Differences in Substorm Onset Times at Conjugate Stations: Preliminary Report

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Funded by NSF Antarctica program:
NSF–ANT-1043621

Southern Auroral Electrojet Index

- **We have created a southern auroral electrojet (SAE) index and compared it with a near conjugate northern auroral electrojet (NAE) index.**

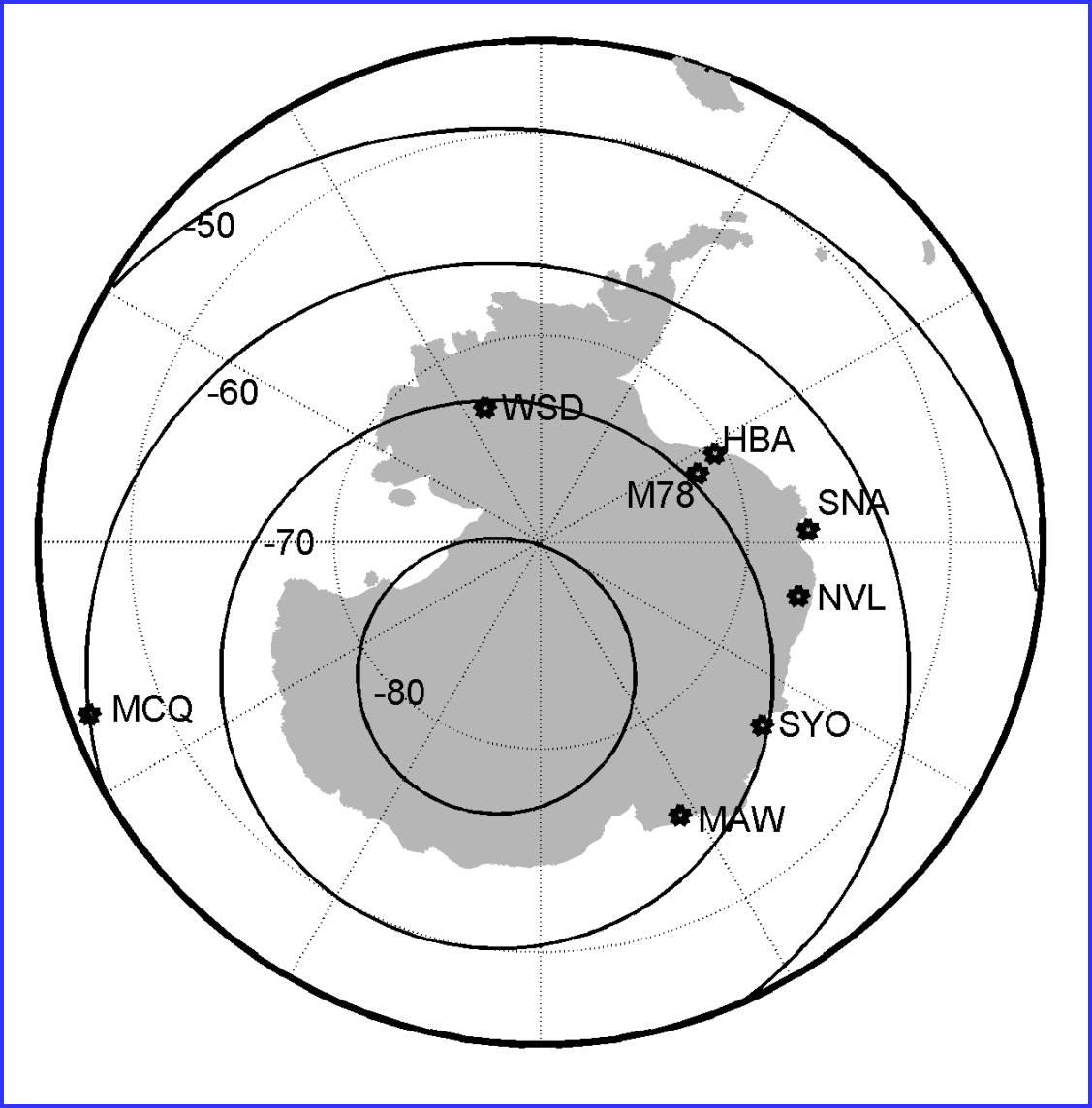
- **I noticed some conjugate substorm onsets occurred at different times.**
  - **Sato et al. [1998]: ~1 min difference**
  - **Frank and Sigwarth [2003]: ~ 1min difference**
  - **Morioka et al. [2011]: few minutes**

Objective

- **Identify a set of substorm onsets in the SAE/SAL index data using Hsu et al. [2012] method.**
- **Compare with near conjugate NAE and WDC AE indices.**
- **Determine reason for difference in onset time.**

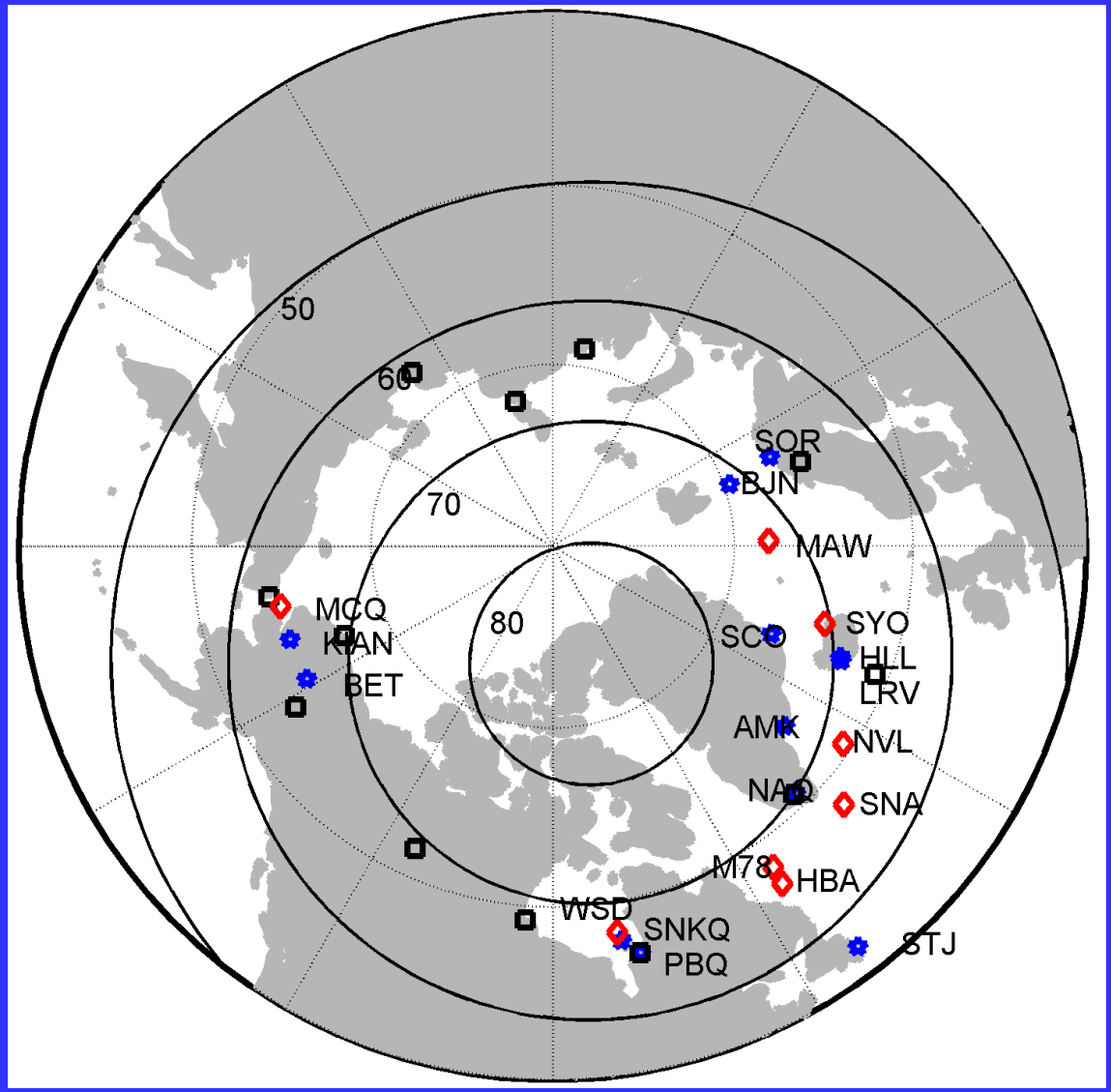
SAE index

- 8 ground magnetometers in Southern Hemisphere.
- Same method as WDC.
- Average of 5 quietest days removed.
  - If a quiet day not available, then next available quiet day is used.
- Large gaps in array.



