A ubiquitous pre-condition of the magnetosphere: Occurrence statistics of cold, streaming ions in the near-Earth magnetotail

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Ionospheric Ions in the Magnetotail

- First observed 3 decades ago [Shelley et al., 1972]
- Ions stream out of the high-latitude ionosphere
- Cold streams observed in the lobes
  - Sometimes 100s of R_E downtail
- Also observed in the plasma sheet and PSBL
  - Significant enhancements during storms and substorms
- Energetic O^+ is a contributor to the ring current
  - Usually a minor species, but sometimes dominant
  - Low-energy, field-aligned O^+ seen deep in RC (zippers)
  - RC O^+ Coulomb loss causes SAR arc formation
- Postulated that ionosphere is a fully adequate source of plasma for the magnetosphere

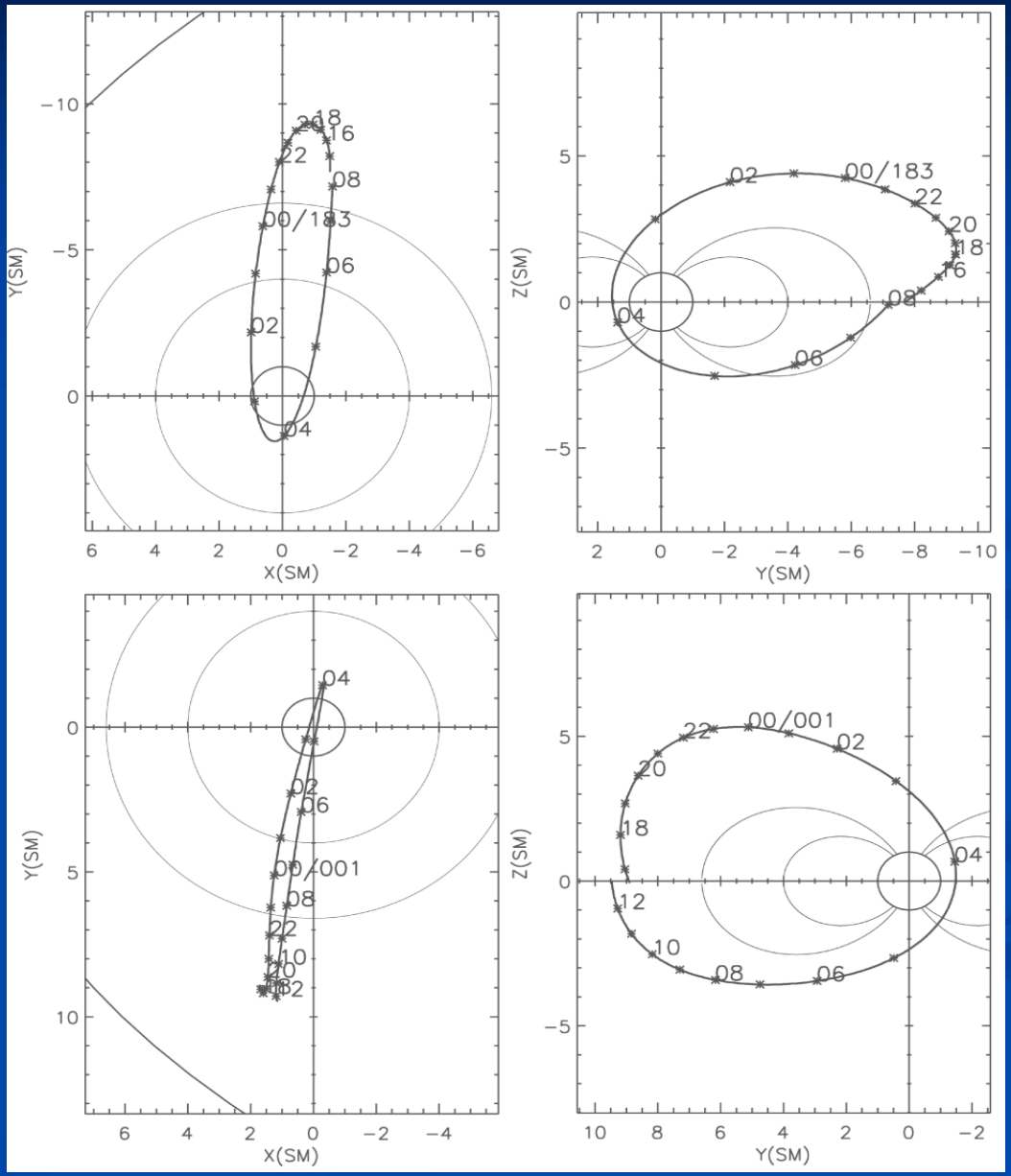
Polar in the Magnetotail

- Orbit apogee slowly precessing since launch
  - Launched in 1996 with apogee latitude of 75°
  - Precessing ~16° per year
  - Precessed over the pole, then equatorward
  - Crossed the equatorial plane in summer 2002
- Apogee at midnight around autumnal equinox
  - As apogee precessed equatorward, Polar crossed the near-Earth magnetotail in the second half of every year
  - 2001 is a great year for viewing the tail with Polar
- What can Polar say about ionospheric ions in the near-Earth magnetotail?

