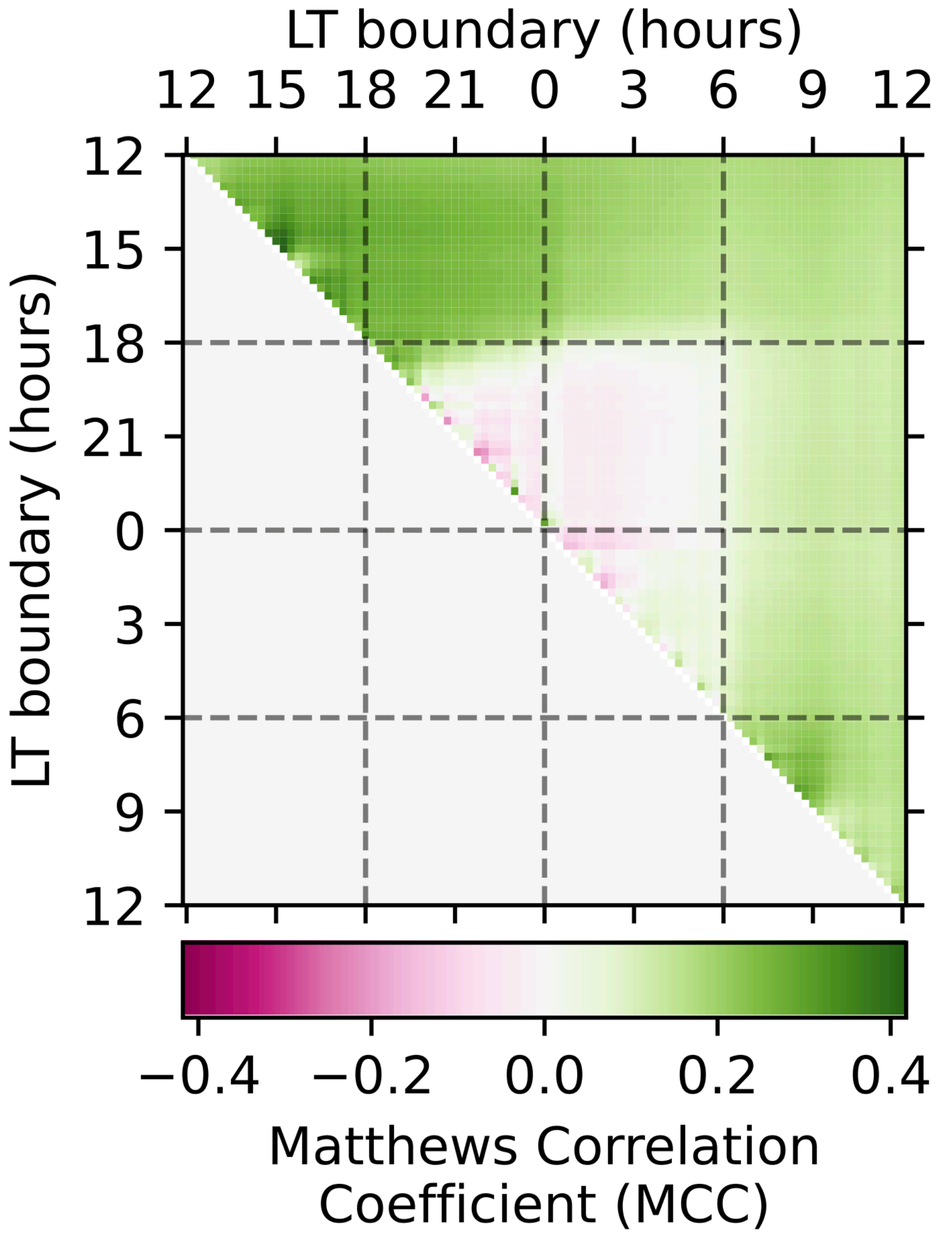


Waters+ 2025

j.e.waters.space@gmail.com

Binary classification of substorms with remote AKR observations

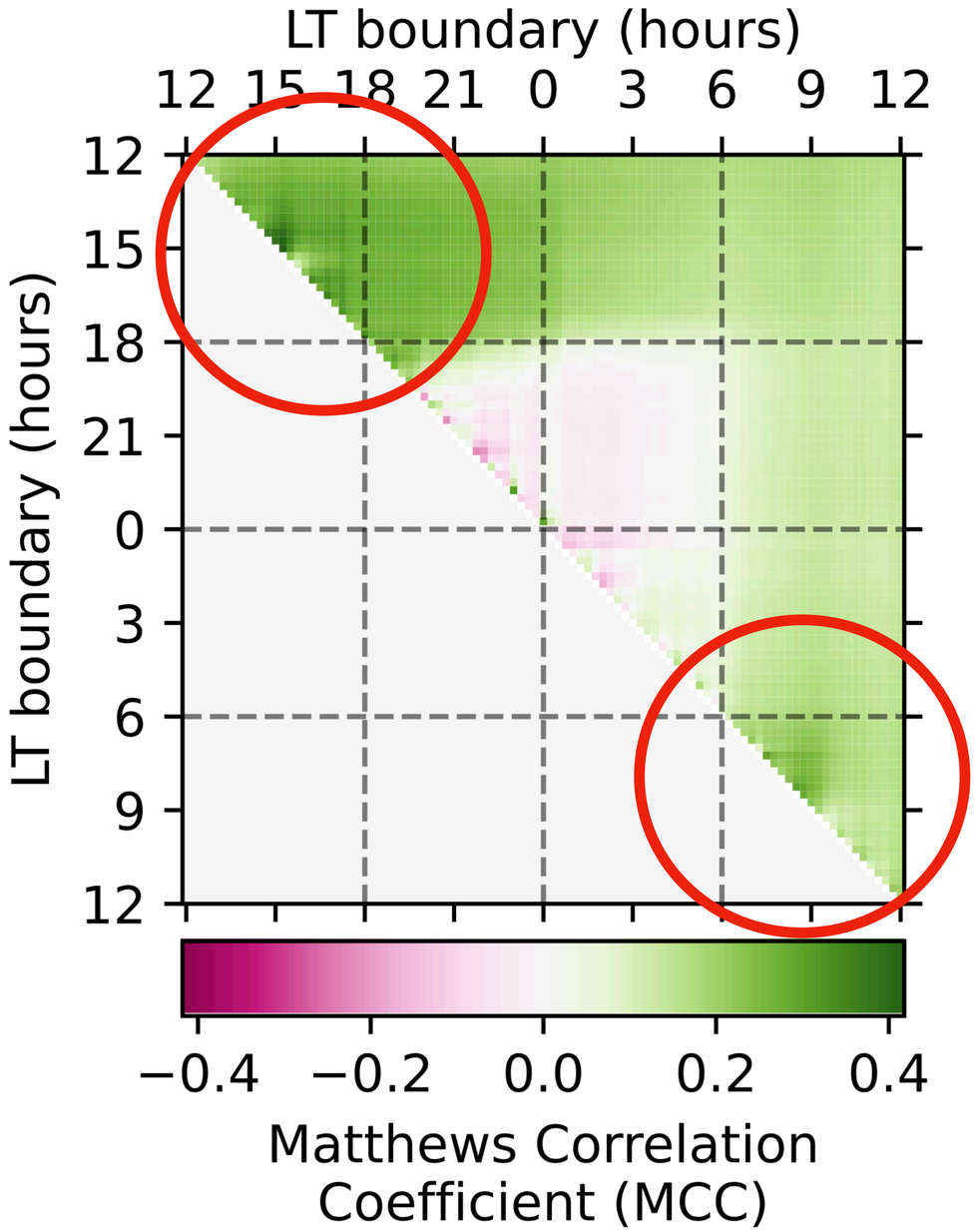
- Extend analysis to examine correlations of all LT sectors, varying widths
- Compute Matthews Correlation Coefficient (MCC) over all combinations of LT sectors from widths of 15 minutes
  - Observations at all duskside local times correlate positively (12-24 hrs LT)
  - Highest-skilled dawnside observations are more constrained made between 06-10 hrs LT



j.e.waters.space@gmail.com

Binary classification of substorms with remote AKR observations

- Extend analysis to examine correlations of all LT sectors
- Compute Matthews Correlation Coefficient (MCC) over all combinations of LT sectors from widths of 15 minutes
  - Observations at all duskside local times correlate positively (12-24 hrs LT)
  - Highest-skilled dawnside observations are more constrained made between 06-10 hrs LT