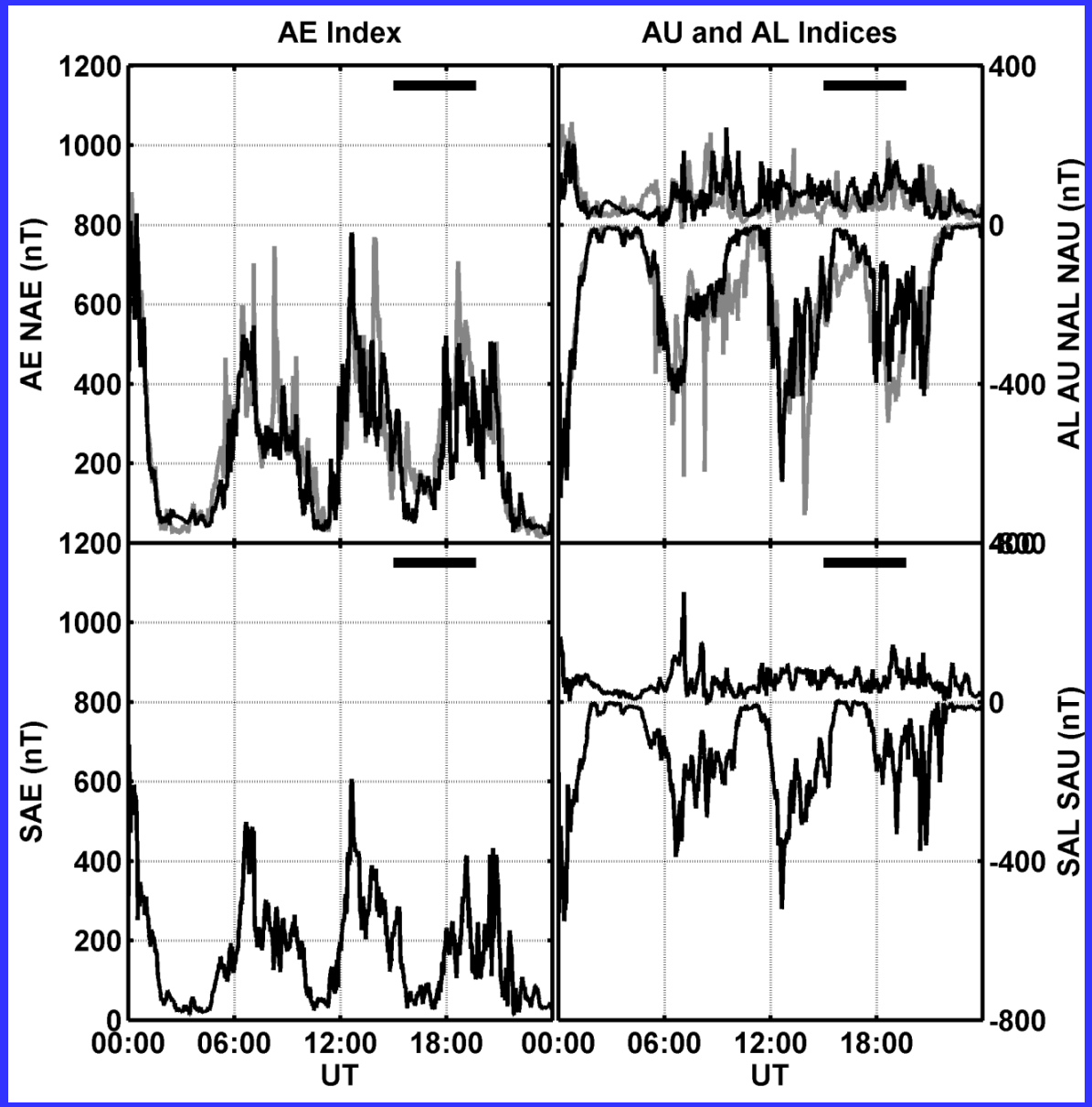
NAE and WDC AE indices

- **Black squares: WDC AE stations.**
- **Red diamonds: mapped footpoint of southern magnetometer station.**
- **Blue *: nearest northern stations to footpoint.**
- **Not all southern stations have an exact conjugate northern station.**
  - **WSD/SNKQ**
  - **MCQ/KIAN**
  - **SYO/HLL**



Example
Feb 19, 2008

- **Top Left: WDC AE (Gray) and NAE (Black).**
- **Top Right: WDC AU and AL (Gray) and NAU and NAL (black).**
- **Bottom Left: SAE index.**
- **Bottom Right: SAU and SAL index.**
- **Black Bar: no Southern stations in the midnight sector.**



Hsu et al [2012]

- **A negative perturbation in the AL index with a sudden break in the slope. The duration of the negative bay must be >20 min.**

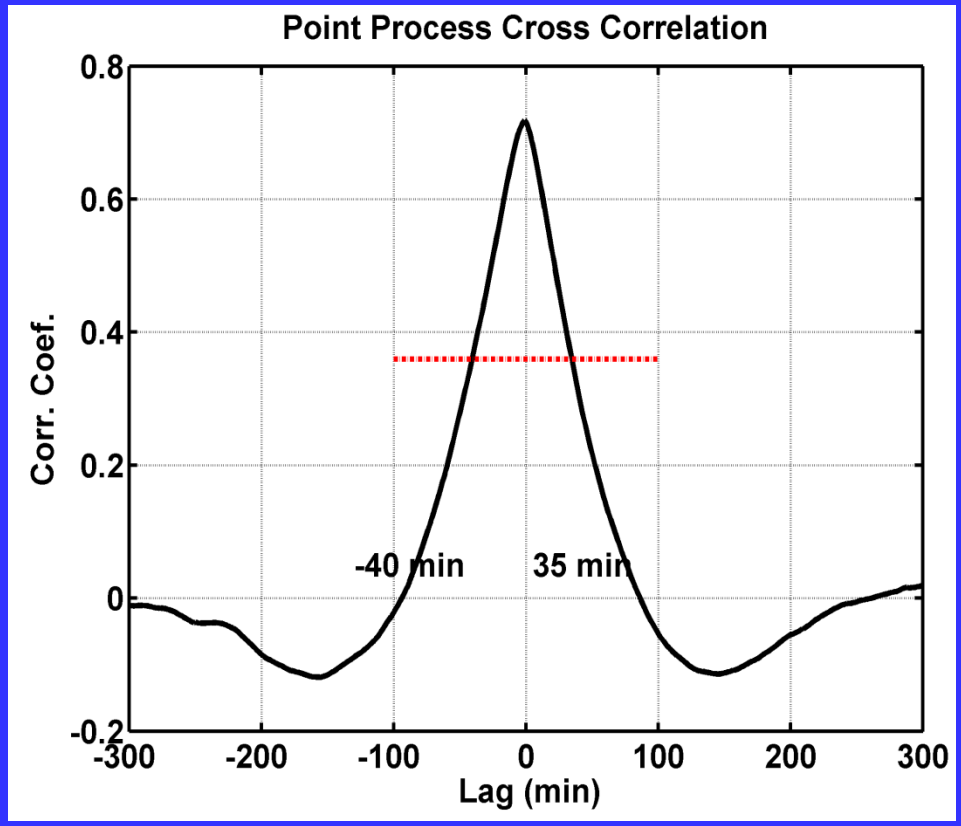
- **Minimum AL drop ≤ -100 nT.**

- **If the time duration of a disturbed interval is >3 hr, then more than one onset may be selected in that 3 hr period if there is more than one sharp break in slope followed by a second minimum in AL.**