Polar Orbit in Late 2001

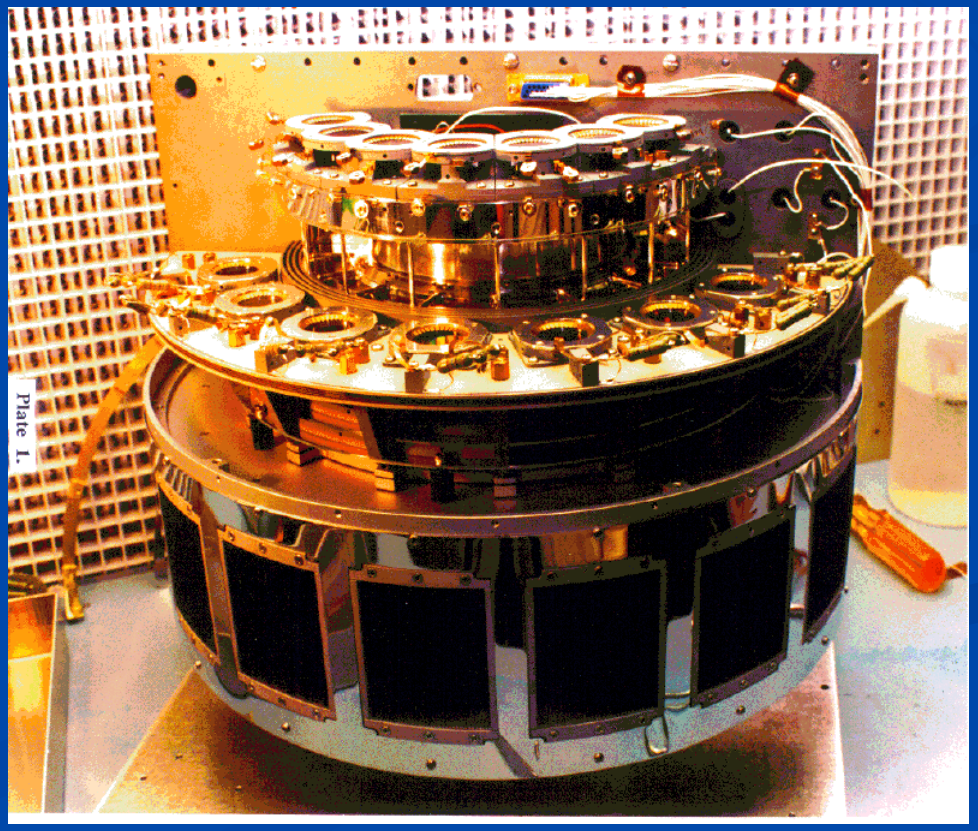
July 1, 2001

December 31, 2001

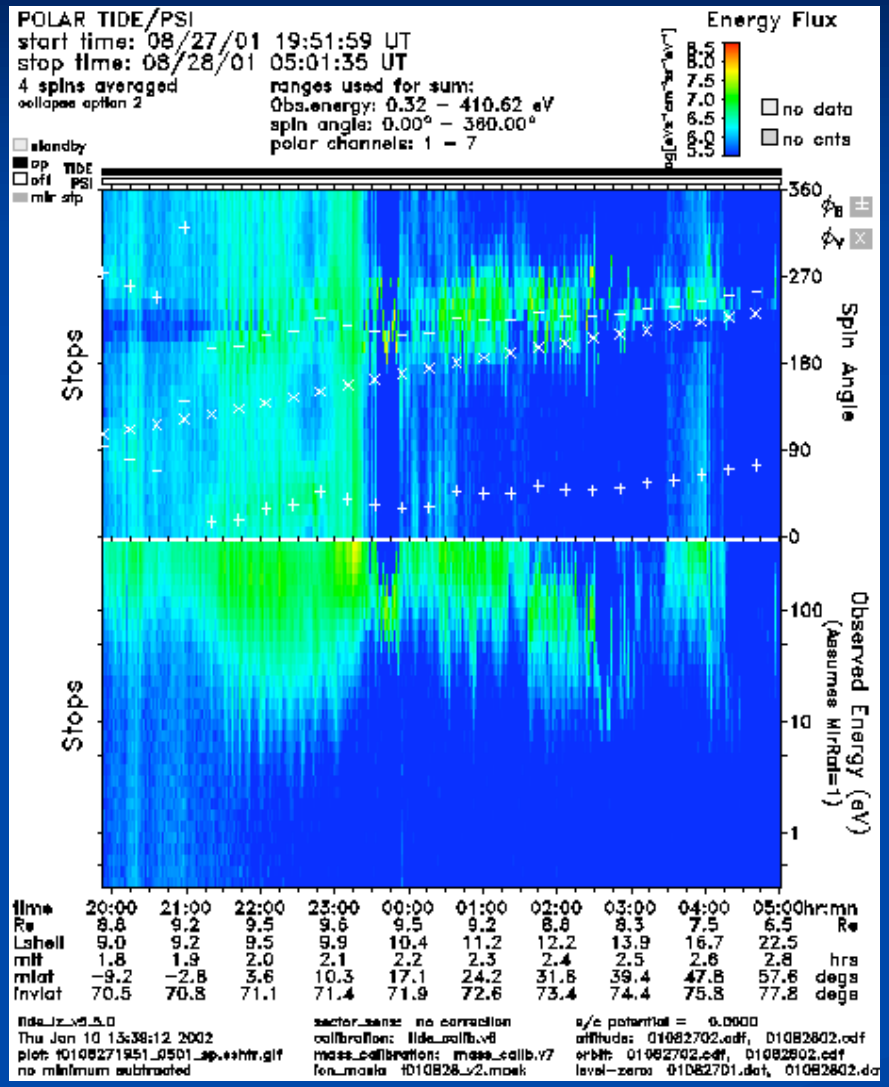


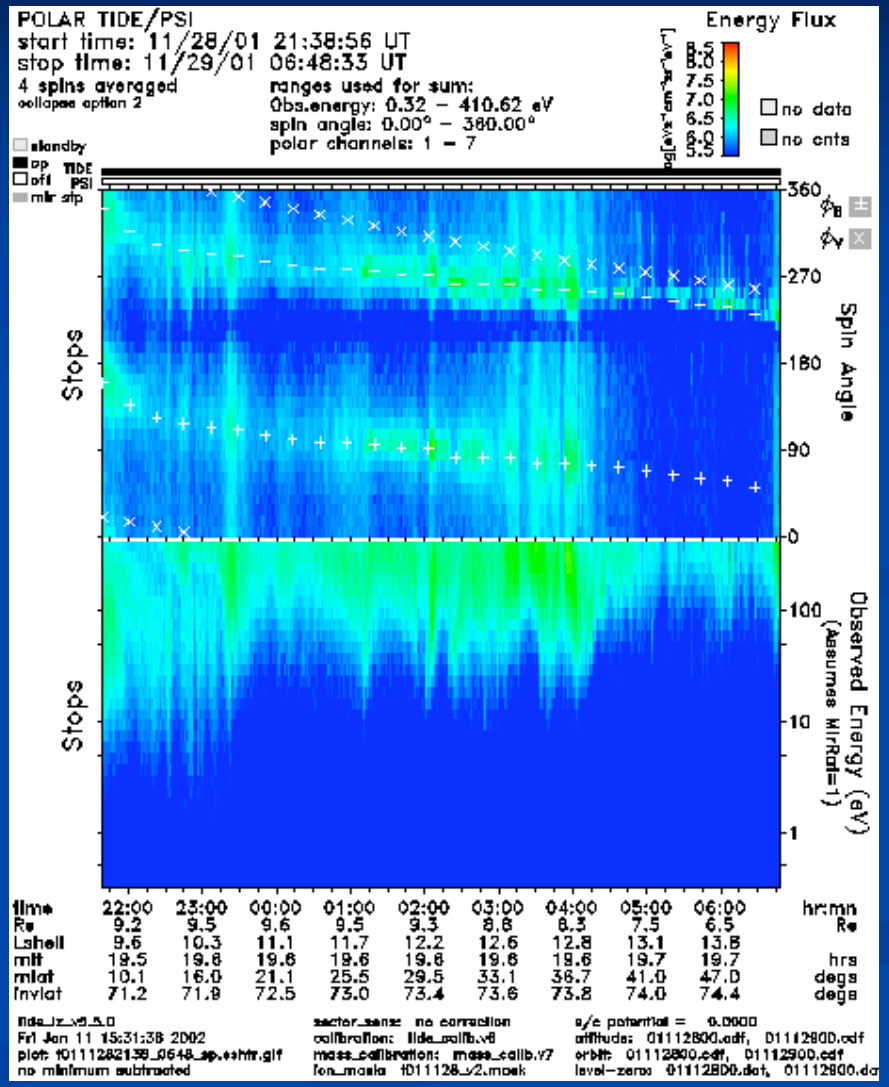
Polar TIDE

- Thermal Ion Dynamics Experiment
  - Measures ions from 0-300 eV energy
  - 2-d velocity space resolution
    - 157° "fan" in polar angle swept through 360° of spin phase
  - In 1996 only: mass resolution and full 3-d velocity space resolution (starts foil degradation)
- The right instrument:
  - Right energy range with high resolution
  - Spin phase sweeps out pitch angle with high resolution
  - Mass composition? Compare with TIMAS...



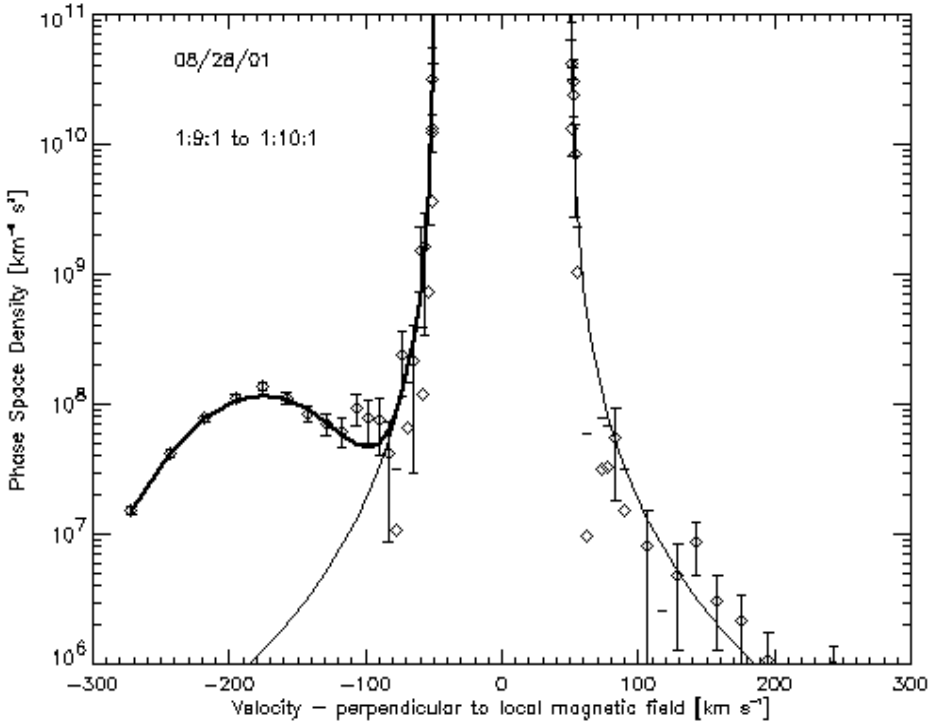
TIDE Measurements of "Lobal Wind"

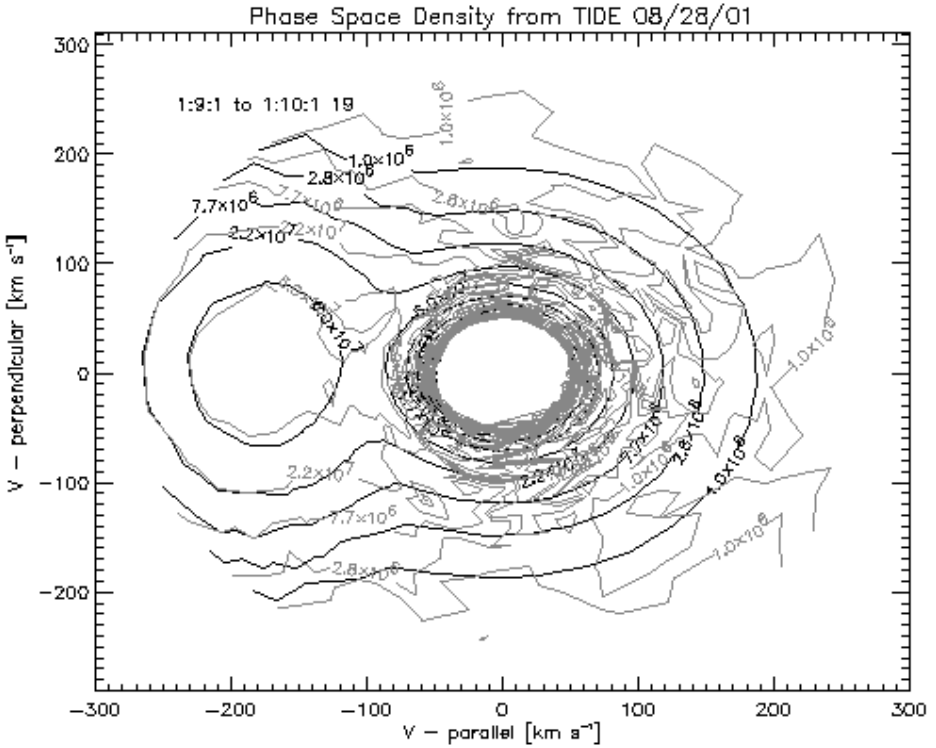




TIDE PSD Fit of "Lobal Wind"

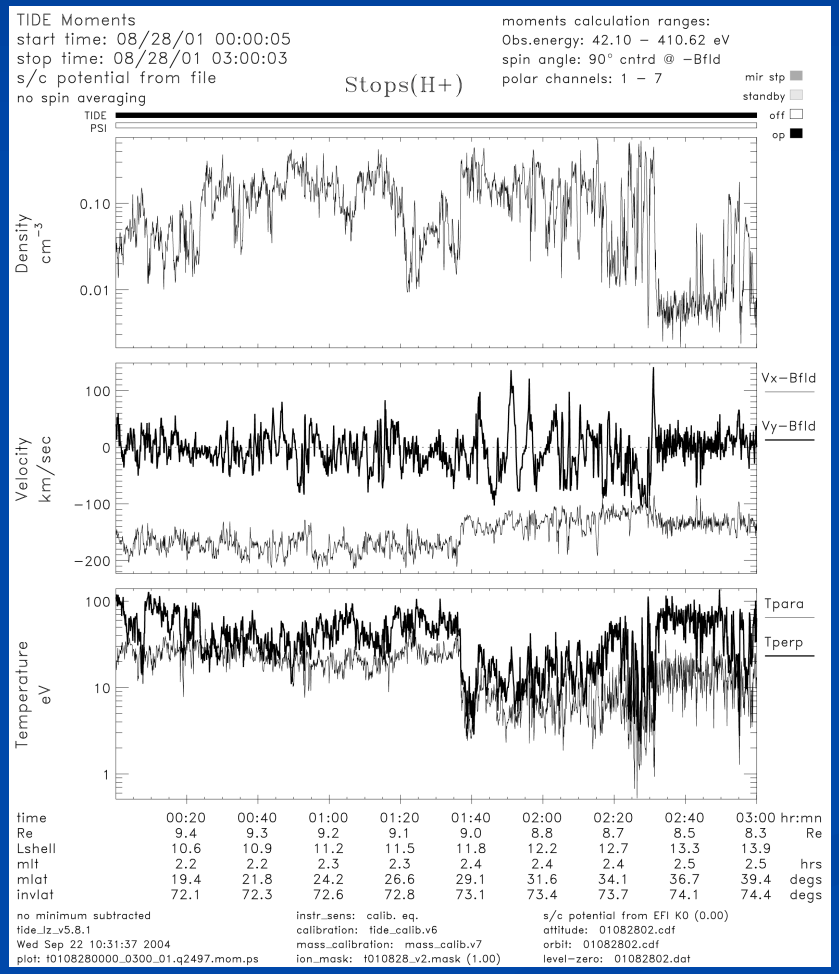
- Maxwellian fits to the velocity space distributions
  - A clear drifting Maxwellian can be extracted from the data
  - Here: $n=0.19\ cm^{-3}$, $v_{||}=-175\ km/s$, $T_{||}=20\ eV$, $T_{\perp}=30\ eV$
    - Assuming H^+ (for O^+, $n=0.76\ cm^{-3}$ and $v_{||}=-44\ km/s$)

