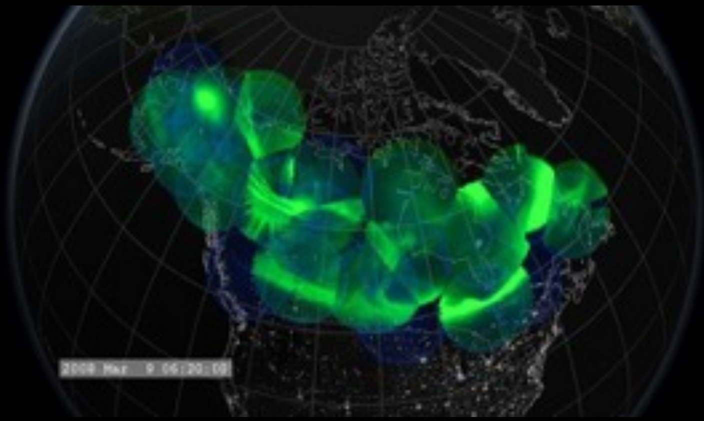
Solar Cycle (Long-Term) Variations of Auroral Acceleration from FAST Satellite Data

John Dombeck - University of Minnesota



Co-Authors & Collaborators : C. Cattell[1], N. Prasad[1], M. Eskolin[1], L. Hanson[2], C. Carlson[2], J. McFadden[2]

CEDAR Workshop
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Auroral Study

What determines the characteristics of quasi-static auroral electron acceleration?
Potential (characteristic energy), Altitude, Energy Flux, etc.

Studied solar illumination and solar cycle dependence of downward electron and upward ion beams from quasi-static potential structures using data from FAST.

Results

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A Lot! (sort of - indirectly)

Auroral Precipitation

Aurora generally looked at as a Magnetospheric input/driver to I-T system
in particular (partial) energy input from magnetosphere that affects conductivity

M-(I-T) Coupling

E-M Input (Transfer)

Particle Input (Transfer)

(Primary) Electron Auroral Mechanisms

Quasi-static (inverted-v)

Alfvénic

Diffuse (scattering)

SW-M-I-T System Drivers

Solar Wind

Earth's Magnetic Field

Solar Radiation

Configuration – Dipole Tilt, Seasons, etc.

System reacts to driver dynamics, and to the system reactions to those dynamics, with various time lags, but driving conditions (may) have changed during lag

Highly complex system with many different scales (in time and space)

I-T Conditions depend on …

Short-Term Dynamics/Effects (too many to list, small scale local, sub-storm, etc.)

Convection Driven Effects

Daily Cycle

Solar Illumination Variation

Seasonal Effects

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Solar Cycle

Solar cycle is not a direct driver of aurora (except perhaps occurrence frequency – opposite expected)

Mostly studying feedback on aurora from I-T conditions

If solar cycle affects auroral characteristics dramatically (not just through conductivity) it is potentially affecting entire system

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it is potentially affecting entire system

Causing…

Difference in total energy transfer (efficiency) and/or

Difference in details of that transfer (at least)