- **Identified about 600 onsets.**

Determine Difference in Onset times

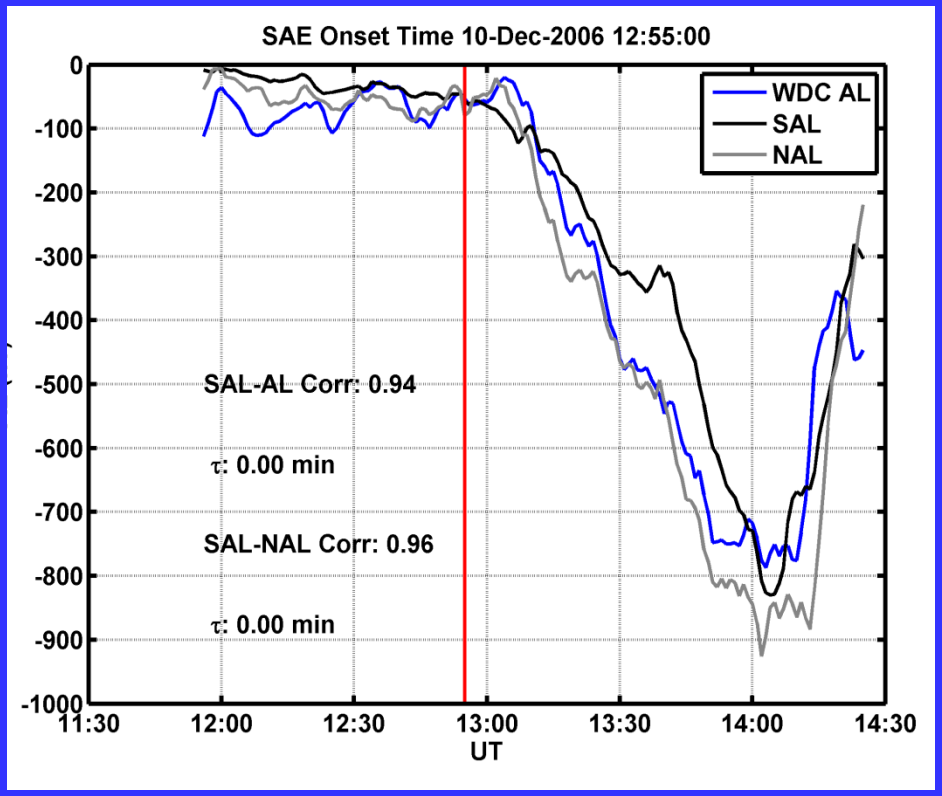
- Point Process Cross Correlation (PPCC)
  - Use 5 hours on either side of the onset time.
  - Step one times series with respect to the other 1 min at a time to find window of peak correlation.
    - Superpose all events.
  - FWHM is window size: -40 min to 35 min.



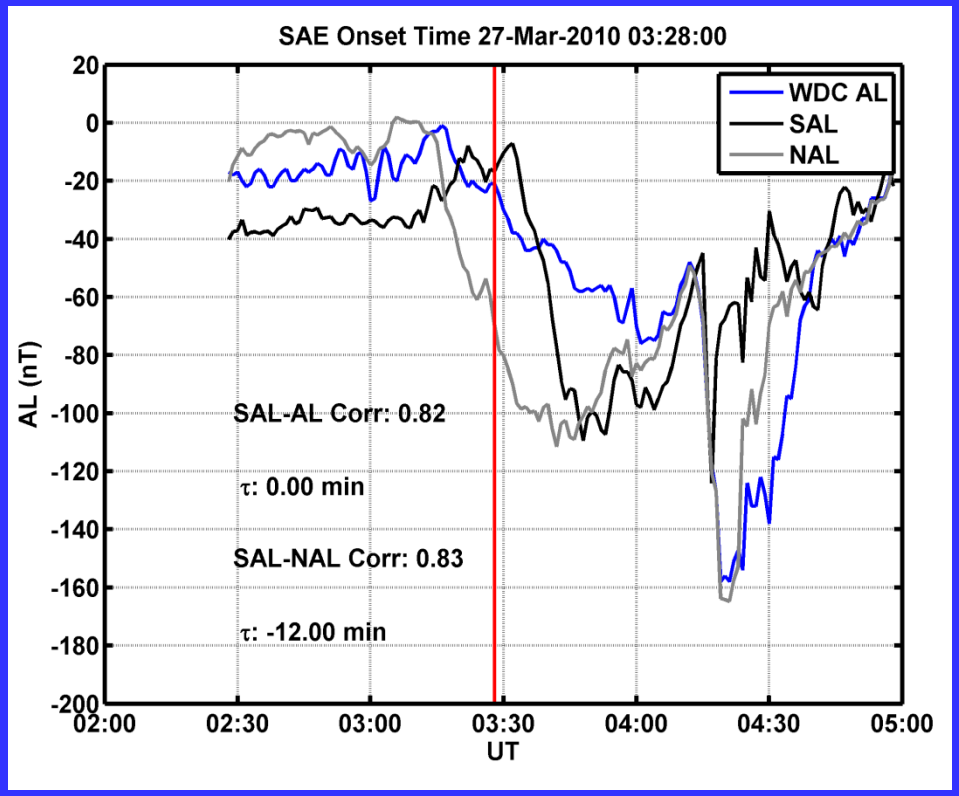
- Cross-Covariance for each event with PPCC window to find onset time difference.