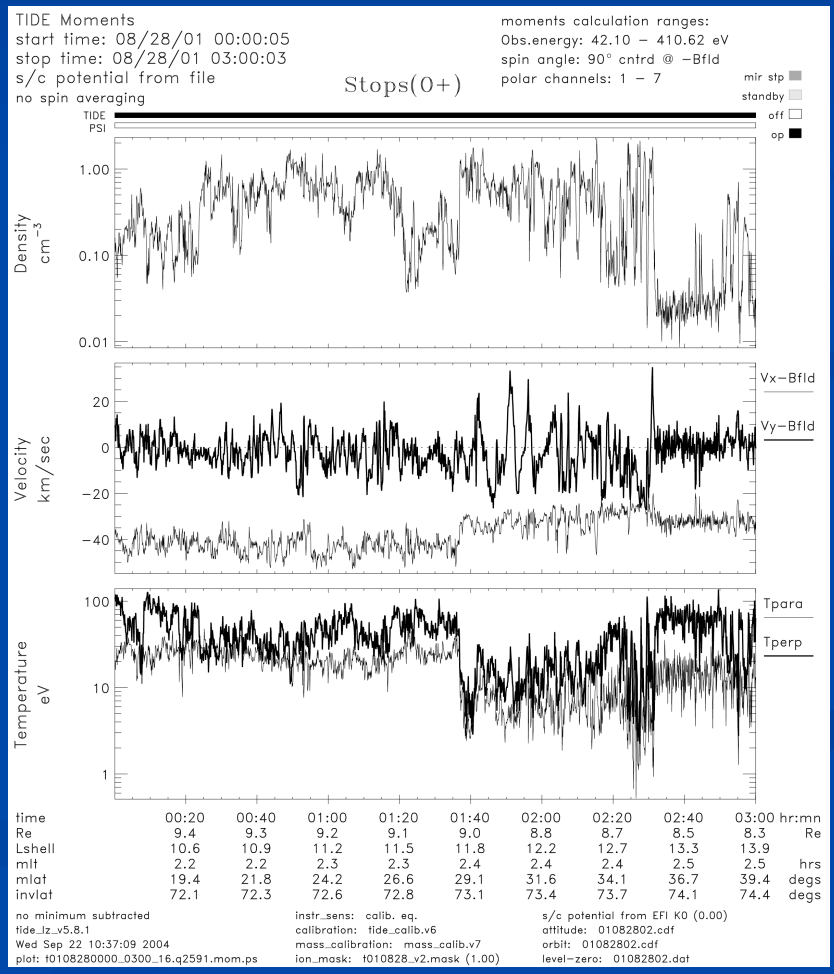




TIDE Moments of "Lobal Wind"

- From the automated moments software
  - 90° track width along negative B-field in spin phase
  - Integrate over 50 eV < E < 300 eV





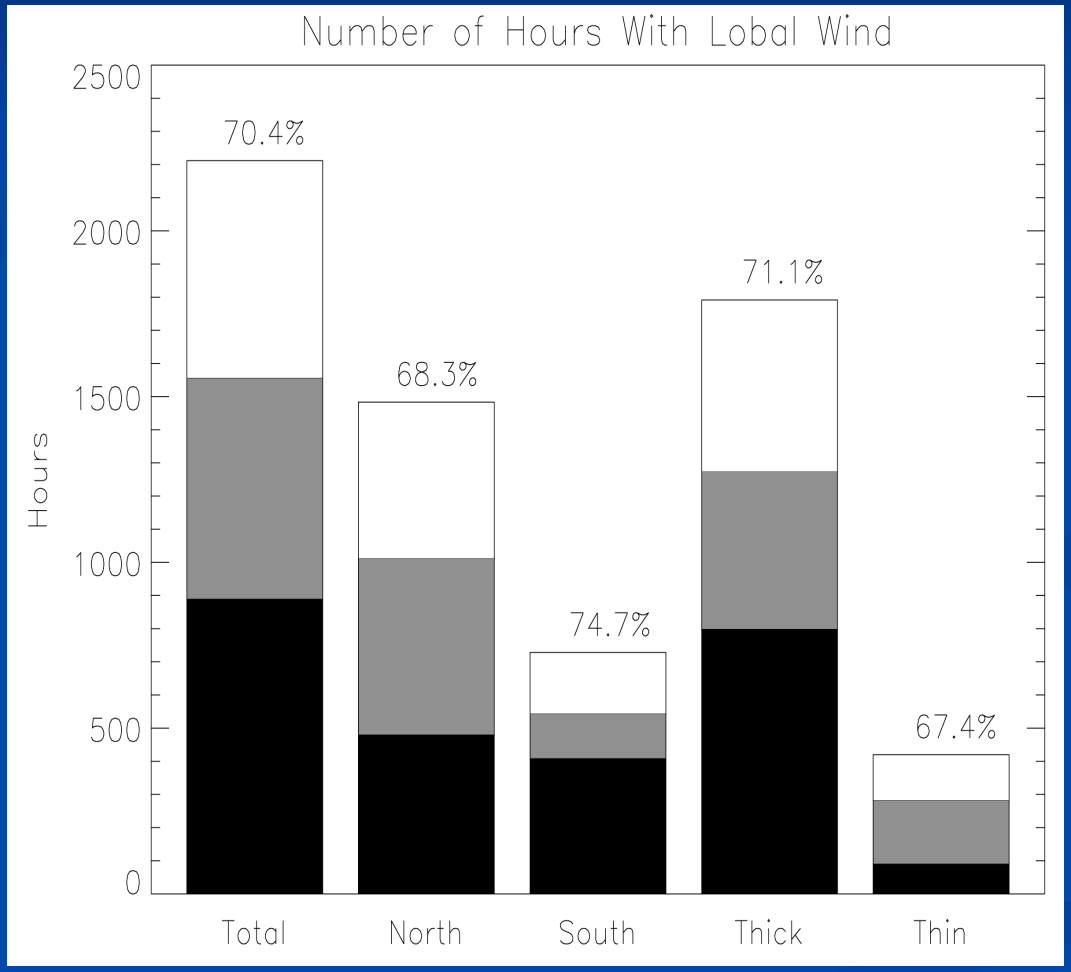
TIDE Lobal Wind Occurrence Survey

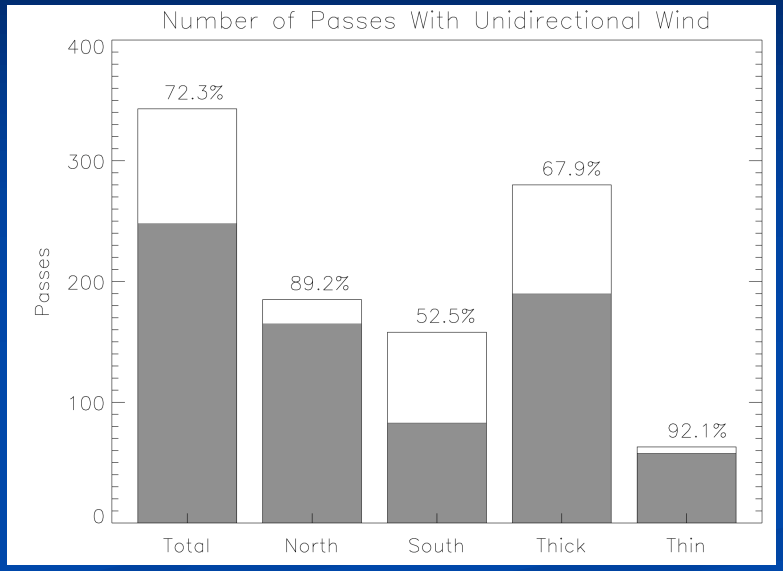
- Second half of 2001:
  - July 1 to December 31: 208 non-eclipse orbits
    - 416 half-orbits, splitting it at the equatorial plane crossing
  - Unusable orbits:
    - TIDE turned off, radiation belt contamination, SEP contamination
    - 73 half-orbits were excluded (23 northern, 50 southern)
  - Database of available TIDE measurements:
    - Half-orbits: 343
    - Total hours: 2,211.5
- Occurrence survey methodology:
  - Examine data for lobal wind measurements
  - Plot occurrence rates versus various SW/GB parameters
  - Look for significant trends, try to explain them

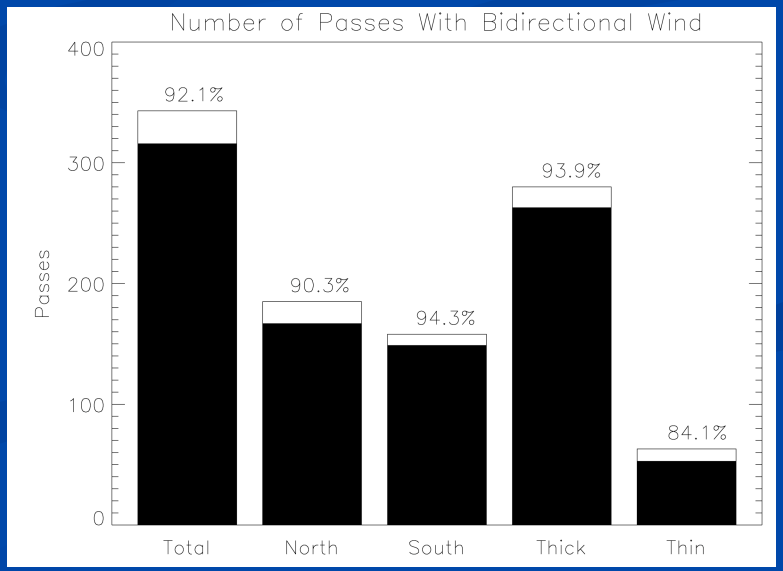
Lobal Wind Selection Criteria

- Manual examination of the summary plots
  - Threshold energy flux of 106 eV/(s sr eV cm^2)
    - Or 5x the background energy flux, whichever is greater
  - Flux peak centered on magnetic field direction (+ or -)
  - Max-to-min ratio in spin angle > 3
  - Flux peak greater than 50 eV
- Parsing the database
  - Data considered in 15 minute blocks
    - Total "data points" in the survey: 8,846
  - Three designations: no lobal wind, uni-directional wind, or bi-directional wind