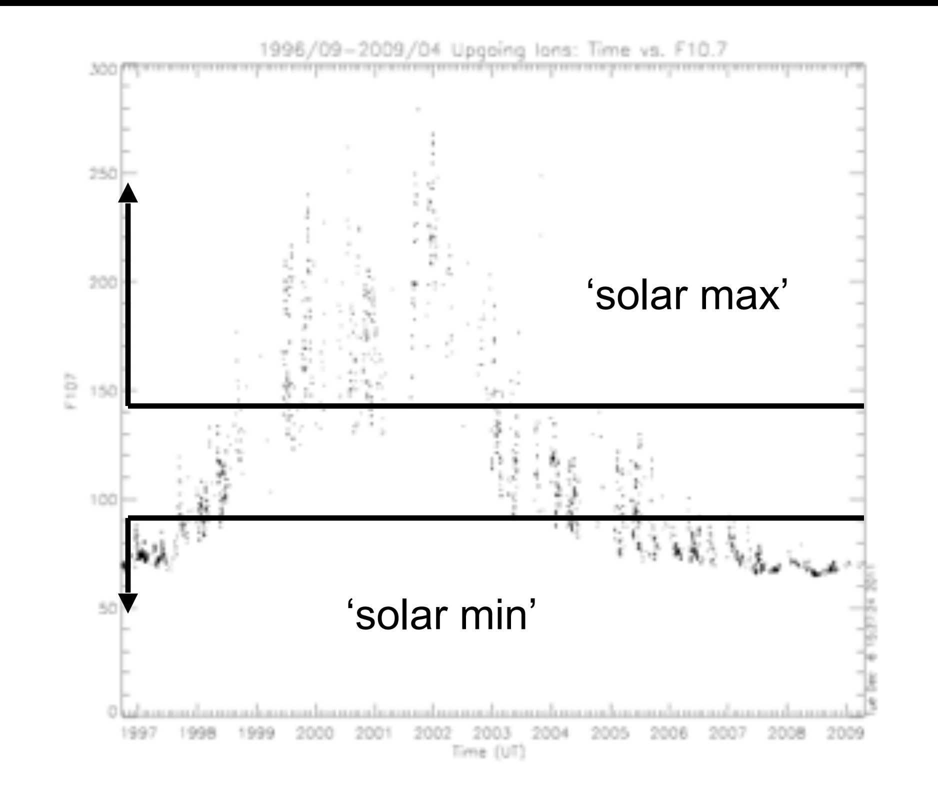
Either way potentially very important

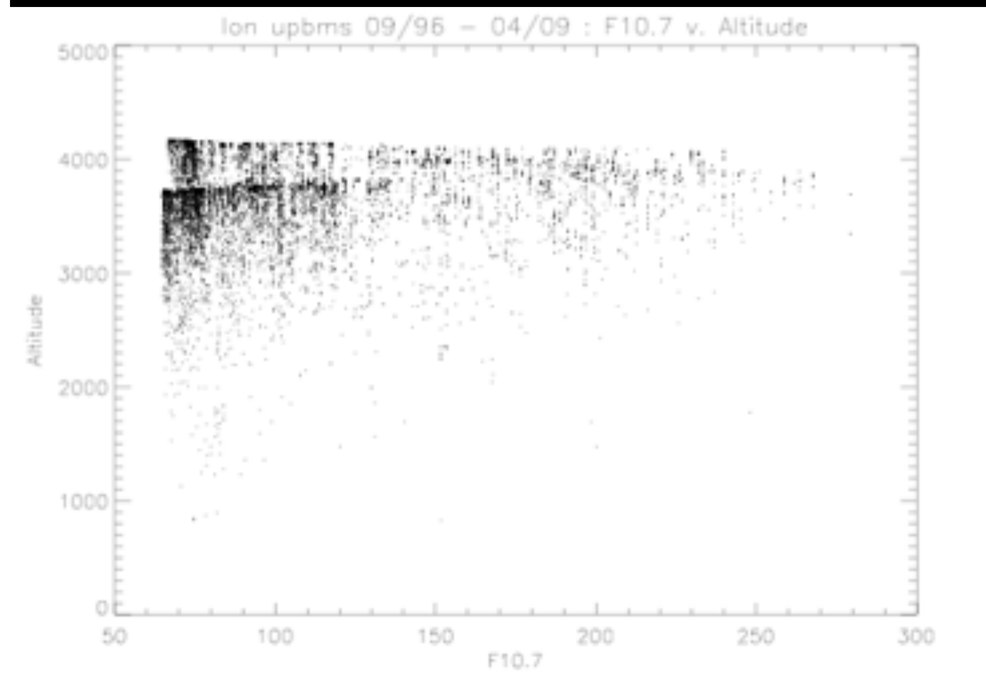
How do we determine (separate out) these long-term effects without averaging over many, many solar cycles?

Taking out/accounting for long-term effects is necessary to generally understand/apply shorter-term physics and predict accurately

If occurrence frequency and energy of quasi-static aurora are affected, at least the mechanism of energy transfer is being affected which in turn affects at least some details of I-T response, but the overall energy transfer may be affected as well.