Examples

Simultaneous

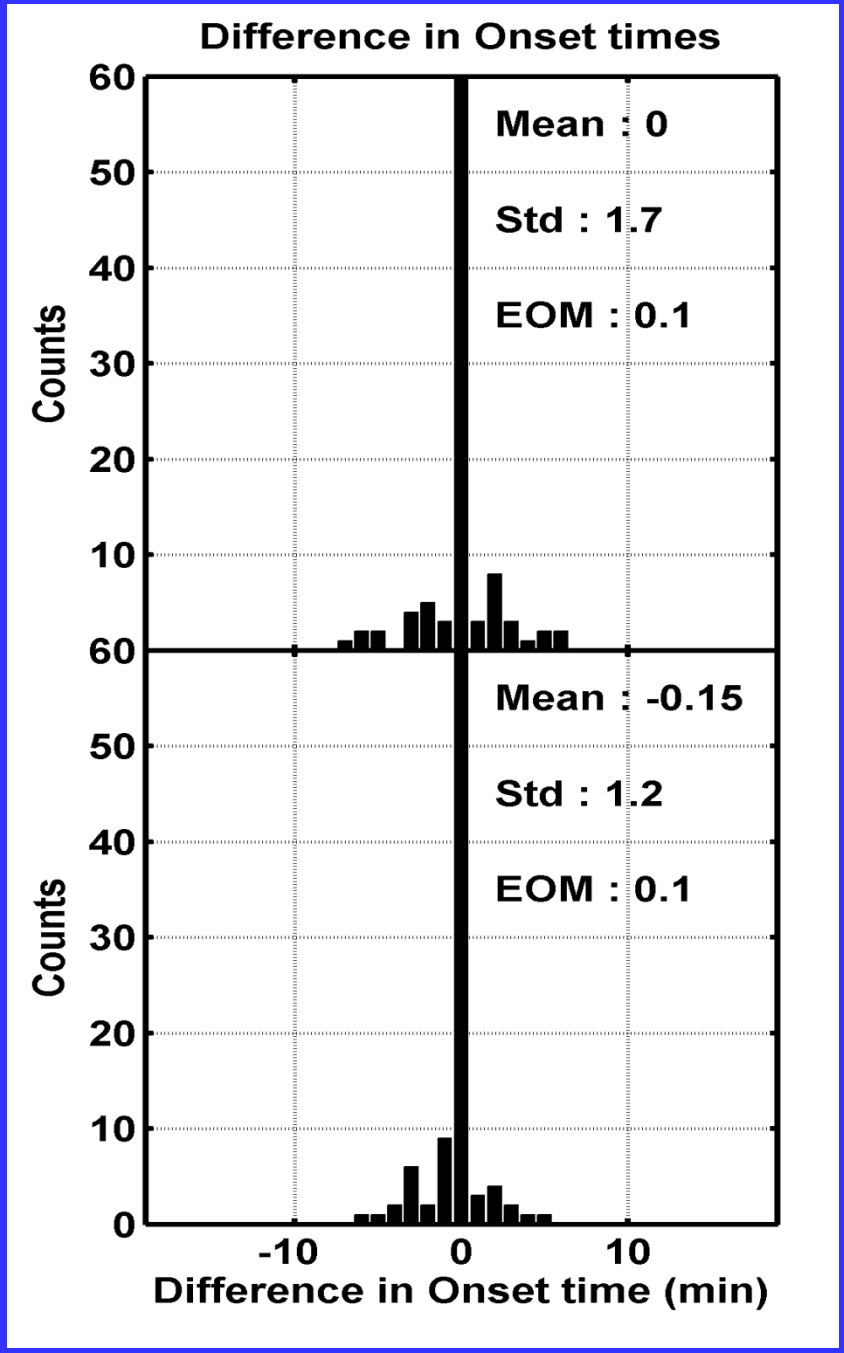


Different Onset times



Histogram

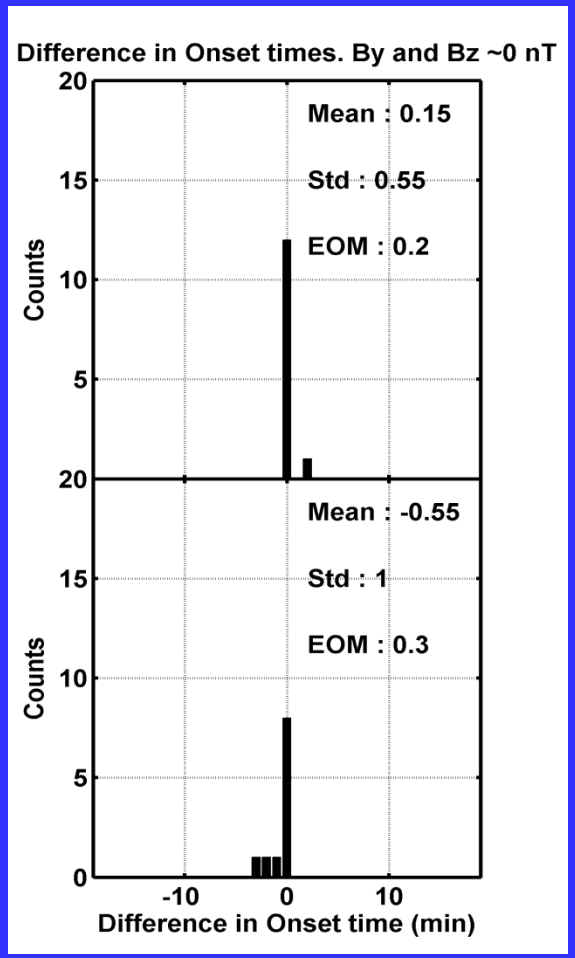
- Top panel diff in onset time SAL and WDC AL.
- Bottom panel diff in onset time SAL and NAL.
- Positive value: SAL onset earlier.
- Negative value SAL onset later.
- Only max corr. Coef. >0.9.
  - ~150 events in both.



Reason for Differences: IMF?

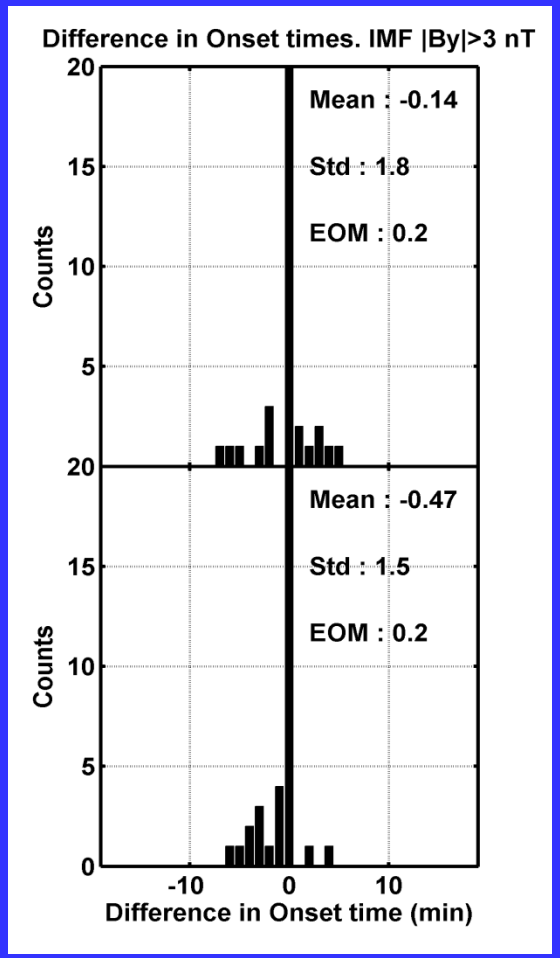
IMF |Bz| & |By| <1 nT

17 pts



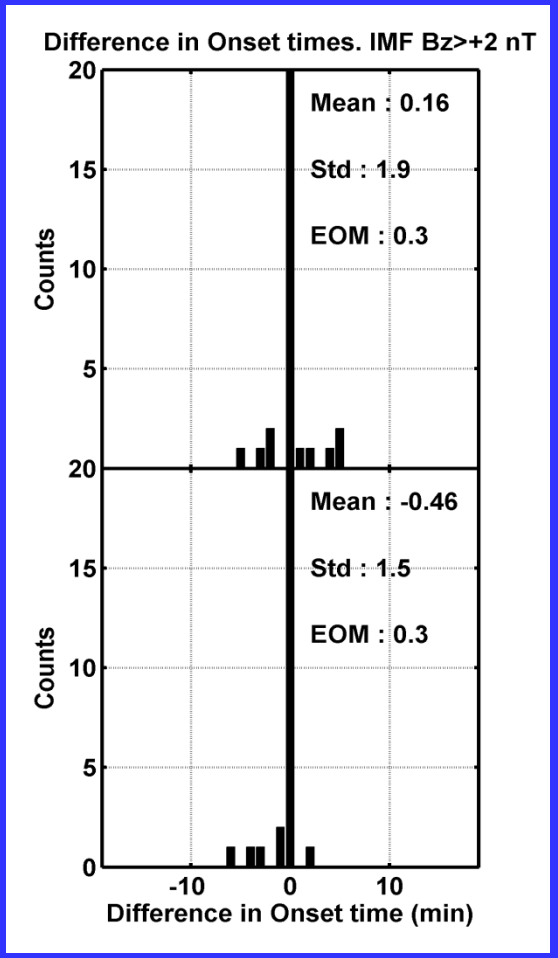
IMF |By| >3 nT

~80 pts



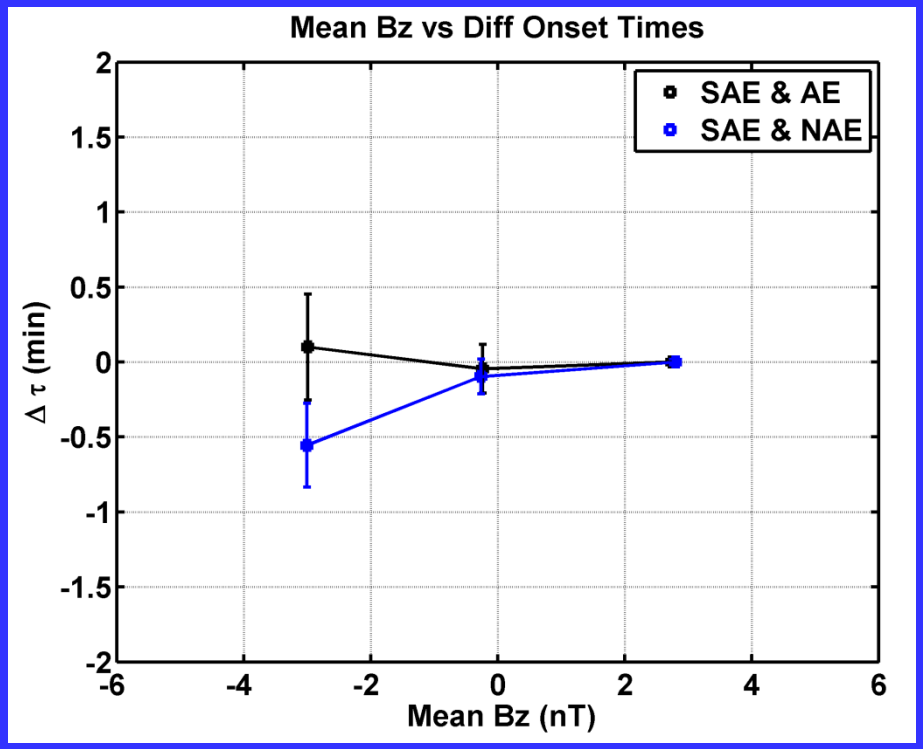
IMF Bz<-2 nT

~40 pts

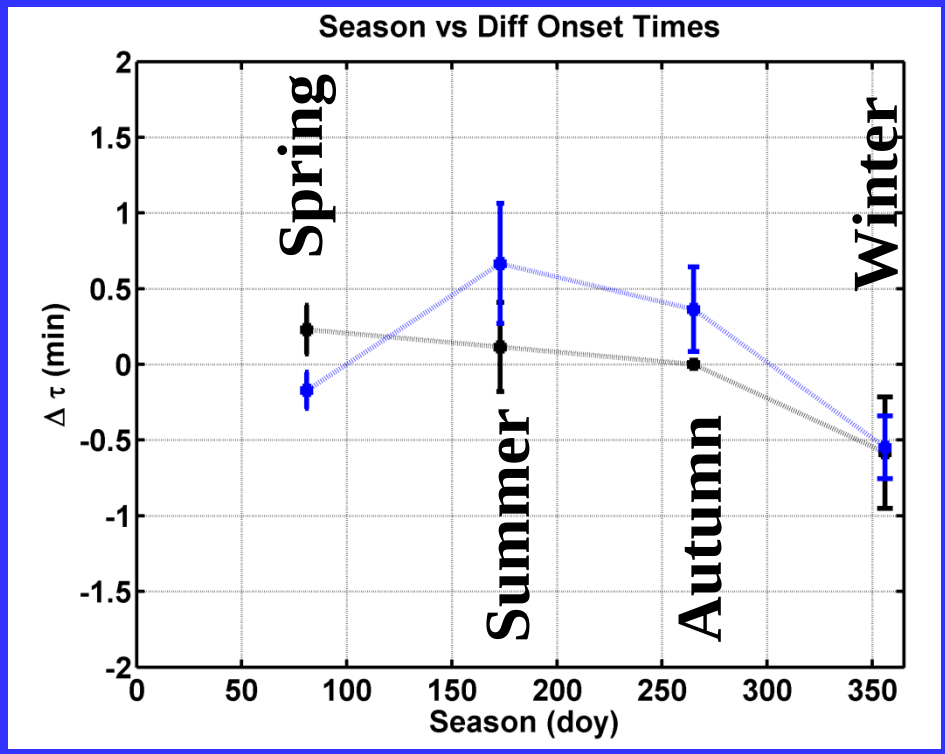


Reason for Differences?