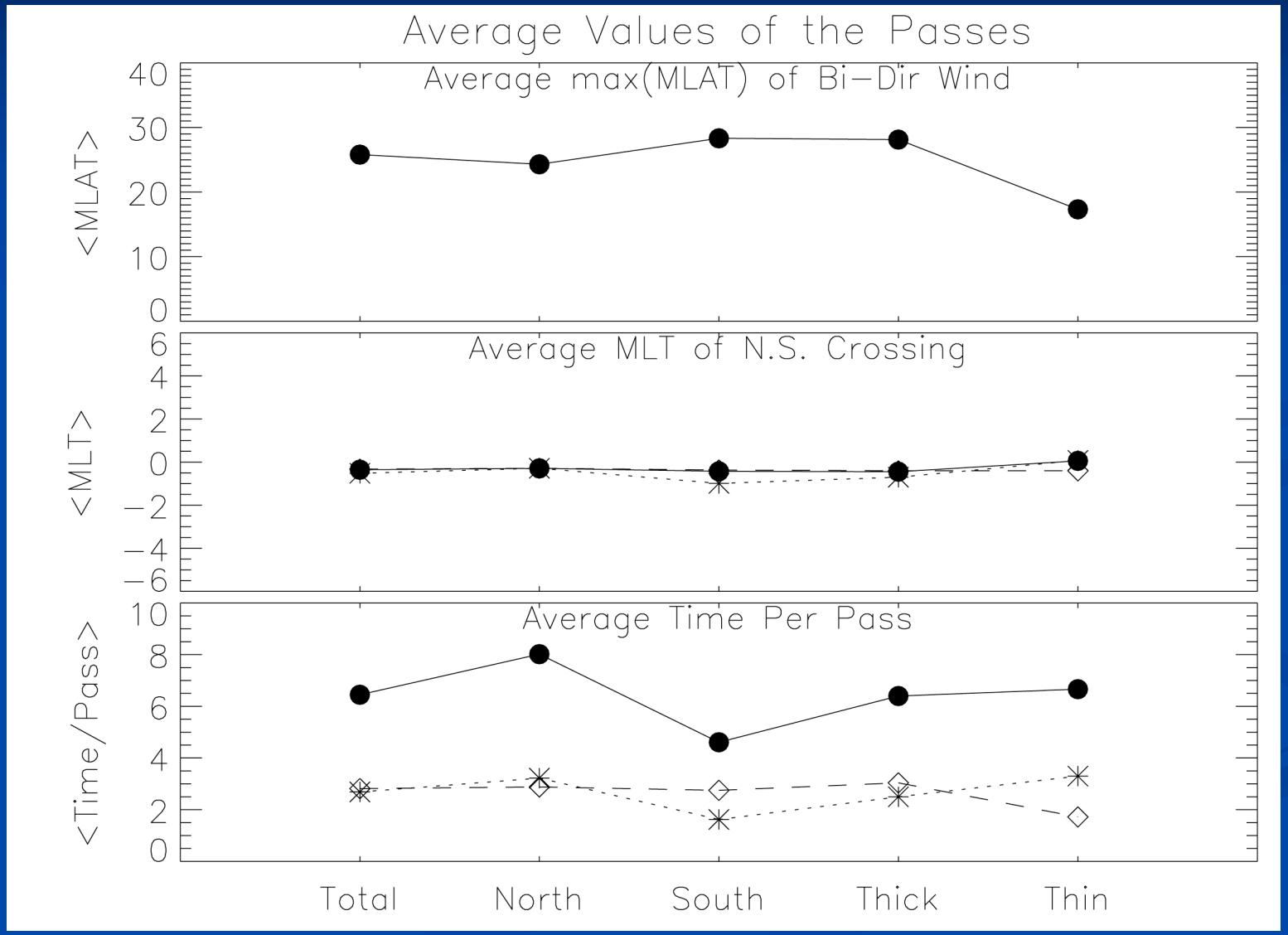
Occurrence Statistics



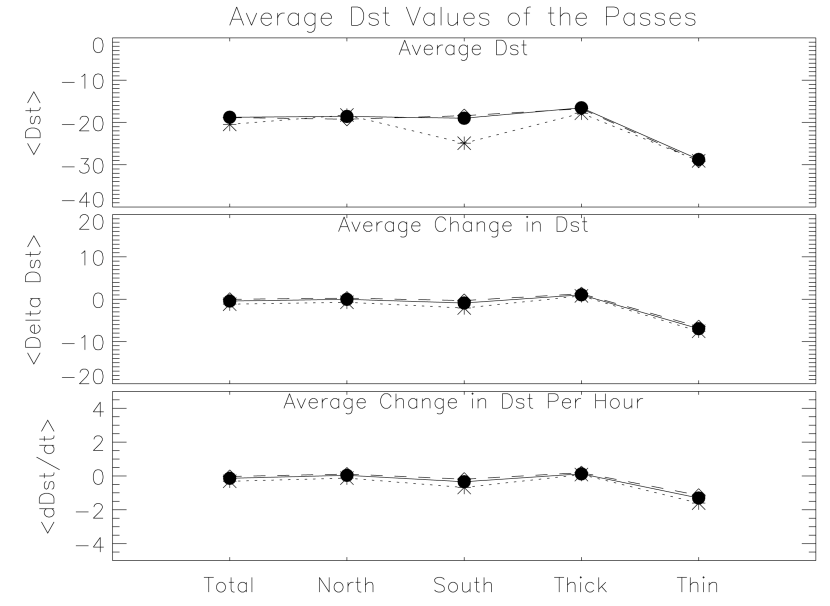


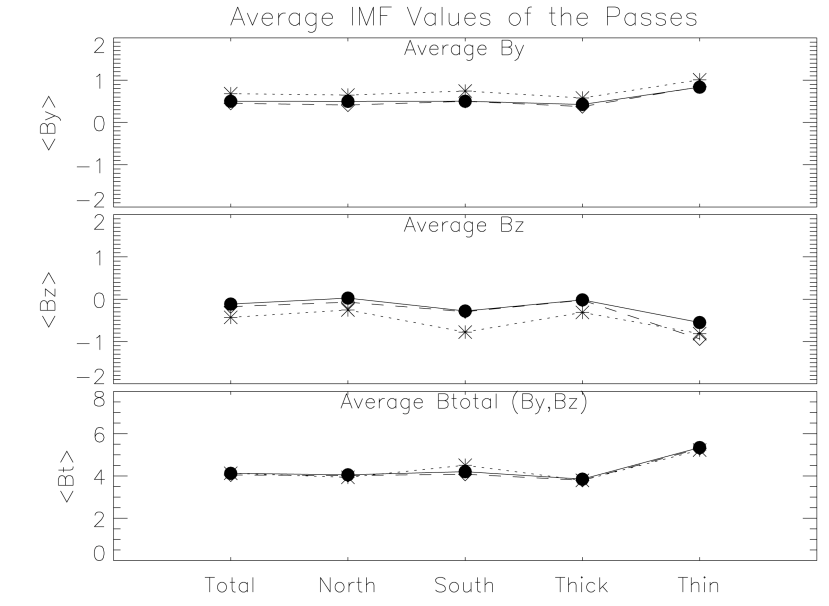


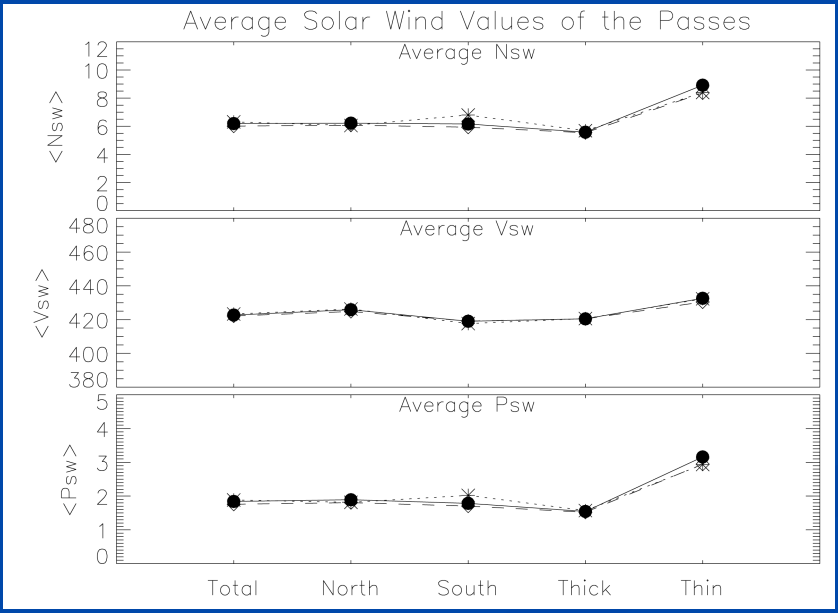
Half-Orbit Average Values

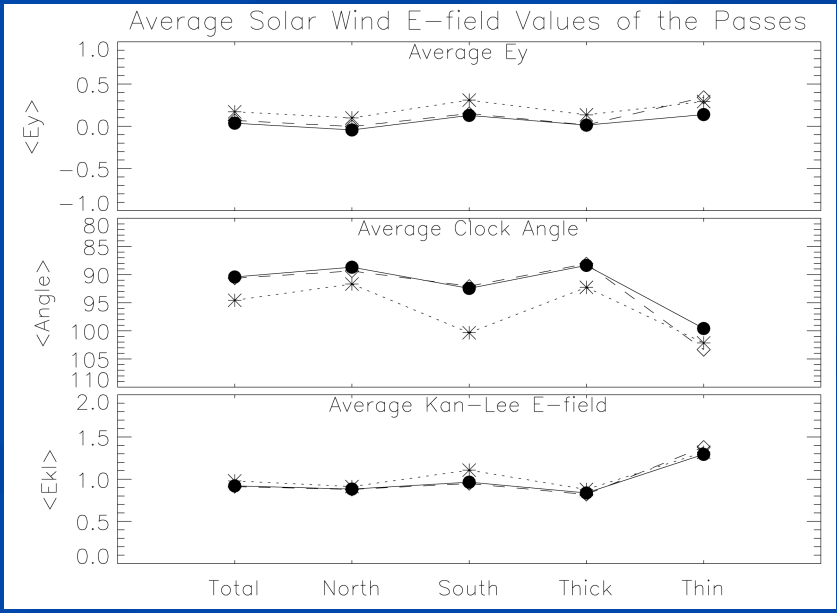


Average Parameter Values

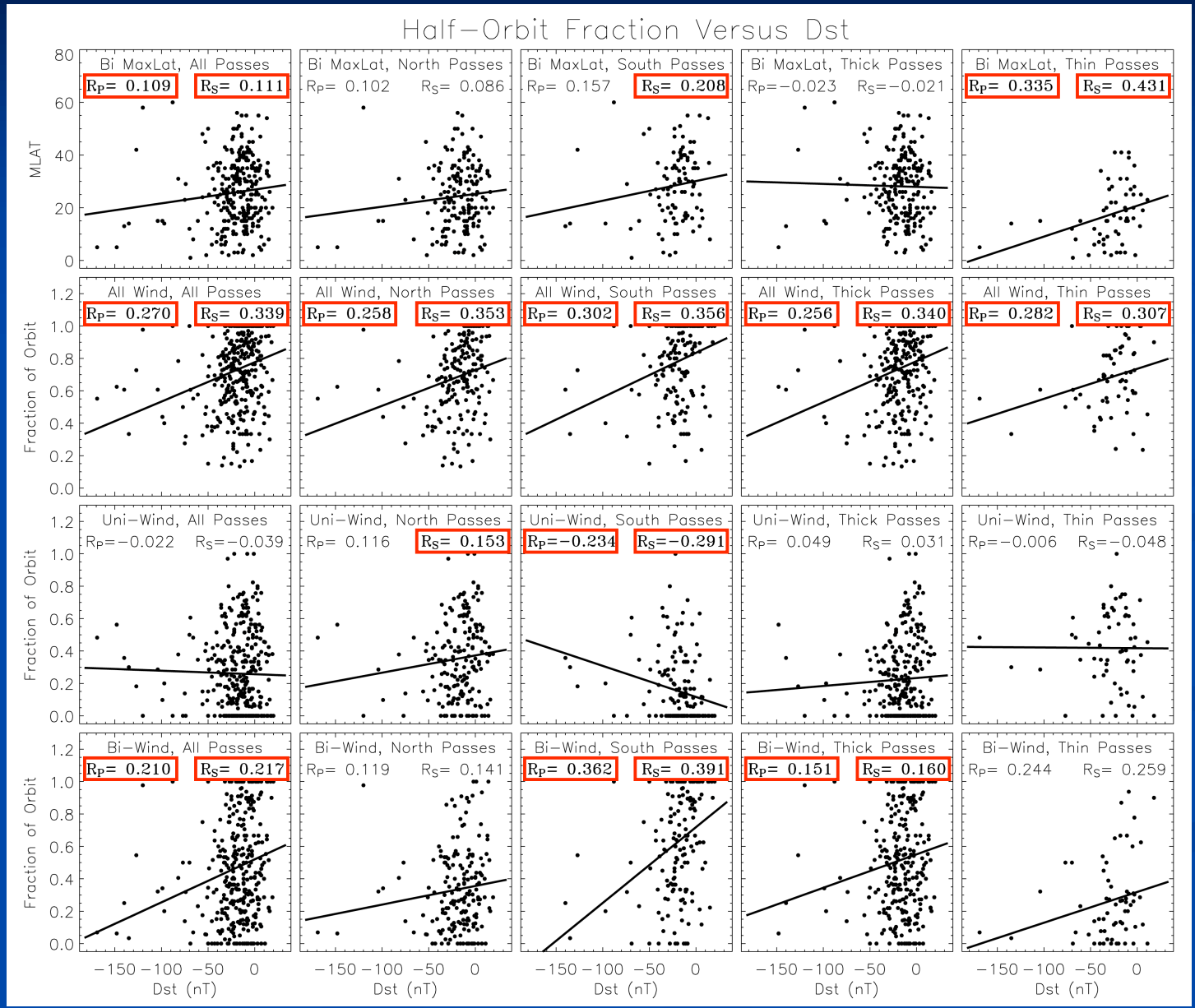




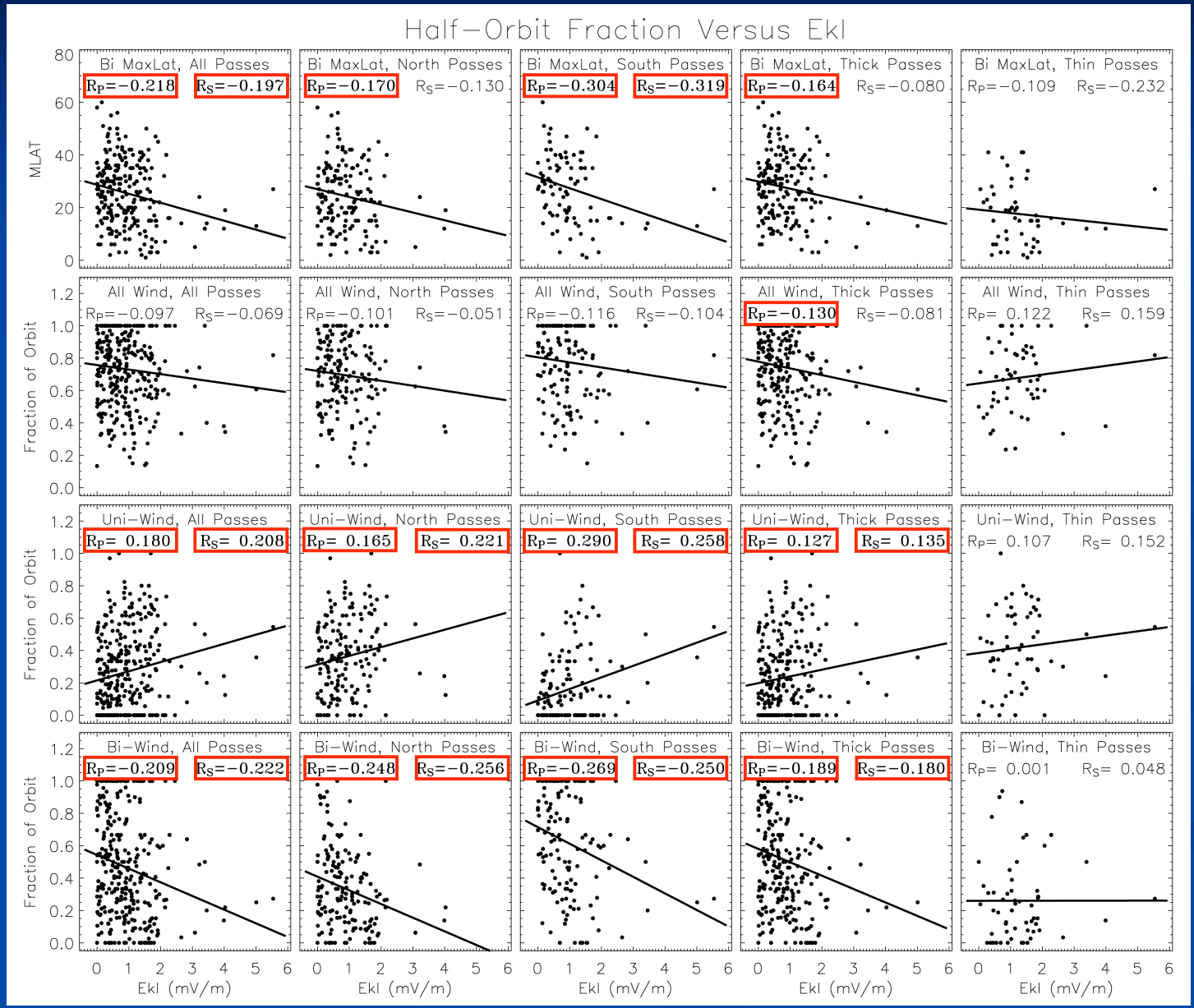




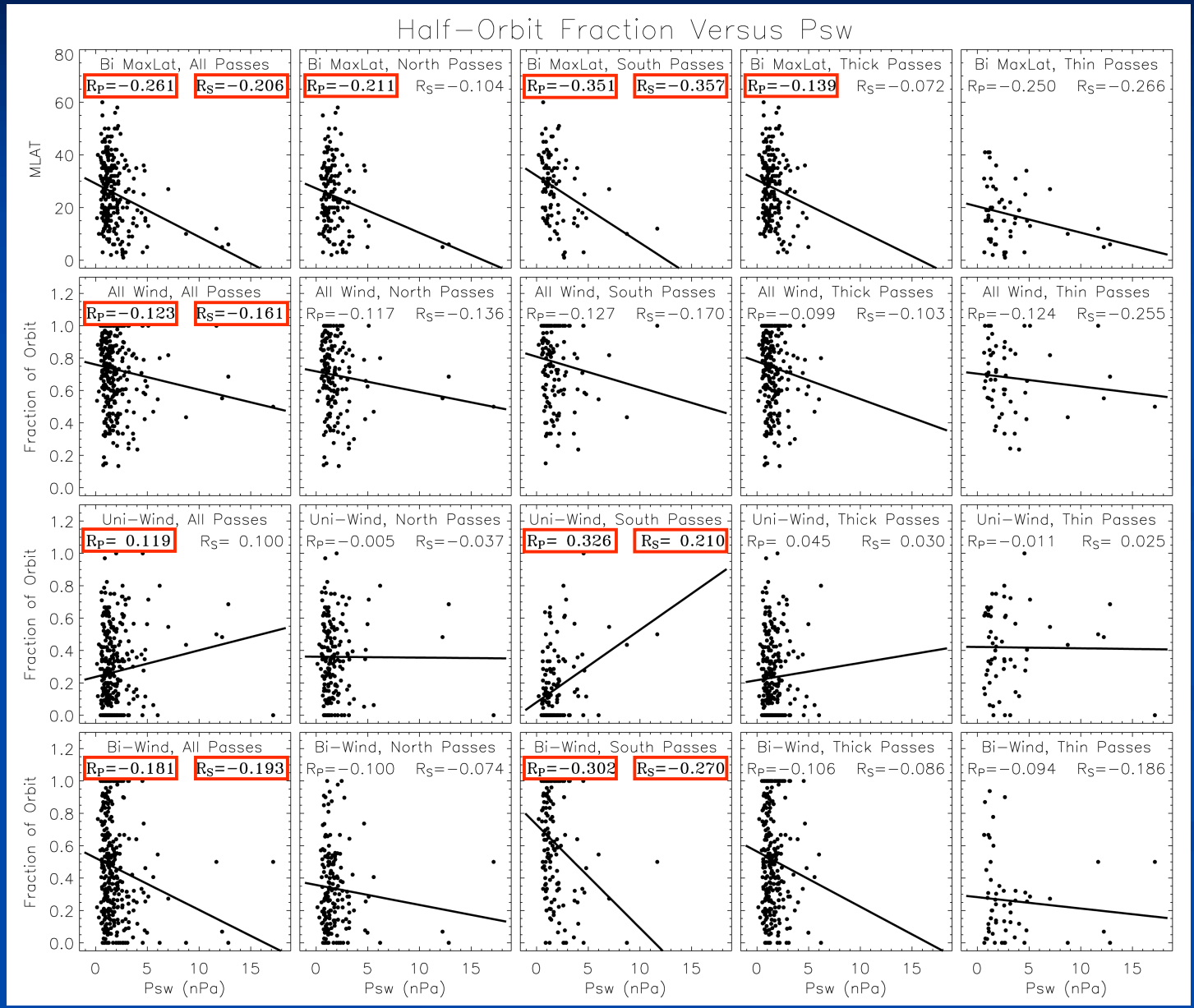
Occurrence Rates Versus Dst



Occurrence Rates Versus E_{KL}



Occurrence Rates Versus Psw



Summary of the Survey

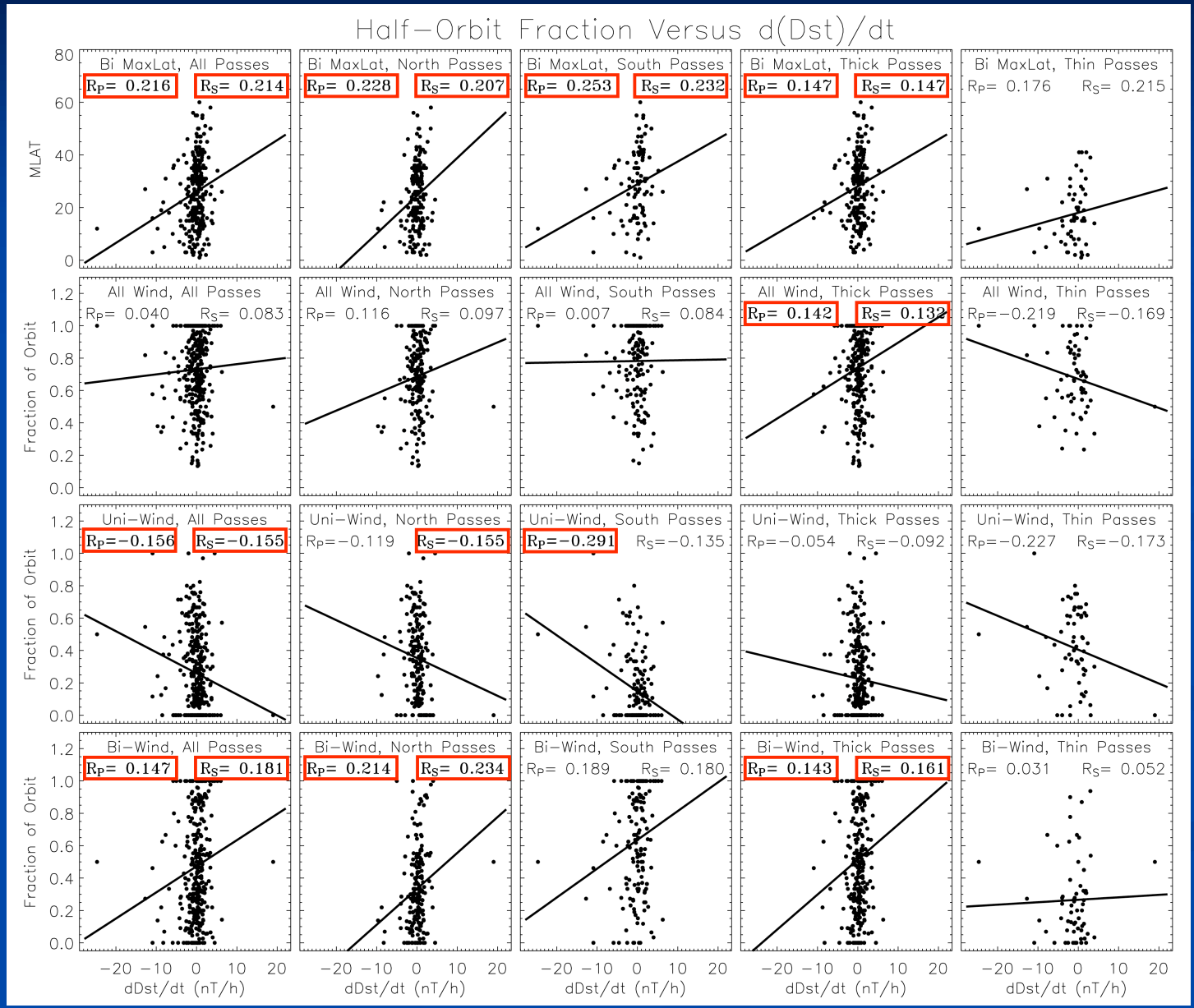
- Lobal wind is ubiquitous
  - All usable half-orbits contained lobal wind measurements