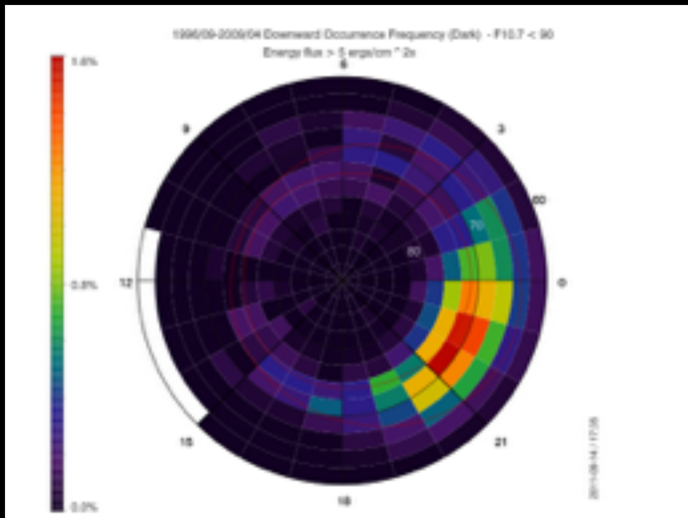
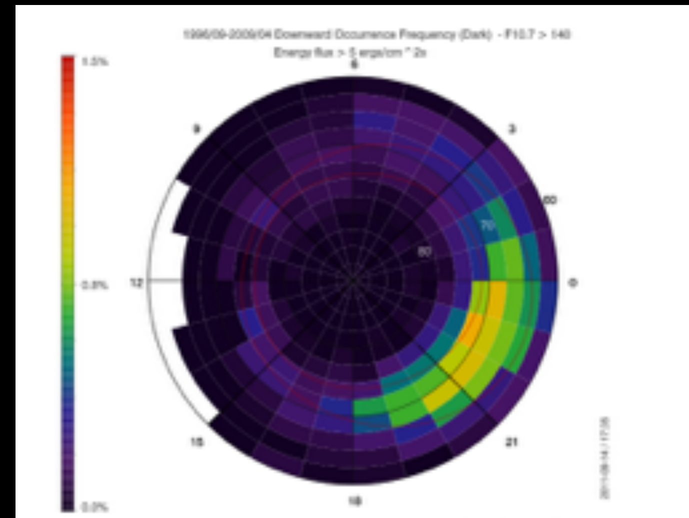
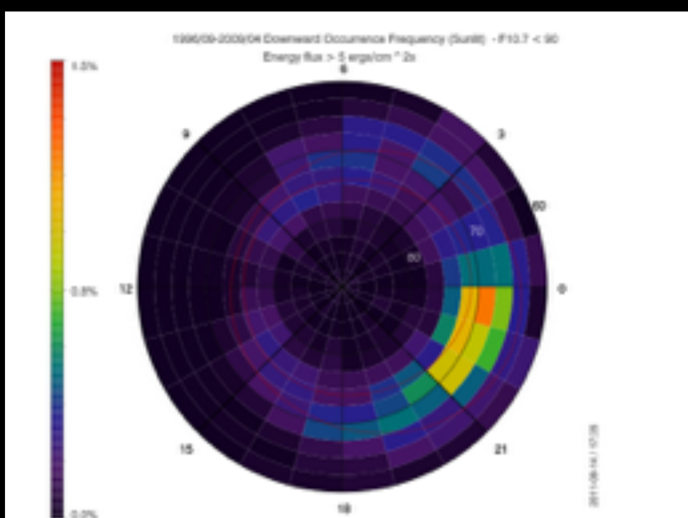
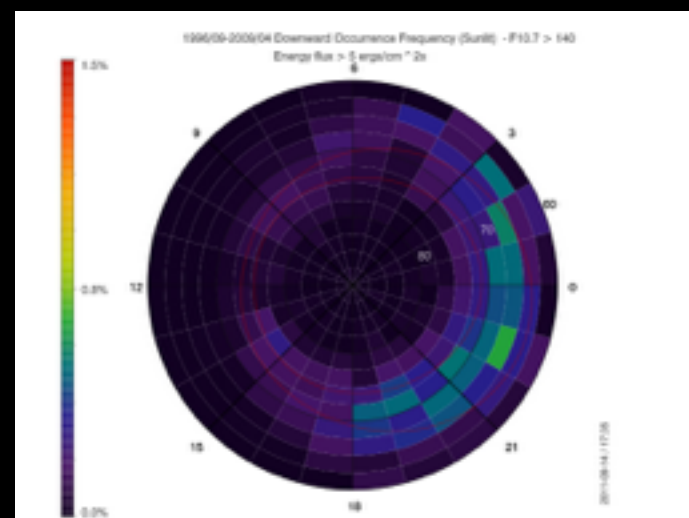
Coverage: Limits for statistics





Decrease in apogee for second solar minimum interval has negligible impact on results

Downgoing electrons (>5 ergs/cm^{2}s)

F10.7<90		F10.7>140
	Dark	
	Sunlit	

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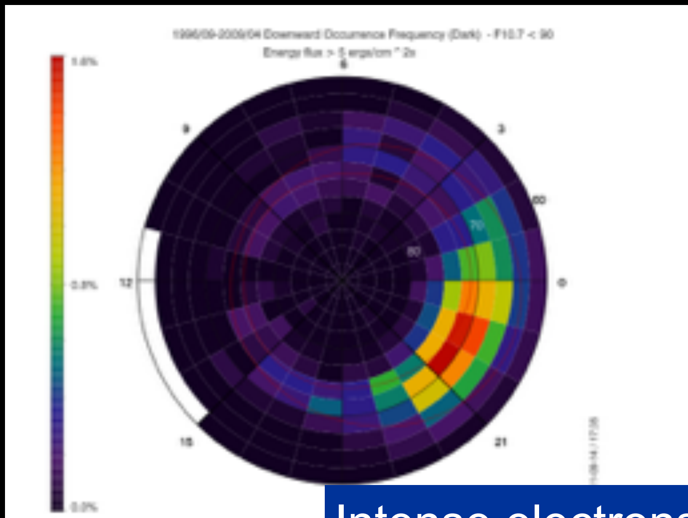
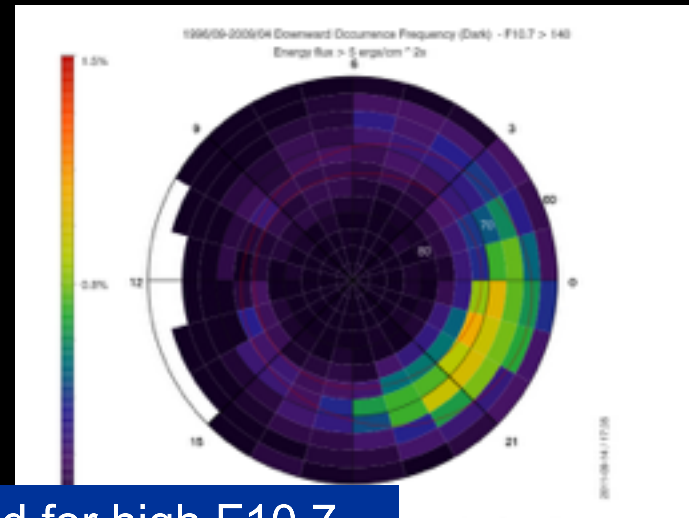