IMF Bz: No?



Season

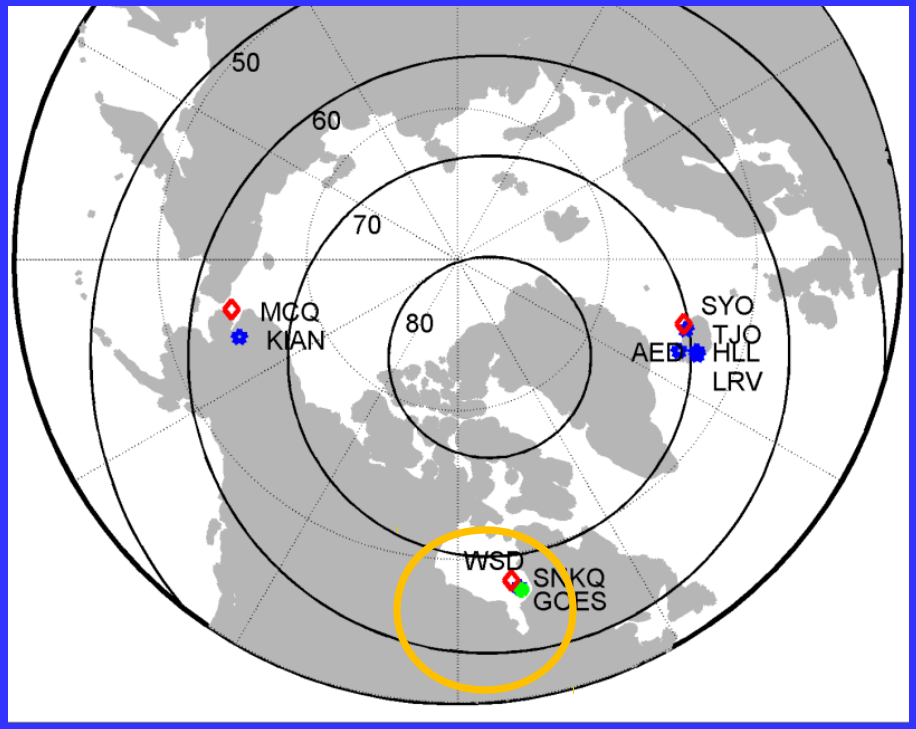


Summary of First Part

- With Conjugate AE indices we see differences in onset times.
- Differences can be as large as several minutes.
- No clear systematic IMF By, Bx, or density variation.
  - IMF Bx and Density plots not shown.
- Systematic variation with Bz and season?
  - Substorm onset time later in the sunlit hemisphere.
  - Our AE Autumn results consistent with Frank and Sigwarth [2003].

WSD/SNKQ

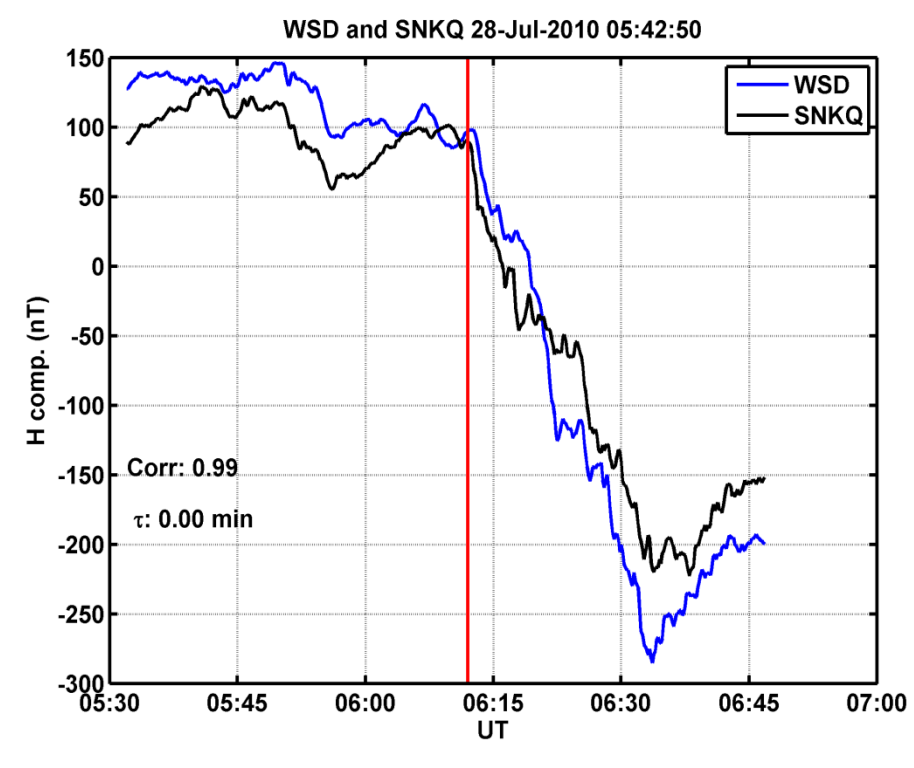
- Examined a conjugate pair of stations.
  - 10 s resolution data.
- Subset of 159 “substorms.”
  - Sharp drop in H component.
  - Minimum AL drop ≤ -100 nT.
  - Limited to midnight sector.
- Same procedure to determine difference in onset time.