    - Over 70% had uni-directional wind observations
    - Over 90% had bi-directional wind observations
  - Bi-directional wind seen near the equator
    - Average maximum MLAT of bi-direction wind was 25˚
    - Variance in this value is huge: ranges from 3˚ to 61˚
- Organized by geomagnetic activity
  - Dst index and $E_{K\text{-}L}$ value are good organizers
    - Uni-directional wind occurrence increases with activity
    - Bi-directional wind occurrence decreases with activity
    - Total wind occurrence not well correlated with activity (maybe down)
- Feeding of the plasma sheet?
  - Maybe, or it could be a sampling bias from B stretching

Challenge to Magnetospheric Modelers

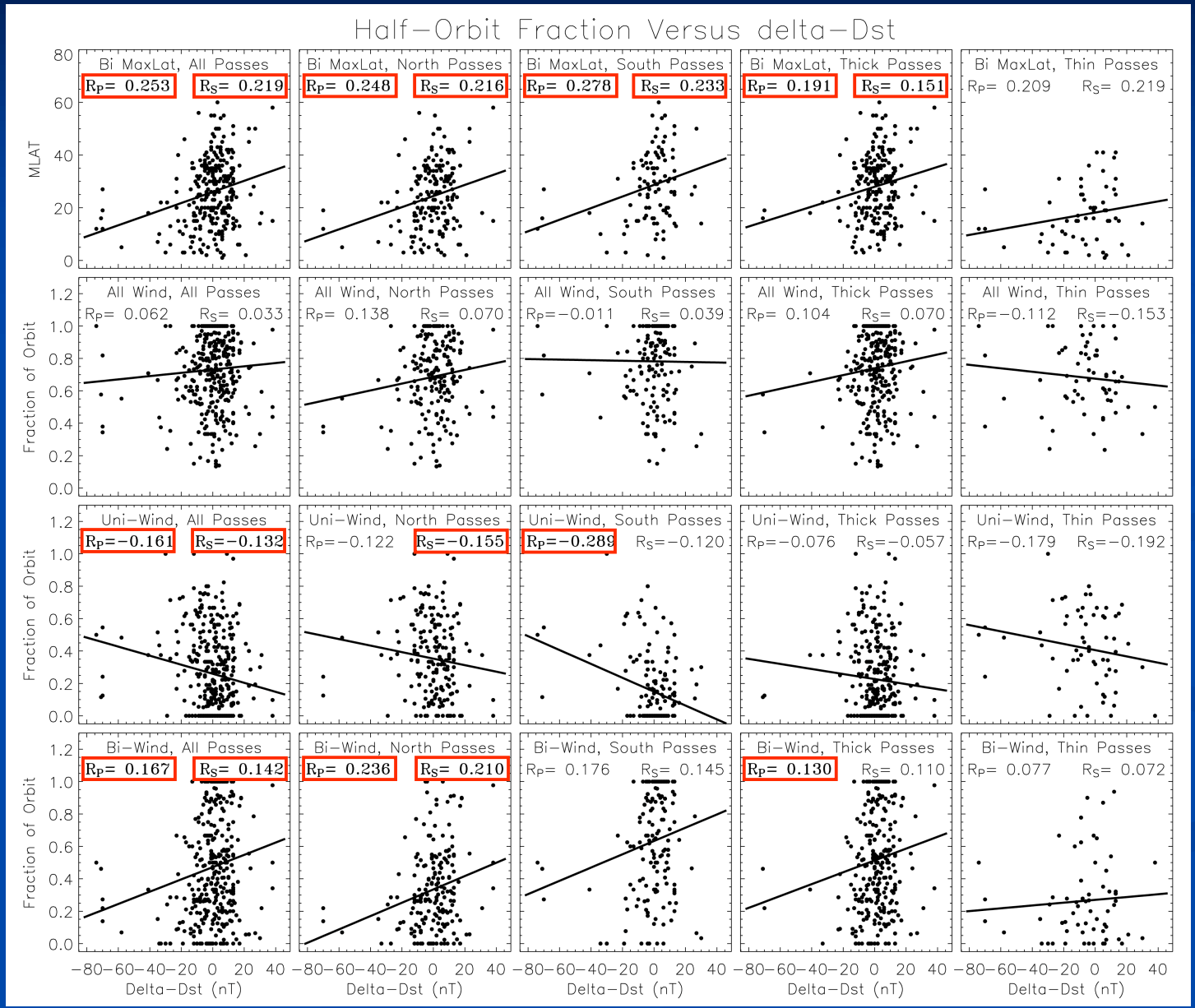
- Ionospheric plasma is always present in the tail
  - Seen across the entire nightside magnetosphere
  - Seen from the equatorial plane through the lobes
  - Cold streams flowing along B
  - Density of 0.1 to 1.0 cm^{-3}: a major source of tail plasma
- Must be included in numerical simulations:
  - Need a good ionospheric boundary condition
  - Need proper acceleration mechanisms
  - Need multi-fluid MHD?
    - Are the moments similar between solar and ionospheric sources?
    - Are the "regions of dominance" by each source distinct?
    - If "no" to either, then perhaps multi-fluid calculations are needed...