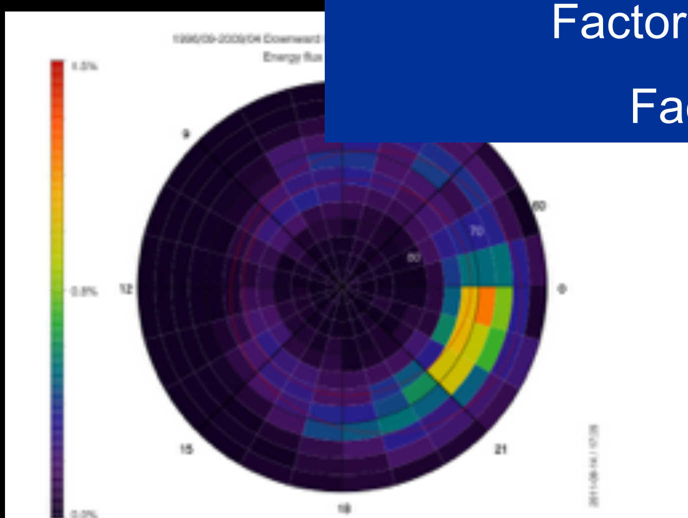


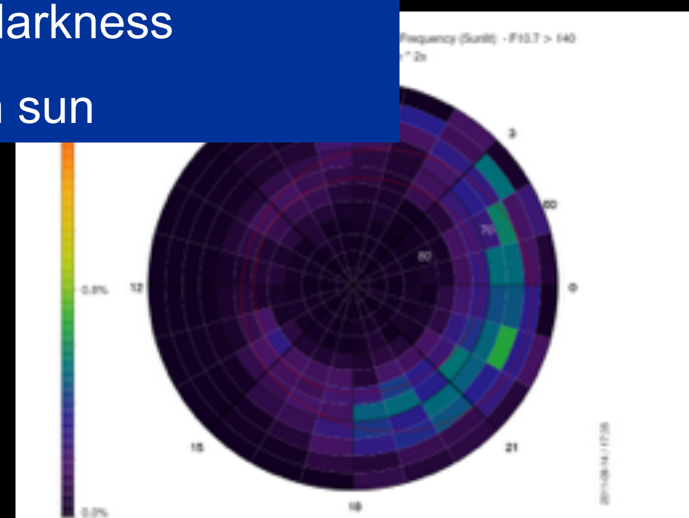
Dark

Intense electrons suppressed for high F10.7

Factor of ~1.4 in darkness

Factor of ~2 in sun





Sunlit

Downgoing electrons (>5 ergs/cm^{2}s)

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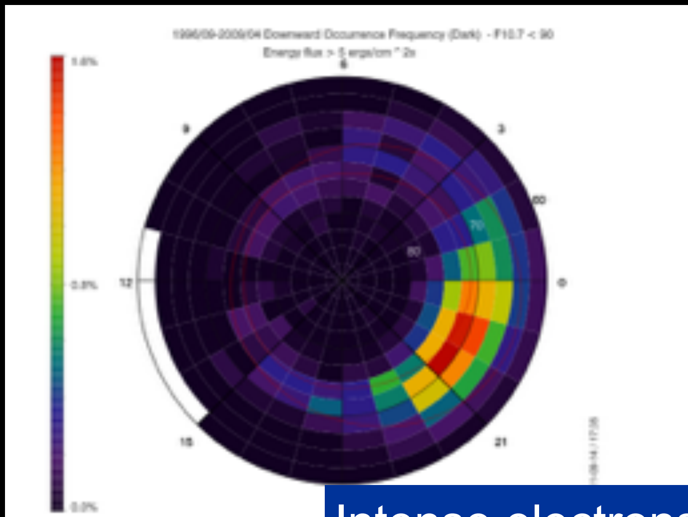
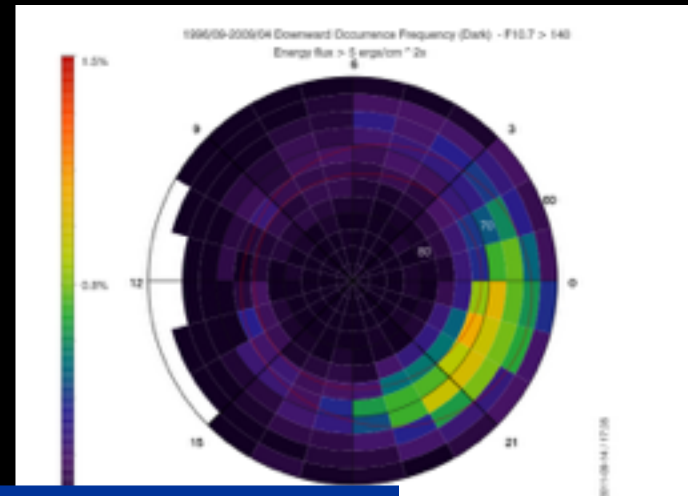