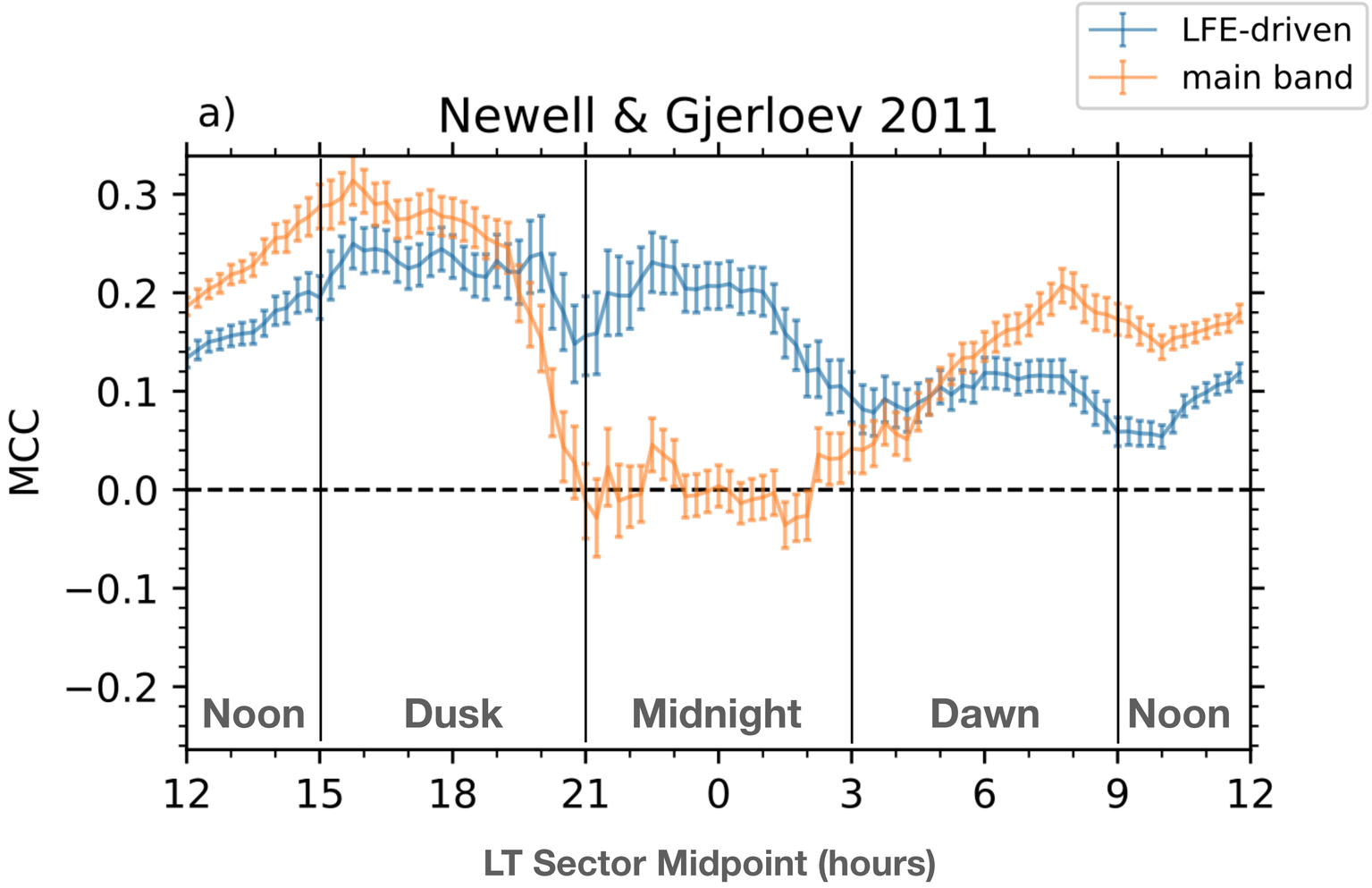


j.e.waters.space@gmail.com

Waters+ 2025

Binary classification with frequency cutoffs

- Applying upper frequency cutoff to AKR burst occurrence
- Characterise “main band” and lower frequency AKR