Extra Slides

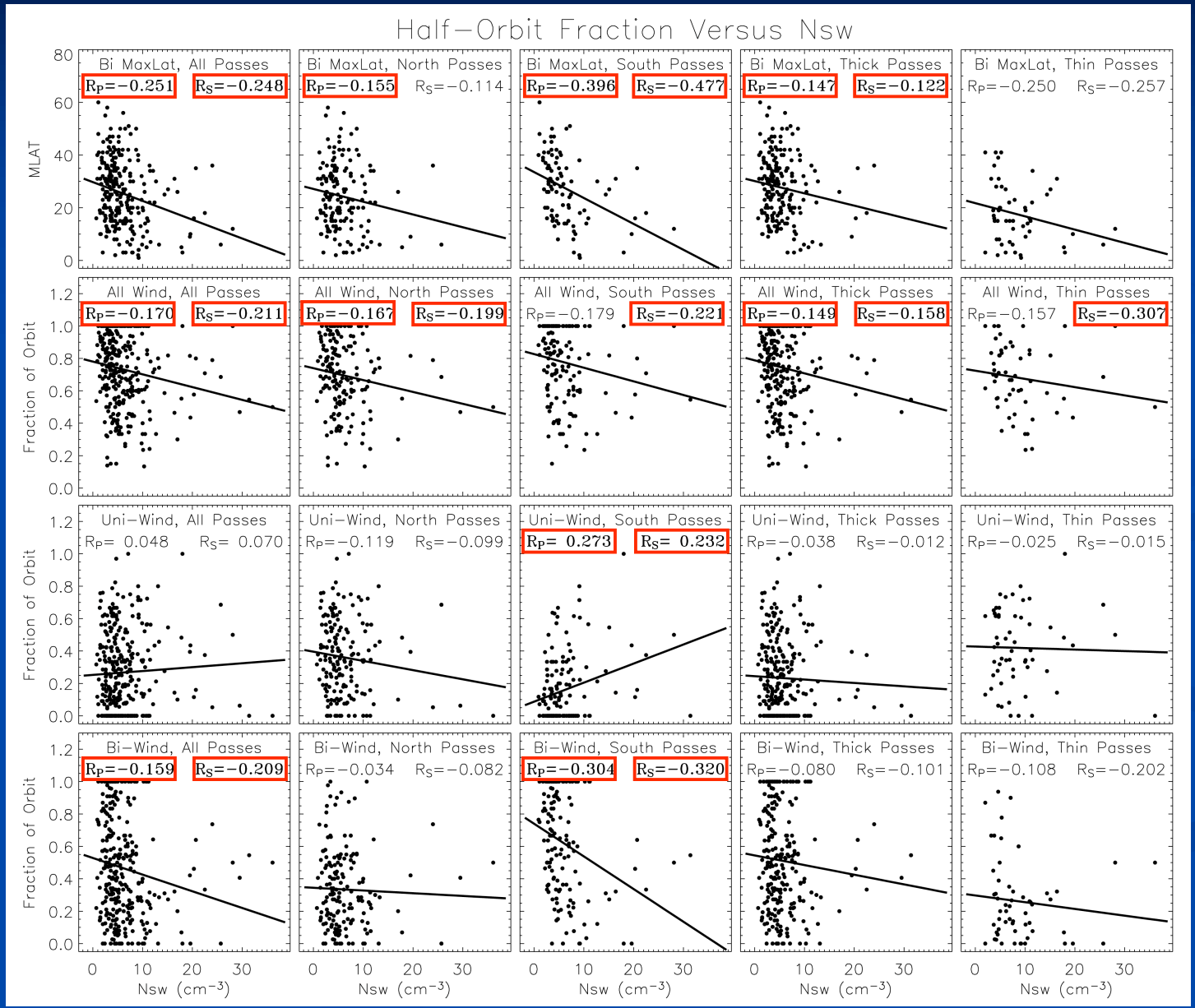
Occurrence Rates Versus dDst/dt



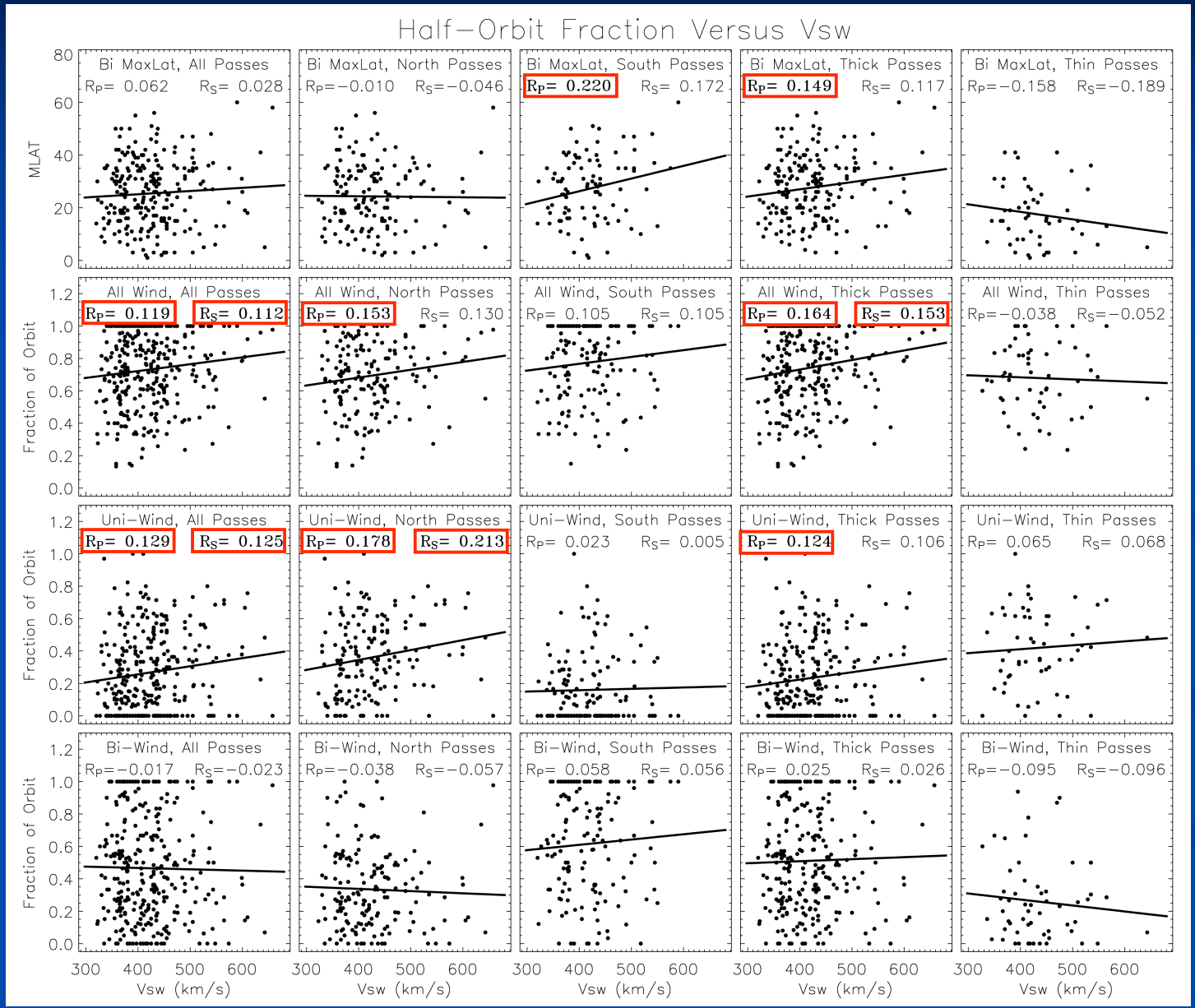
Occurrence Rates Versus ΔDst



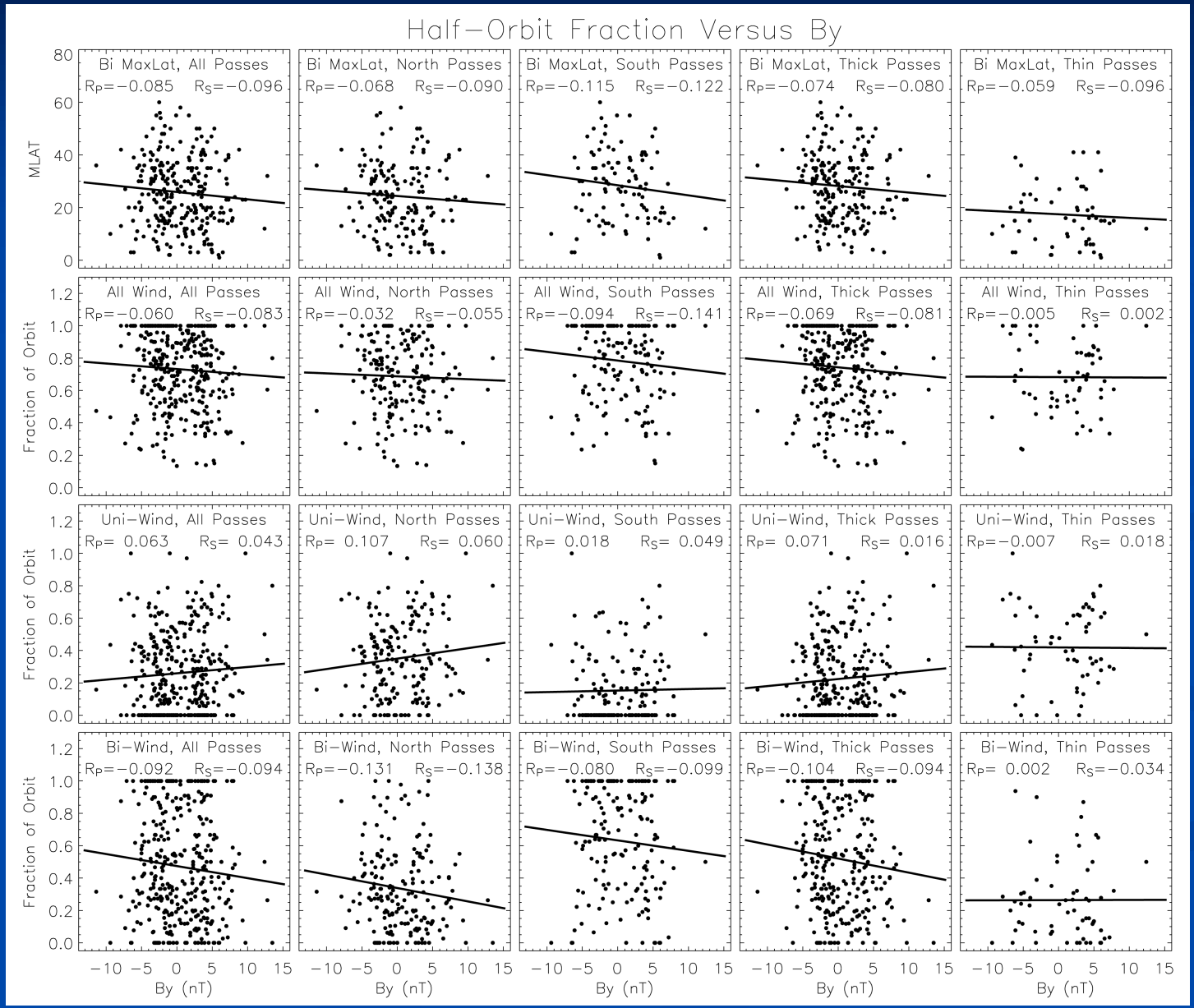
Occurrence Rates Versus Nsw



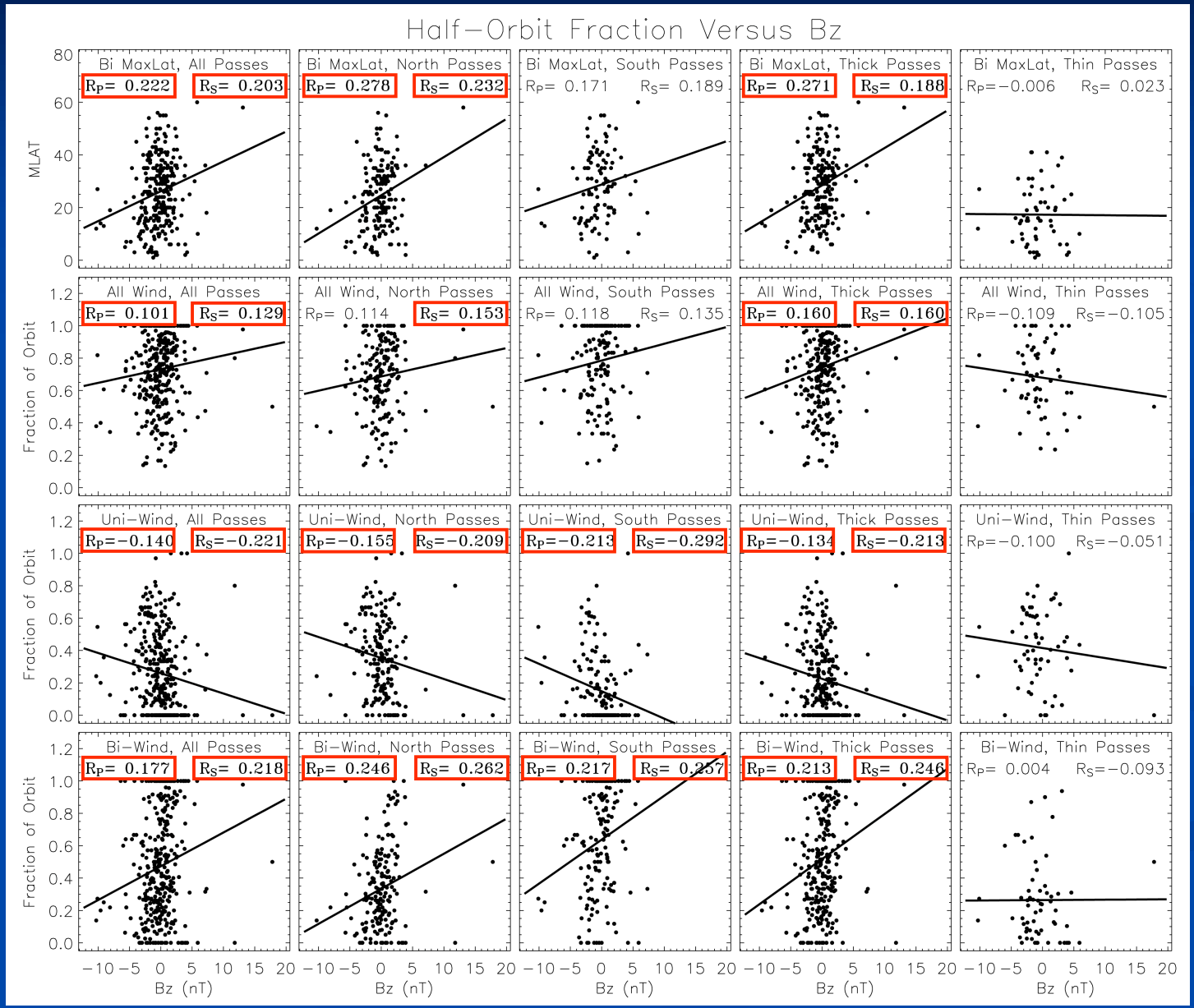