Examples

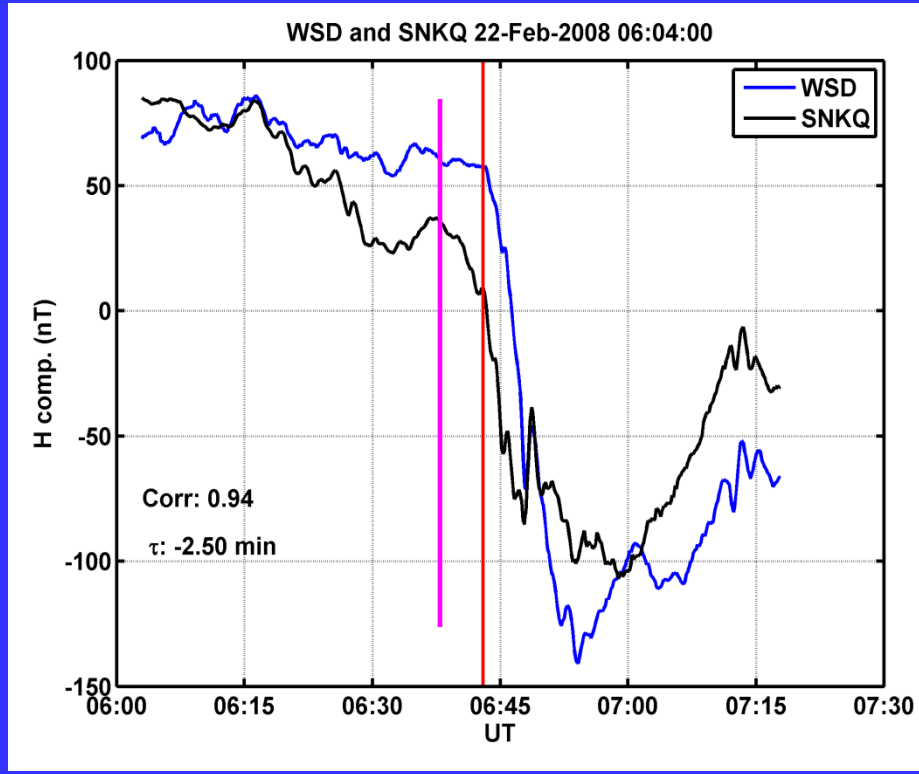
July 28, 2010

No Time difference



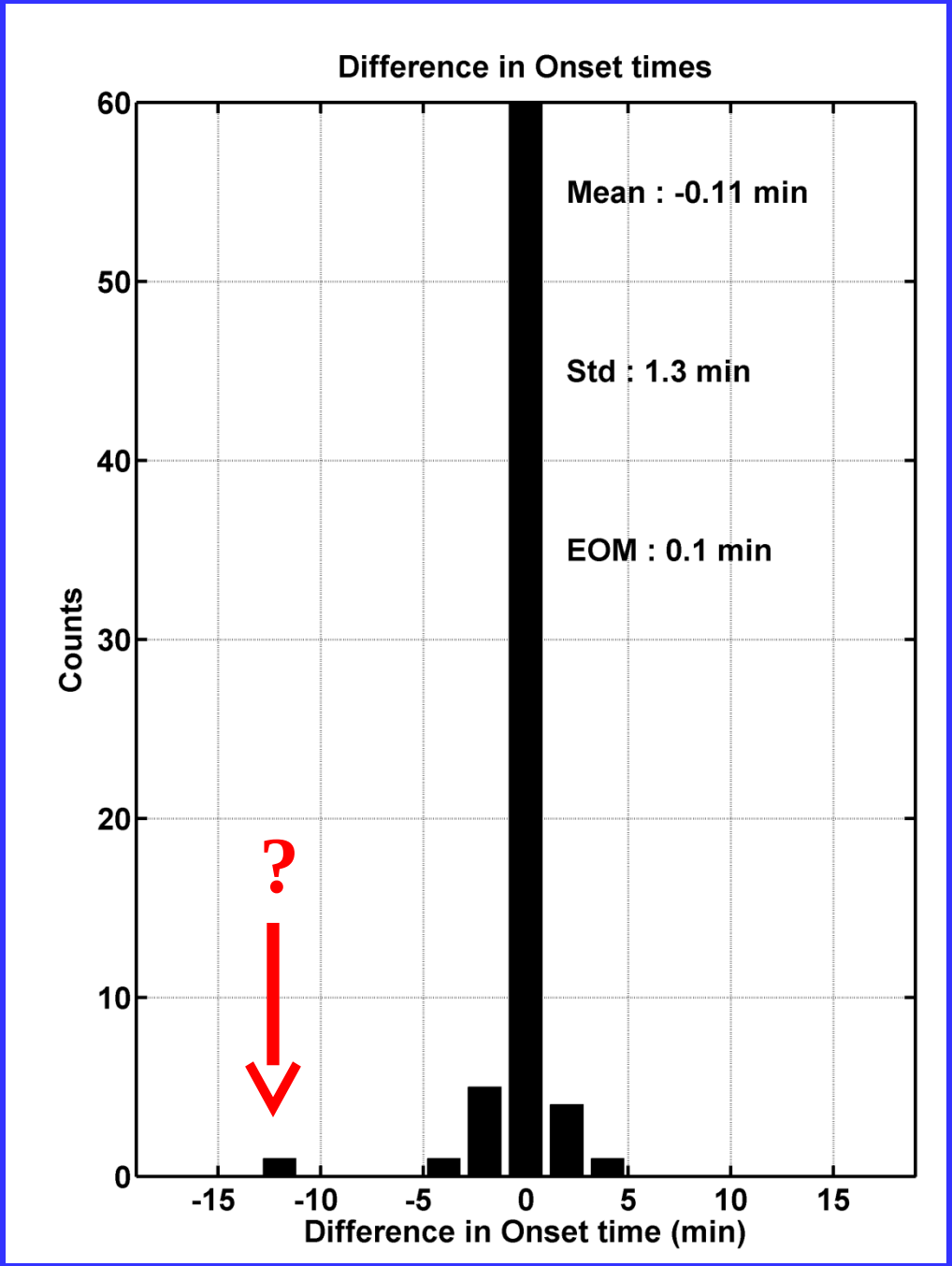
Feb 22, 2008

WSD 2.5 min later

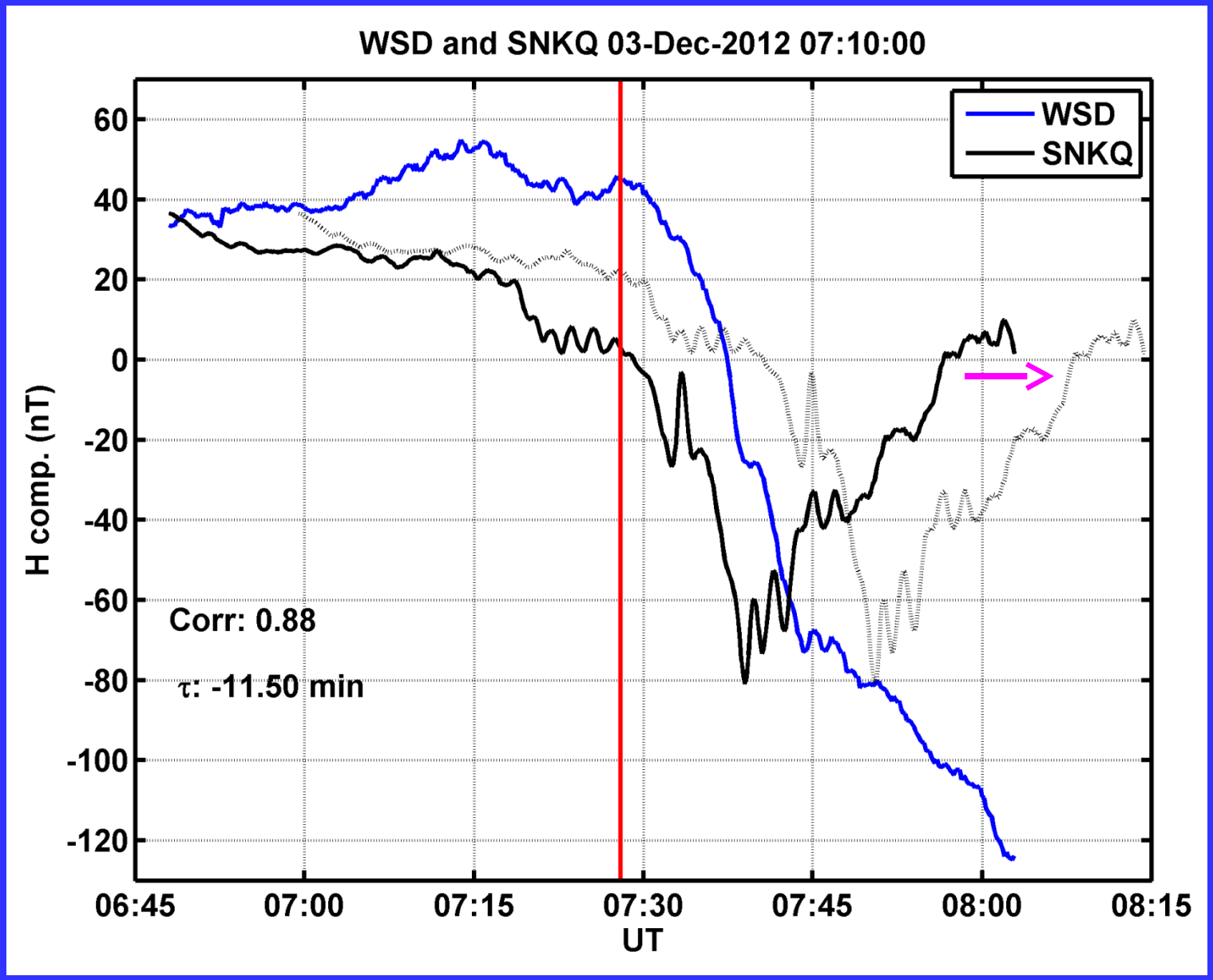


Histogram

- Top panel diff in onset time WSD and SANKQ.
- Negative means onset was EARLIER in the northern hemisphere
- Used correlation >0.8.
- 112 events.