Intense electrons suppressed for high F10.7

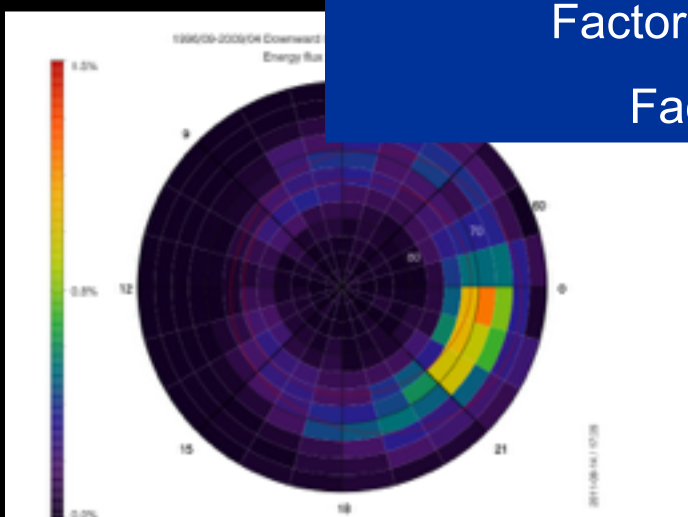
Factor of ~1.4 in darkness

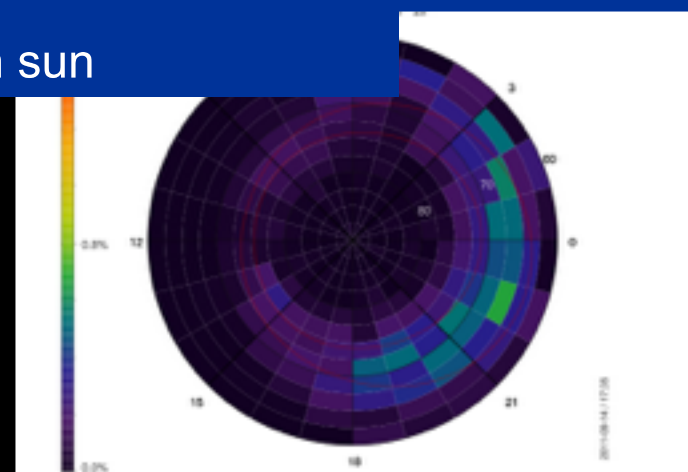
Factor of ~2 in sun

Comparable to sun

Factor of ~3

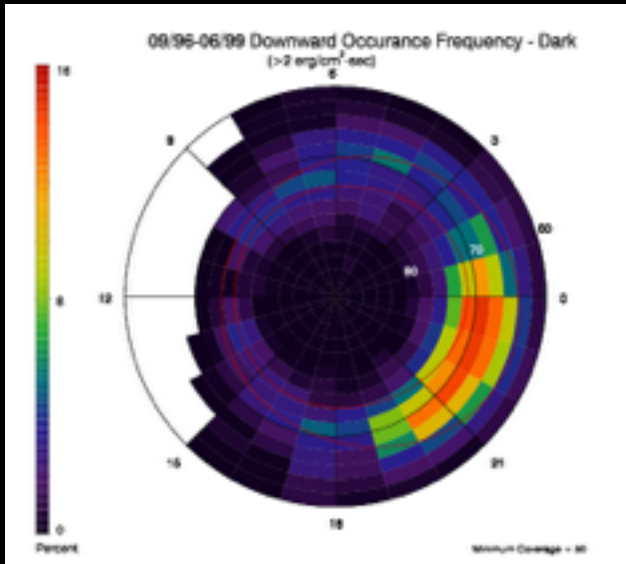
Sunlit

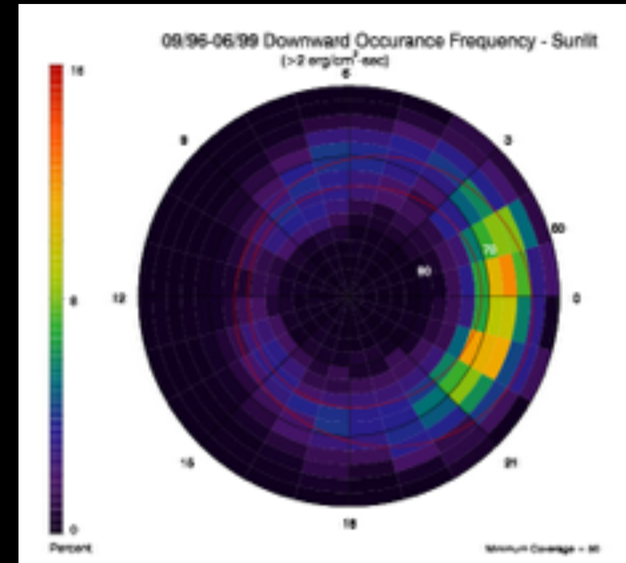