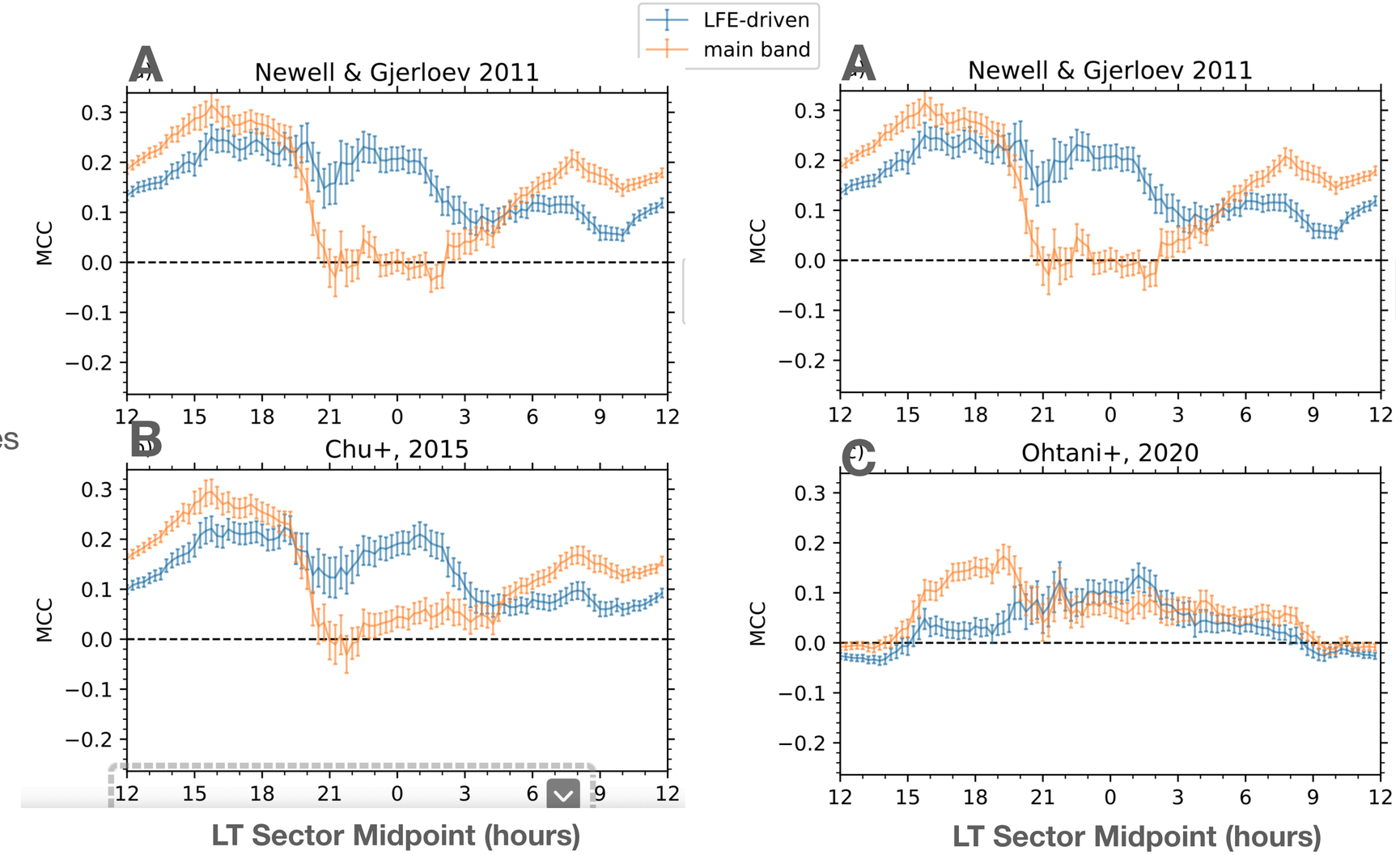


Waters+ 2025

j.e.waters.space@gmail.com

Binary classification with frequency cutoffs

- Panels showing different substorm lists - those shown based on substorm current proxies
- Lists A and B (multiple onset substorms included) have high correlations for dusk, dawn, daysides
- List C (isolated onsets with spatial constraints) constrained correlation on duskside
- Lower frequencies produce greater correlation at midnight, highlighting specificity to substorms