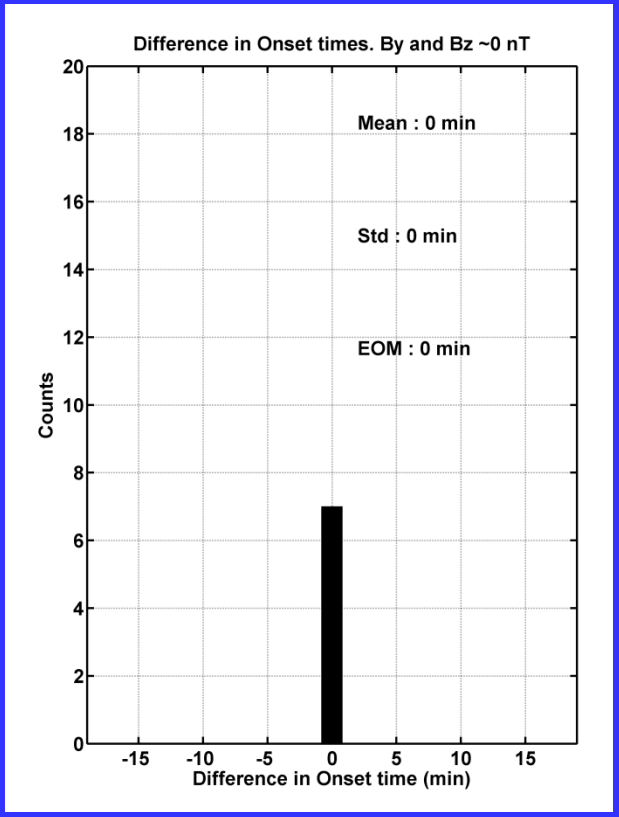
Dec 3, 2012


WSD and SNKQ 03-Dec-2012 07:10:00
WSD
SNKQ
H comp. (nT)
60
40
20
0
-20
-40
-60
-80
-100
-120
Corr: 0.88
τ: -11.50 min
06:45
07:00
07:15
07:30
07:45
08:00
08:15
UT

Reason for Differences: IMF?