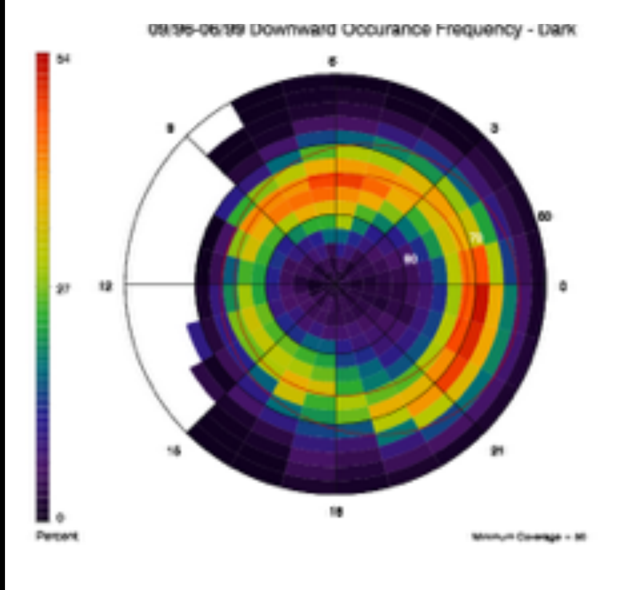
Energy flux dependence

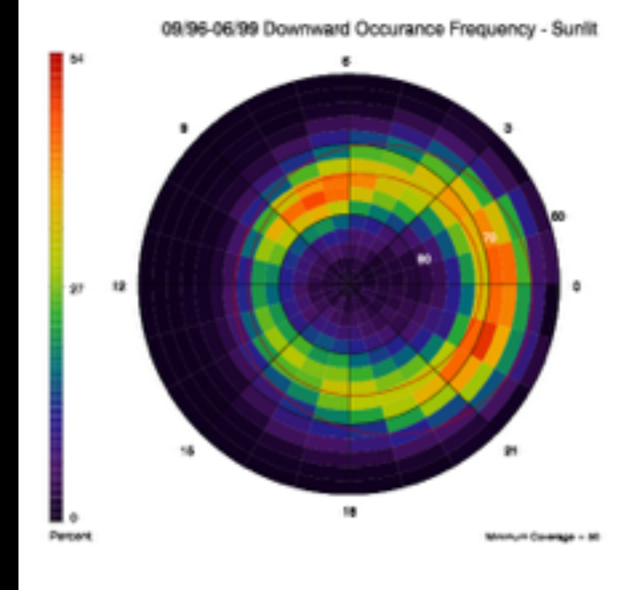
Dark **Sunlit**





Eflux > 2 ergs/cm²s

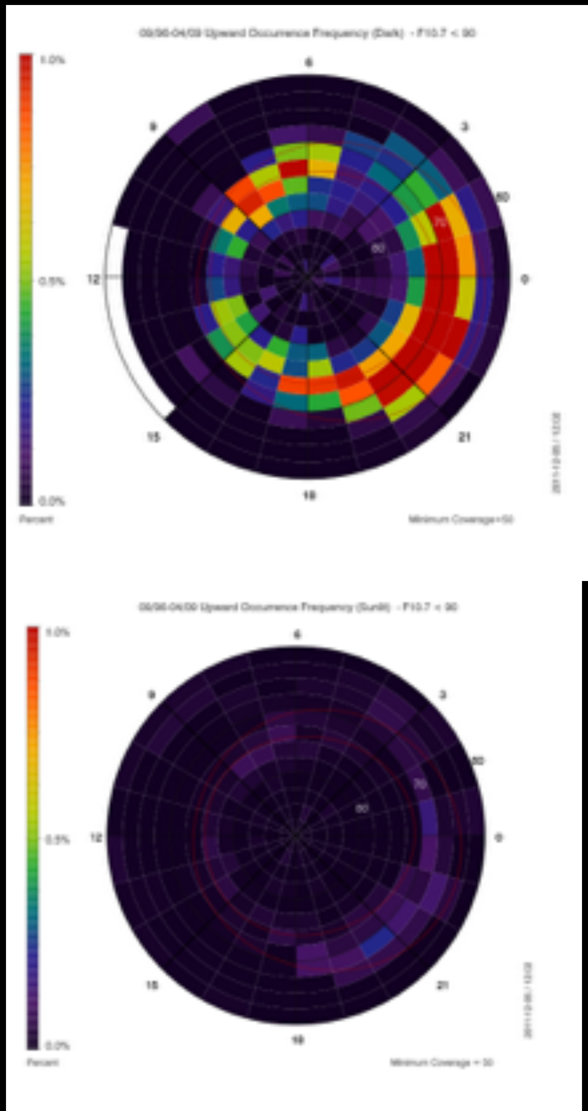




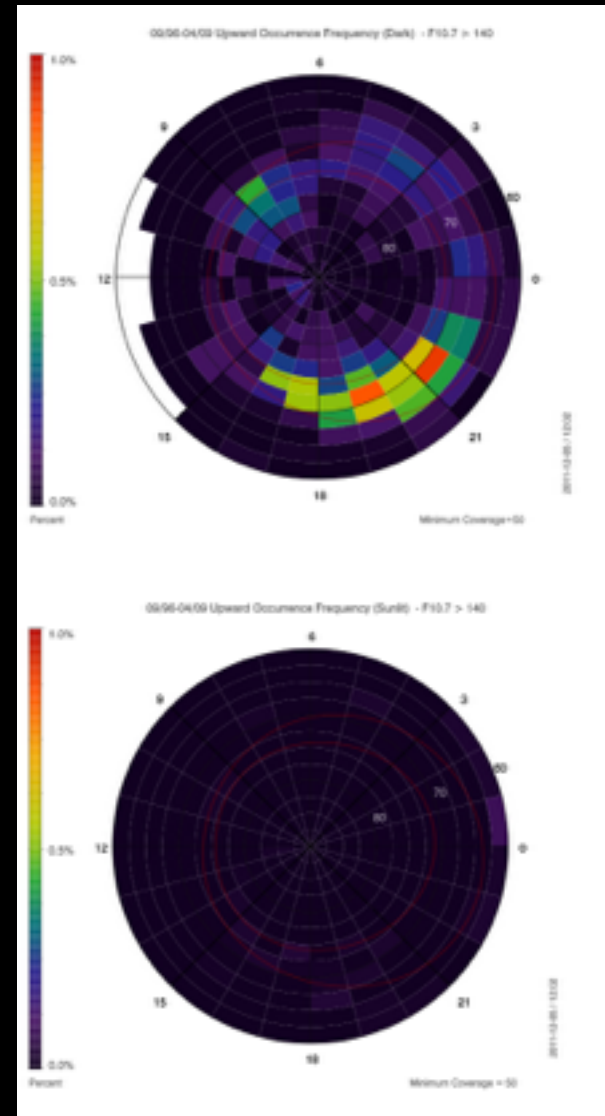
Eflux > 0.5ergs/cm²s

Upgoing Ion Beams (same color scale)

F10.7<90



F10.7>140