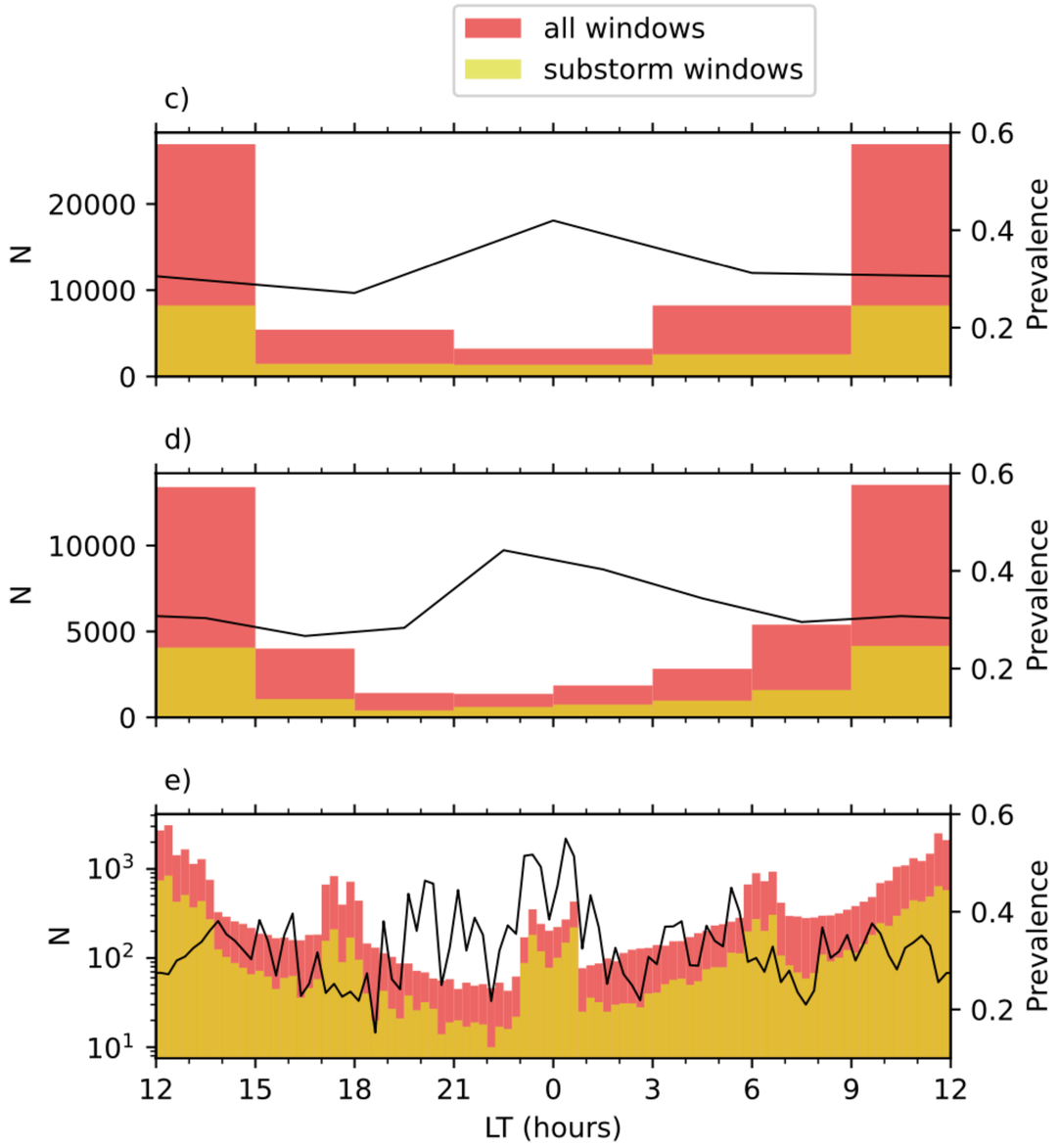
Waters+ 2025

j.e.waters.space@gmail.com

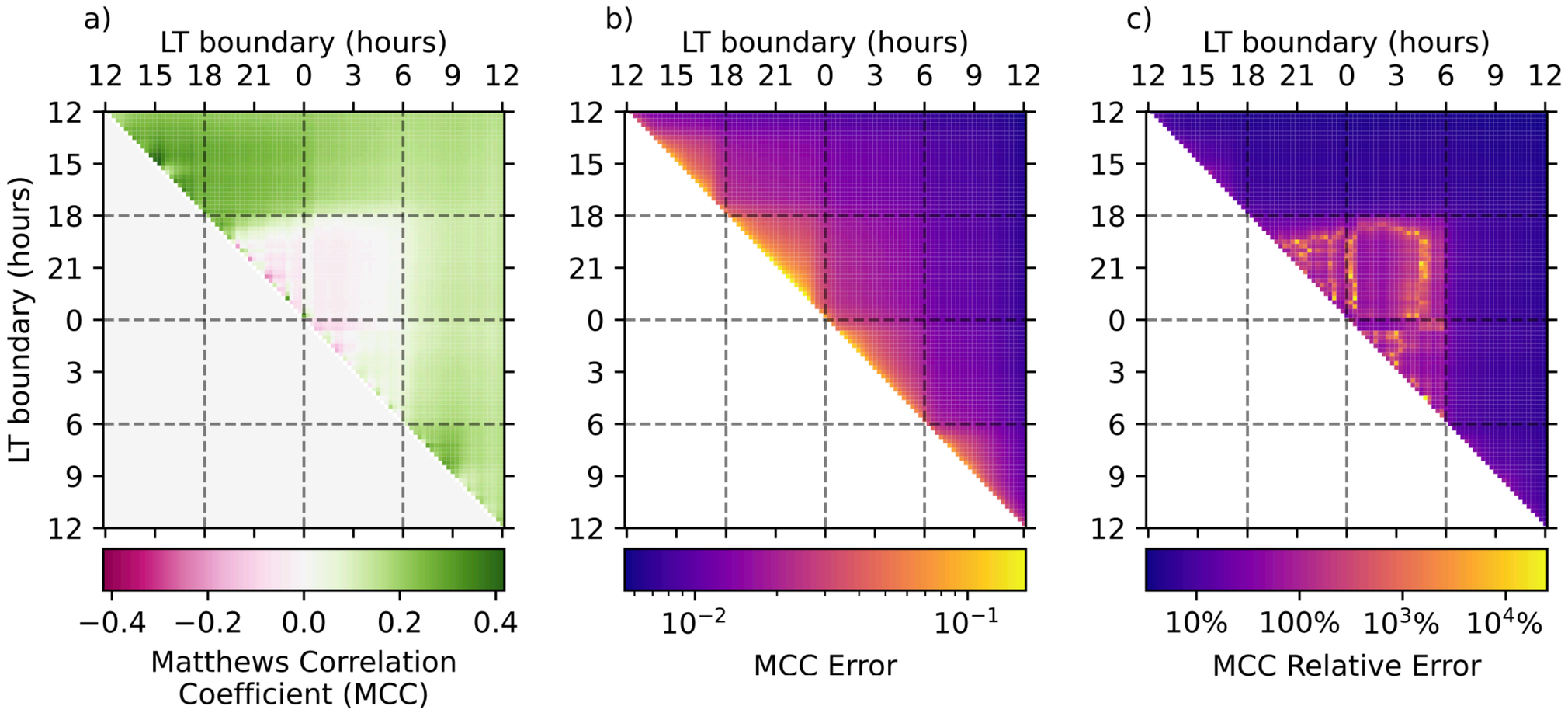
Summary

- AKR occurrence correlates higher with substorm lists when observed from the dusk and dawn flanks, or near noon
- Midnight AKR observations have slightly negative correlation - low specificity from distribution of discrete aurora *(or diffuse? See S. Wu's poster E1)*