Occurrence Rates Versus Vsw



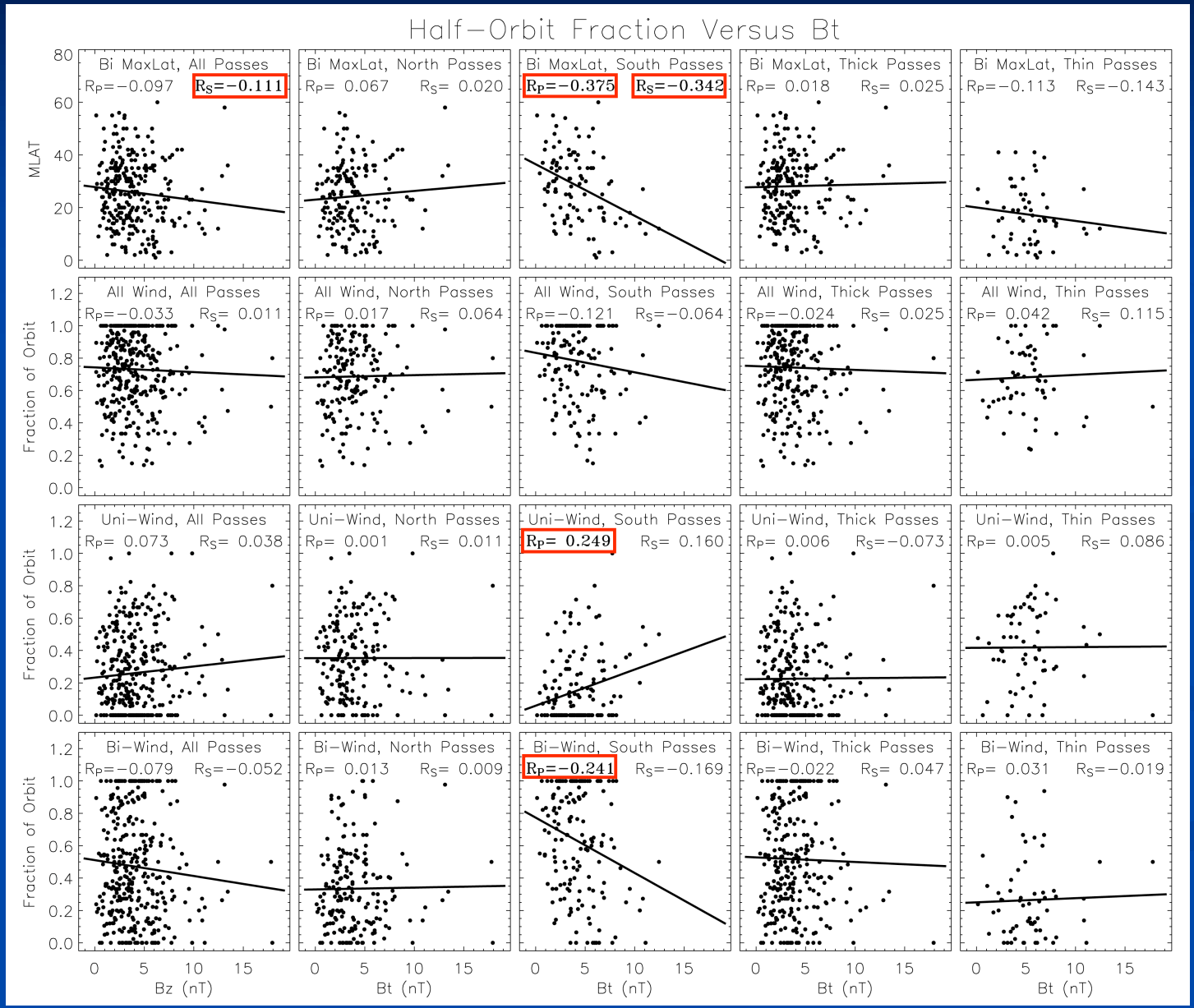
Occurrence Rates Versus By



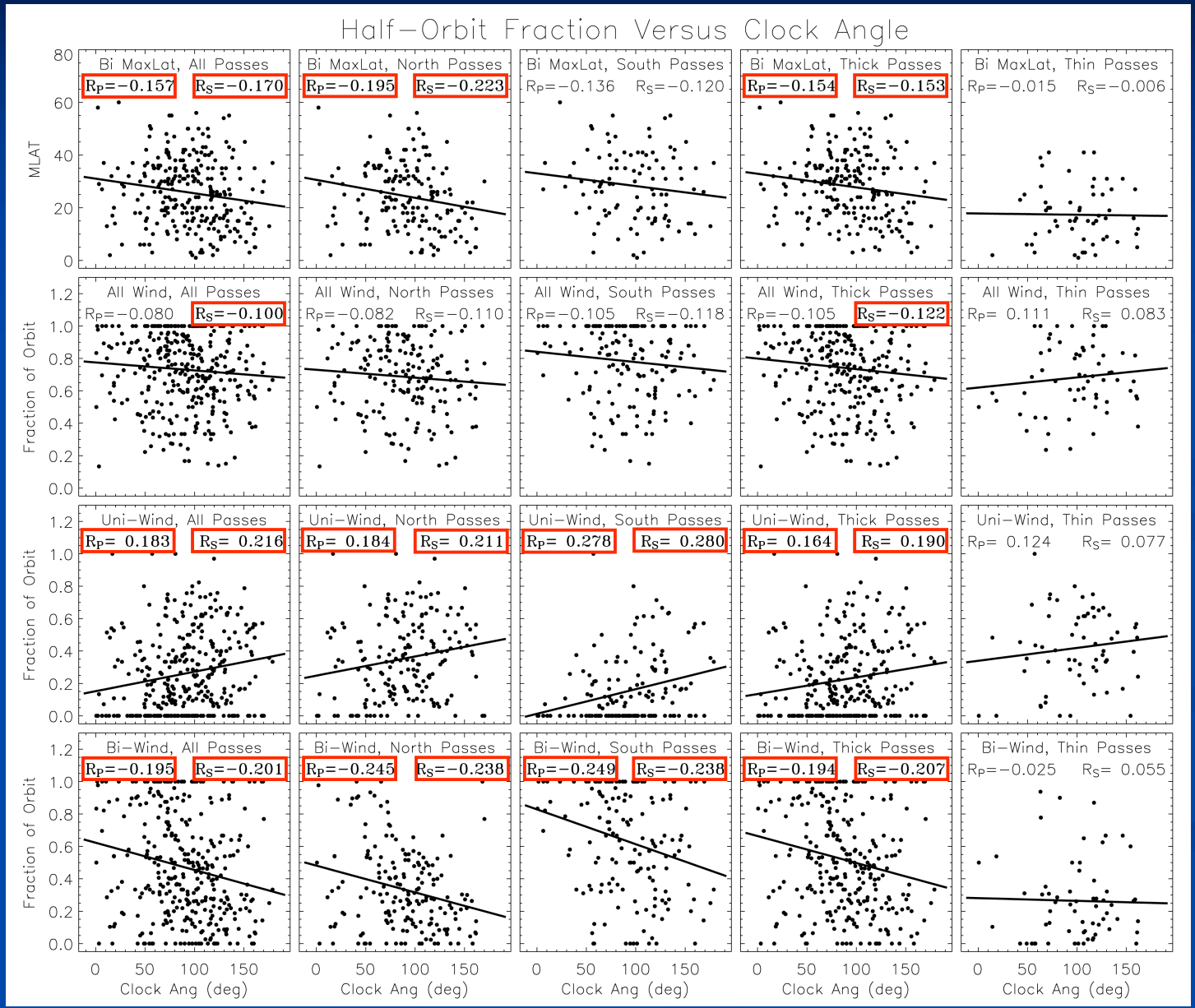
Occurrence Rates Versus Bz



Occurrence Rates Versus Bt



Occurrence Rates Versus Clock Angle



Occurrence Rates Versus Ey