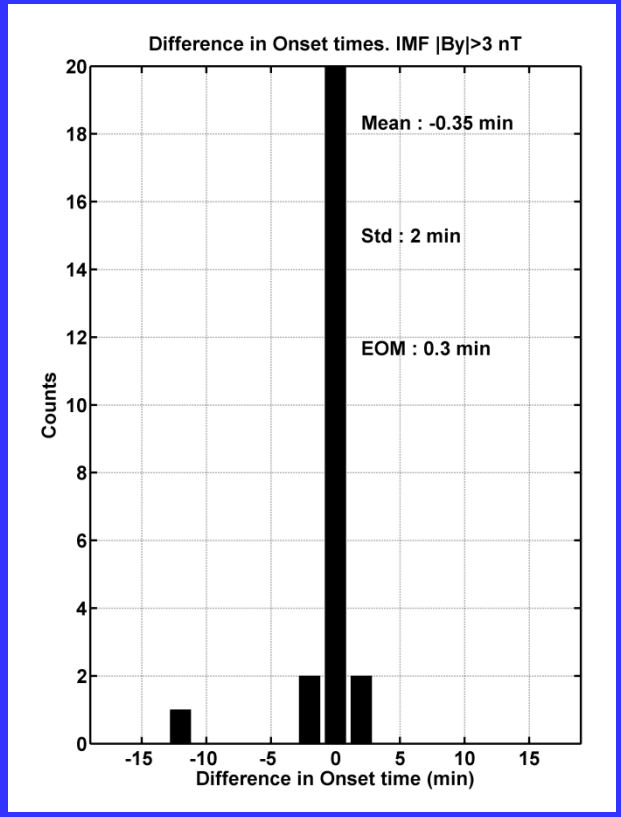
IMF |Bz| & |By| <1 nT

7 pts



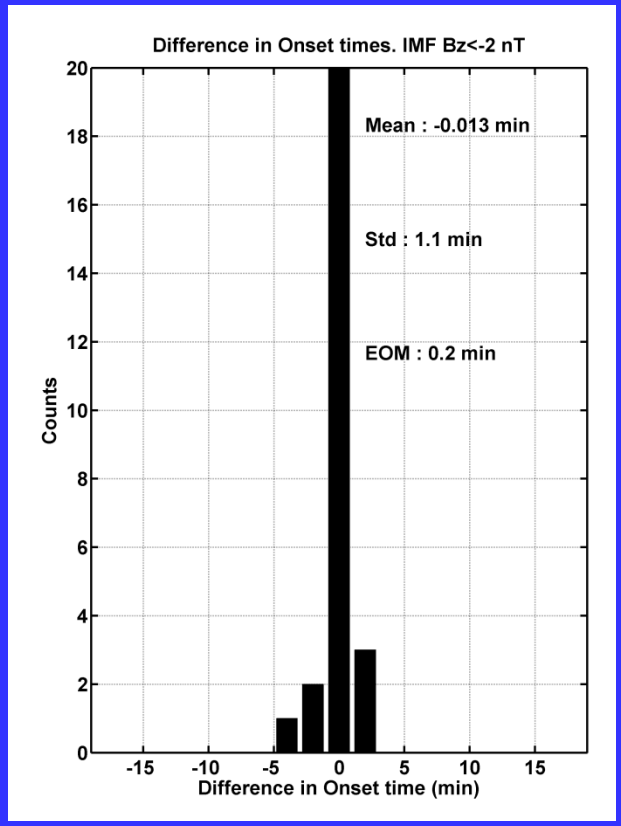
IMF |By| >3 nT

~38 pts



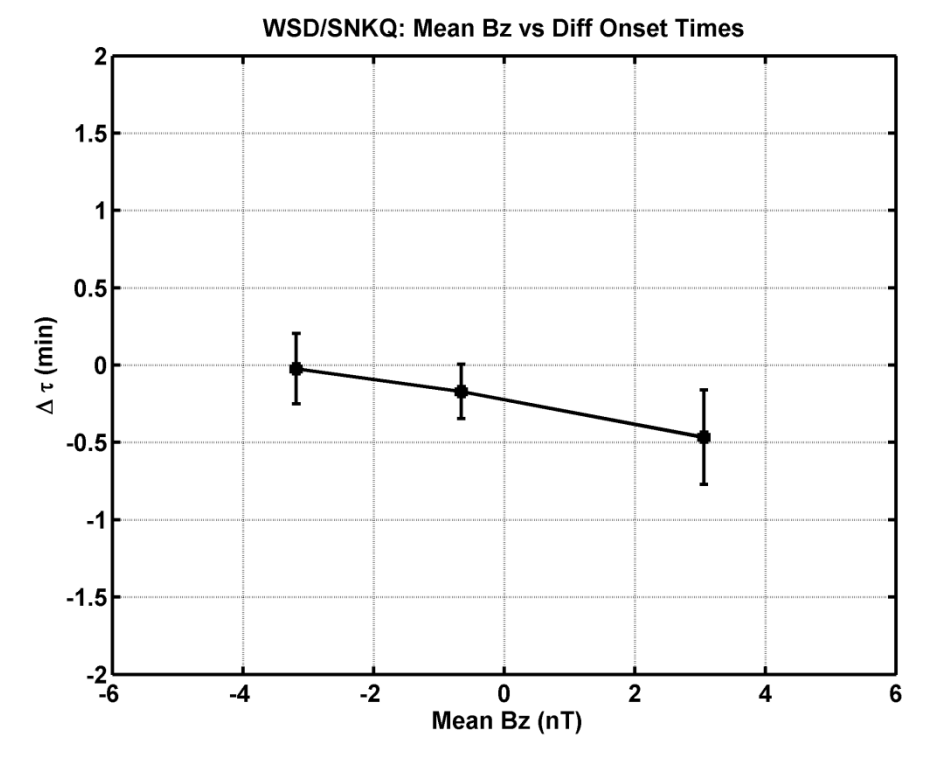
IMF Bz<-2 nT

~38 pts

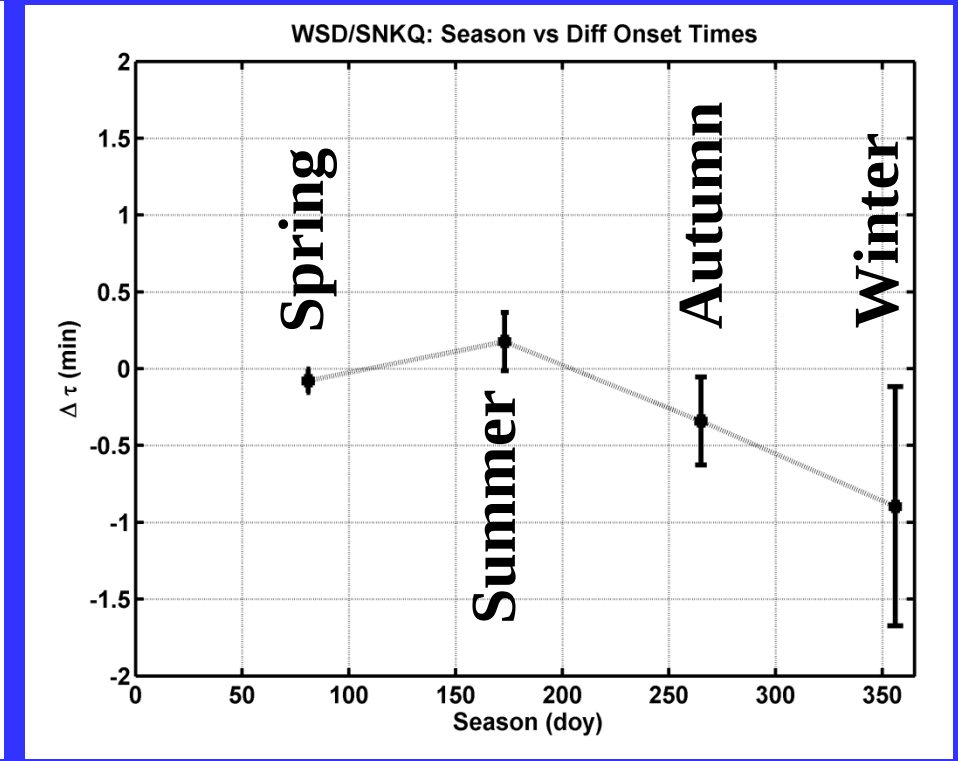


Reason for Differences?

IMF Bz: No agreement with SAE-NAE-AE plot

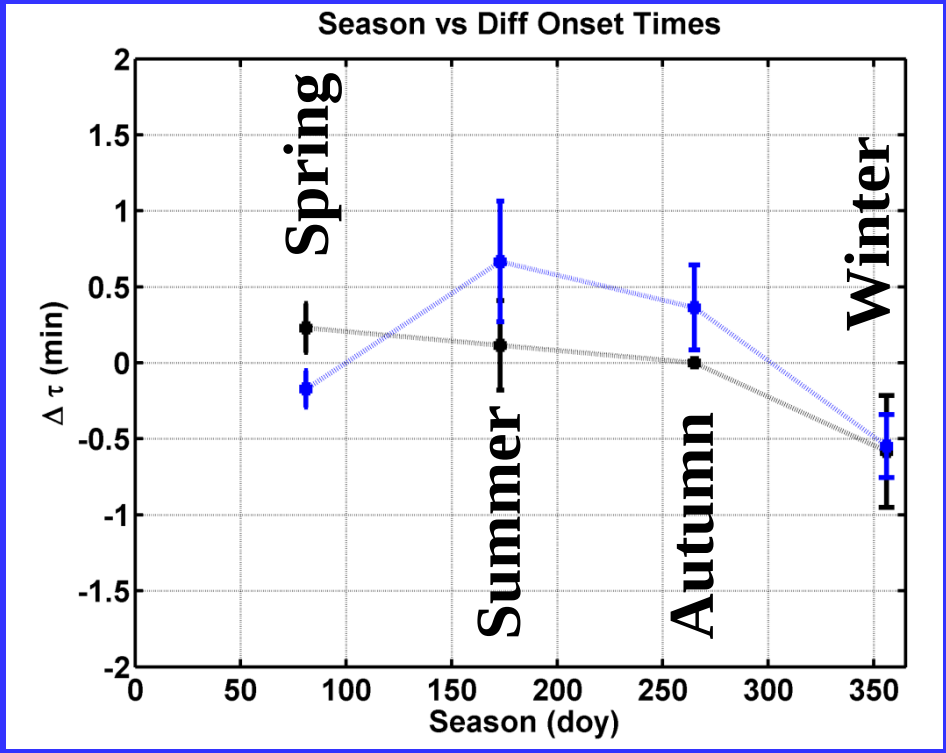


Season: Agreement? with SAE-NAE-AE plot

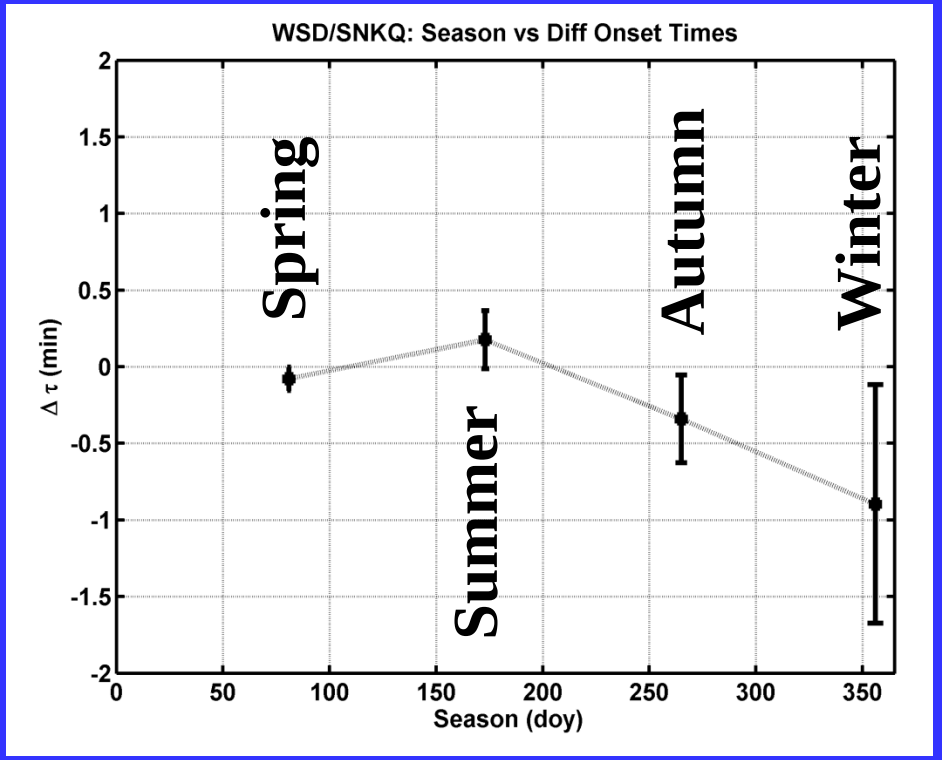


Comparison AE indices with Station Pairs

SAE-NAE (Blue) SAE-AE (Black)



WSD-SNKQ



Previous Observations

- **Sato et al. [1998]: Sept 12, 1988 ~ Fall**
  - **Observed in south before the north by ~ 1 min.**

- **Frank & Sigwarth [2003]: Nov 1, 2001 ~Fall**
  - **Observed in south before the north by ~ 1 min.**
  - **“findings for nighttime auroras were (1) a higher electron energy in the winter relative to that in the summer and (2) a lower electron flux in winter than summer with a net effect of dimmer auroras in the summer.”**

- **Morioka et al. [2011]: Sept 19, 2006 ~ Fall**
  - **Observed in south before the north by ~ 2 min.**
  - **Believes auroral ionosphere controls the auroral breakup to complete the substorm onset.**

Summary and Conclusions

- With Conjugate ground magnetometers we still see differences in onset times.
  - Differences can be as large as several minutes.
- No clear systematic IMF Bx, By, or density variation.
- Trend observed in SAE-NAE data in IMF Bz opposite to WSD-SNKQ data.
- Systematic variation with season?
  - Substorm onset later in the sunlit hemisphere.
  - SAE-NAE results consistent with Sato et al. [1998], Frank & Sigwarth [2003], and Morioka et al. [2011].
  - Station pairs results not consistent.

Acknowledgements

- **DMI: Hans Gleisner and the Danish Meteorological Institute (DMI) for data from AMK, NAQ, and SCO;.**
- **GIMA: Geophysical Institute, University of Alaska Fairbanks.**
- **THEMIS: We acknowledge NASA contract NAS5-02099 and V. Angelopoulos for use of data from the THEMIS Mission, S. Mende and C. T. Russell for use of the GMAG data.**
- **BAS- British Antarctic Survey for data from the HBA and M78-337 stations.**
- **Science Institute, University of Iceland for the data from LVR.**
- **Geoscience Australia for data from MCQ and MAW.**
- **Oleg Troshichev for supplying the data from NVL station.**
- **INTERMAGNET- International Real-time Magnetic Observatory for data from PBQ.**
- **Pieter Stoker for data from the SNA magnetometer.**
- **IMAGE - International Monitor for Auroral Geomagnetic Effects for the data from SOR and BJN.**
- **The WDC for Aurora in National Institute of Polar Research in Japan for data from the HLL and SYO station.**
- **The WDC for geomagnetism, Kyoto for the standard AE index data.**

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