- Dayside observations have higher correlations for substorms with large spatial extension in aurora - can characterise events
- Lower frequency AKR increases correlation at midnight LTs
- These results:
  - Highlight discrepancies between substorm lists
  - Help determine auroral phenomena producing AKR with remote observations
  - Can be used to distinguish substorms with wide longitudinal distribution of aurora
  - Could help to model AKR source distribution for ionospheric auroral phenomena

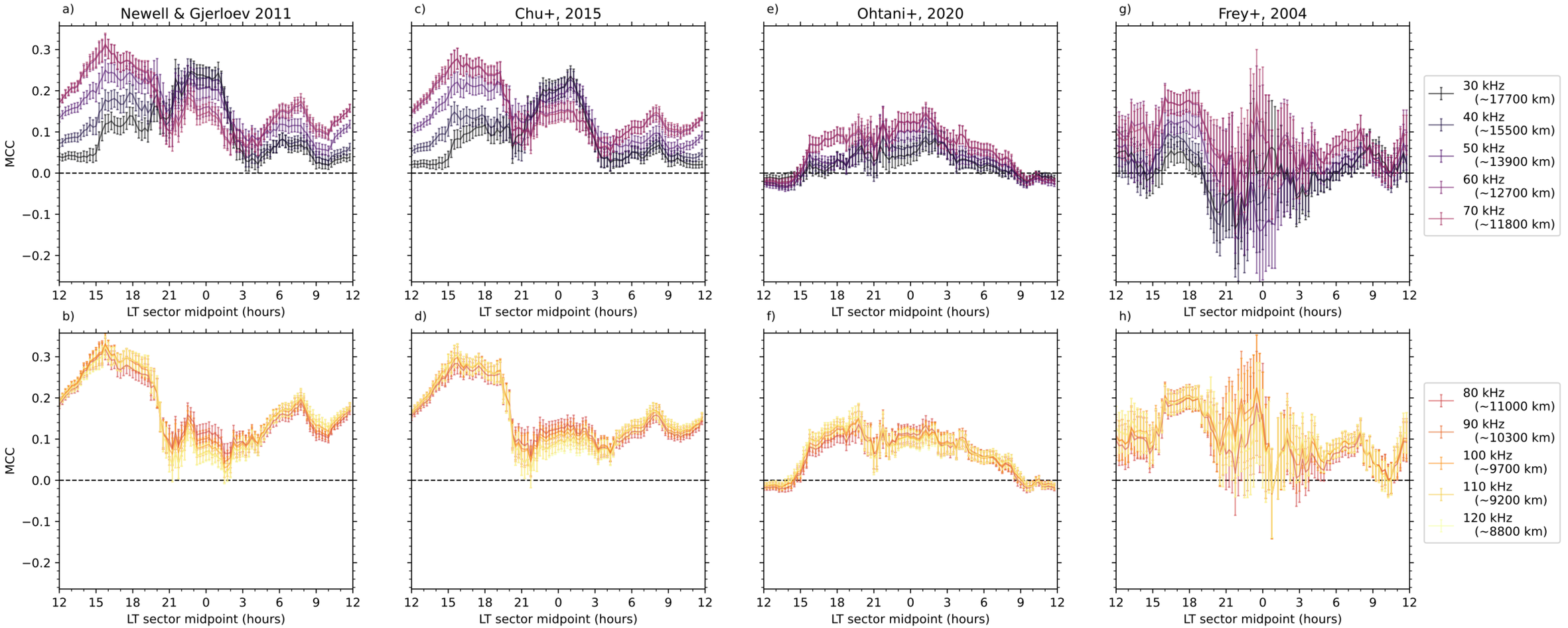
Contact: j.e.waters.space@gmail.com



Contact: j.e.waters.space@gmail.com



Contact: j.e.waters.space@gmail.com



Contact: j.e.waters.space@gmail.com