Dark

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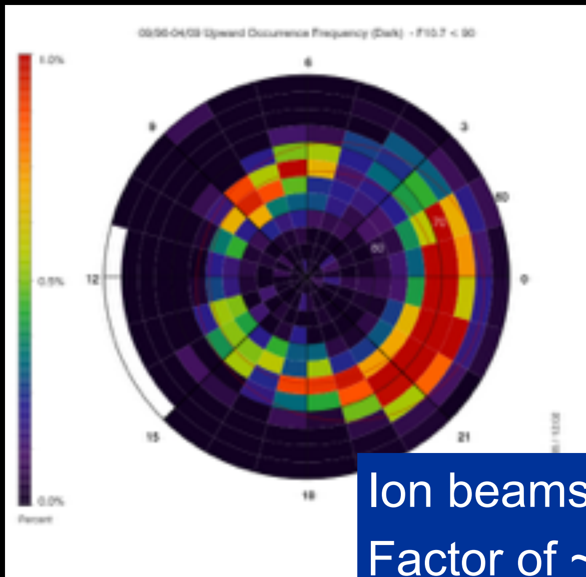

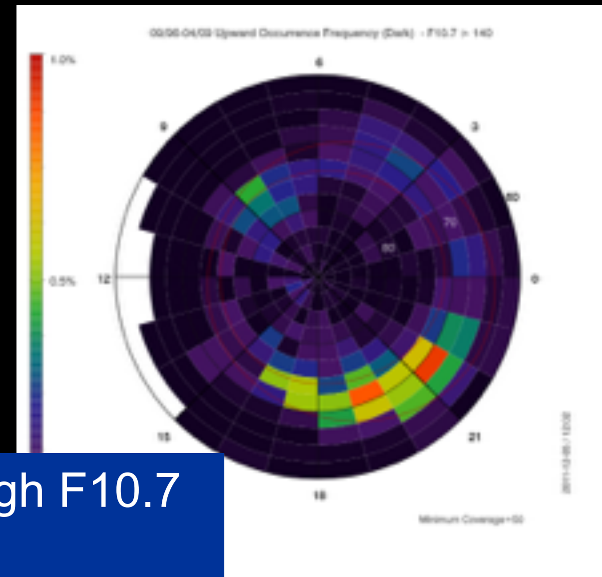

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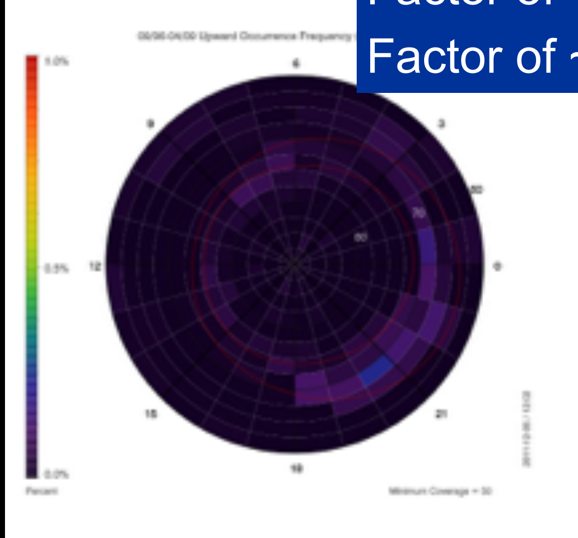
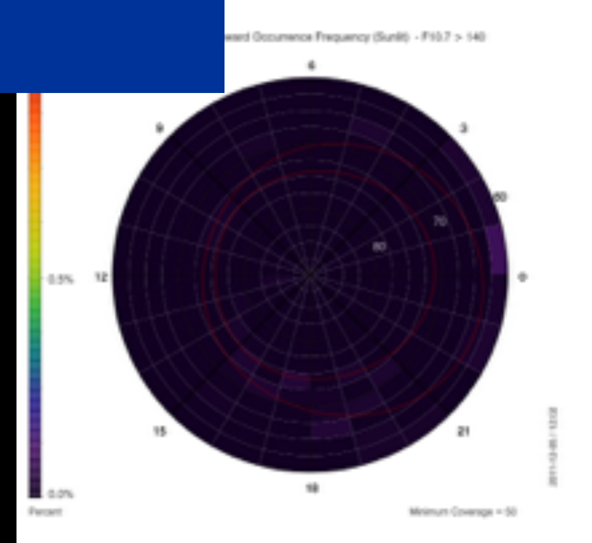
Factor of ~2 in darkness

Factor of ~5 in sun





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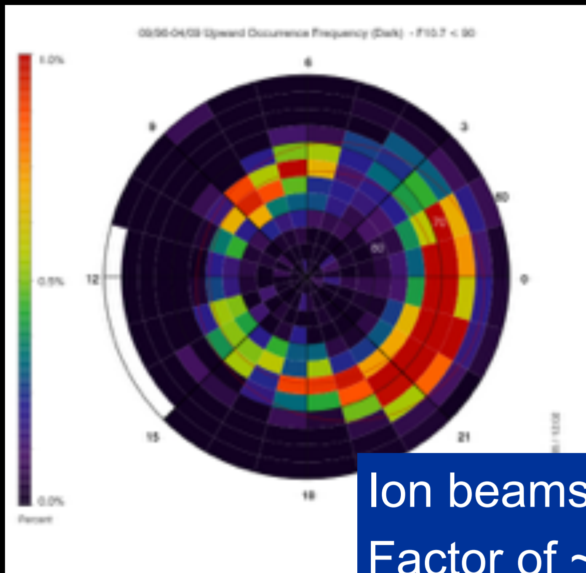

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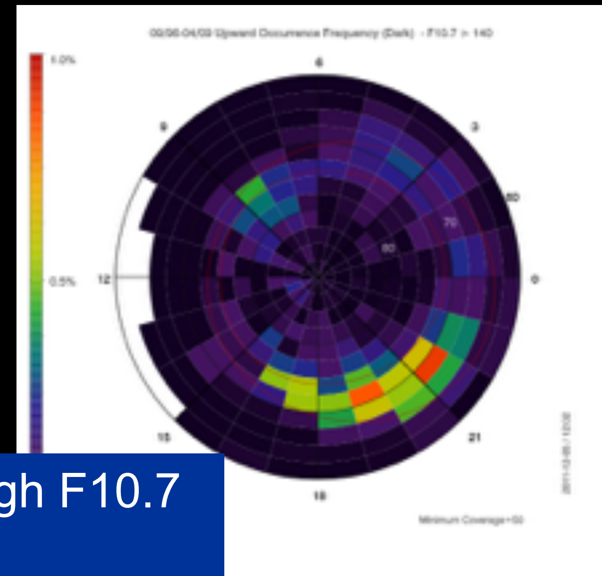

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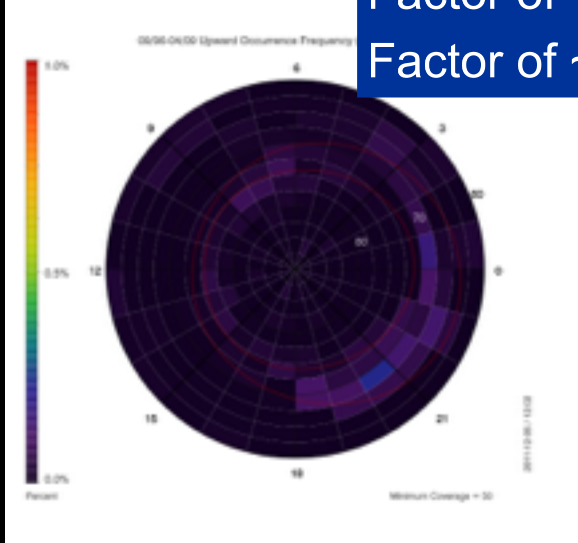
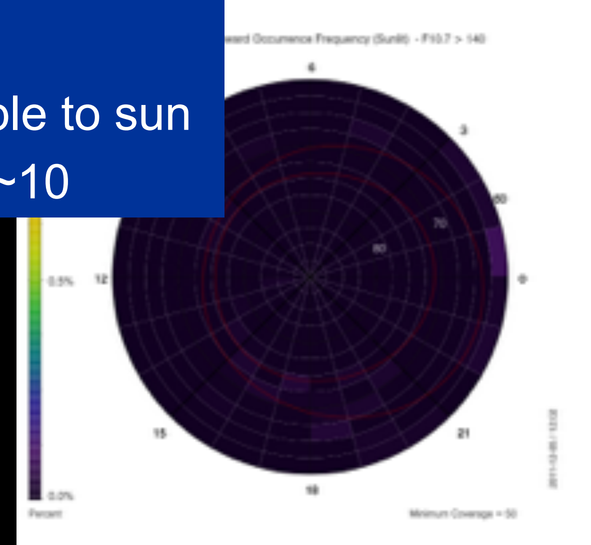
Factor of ~5 in sun

Comparable to sun

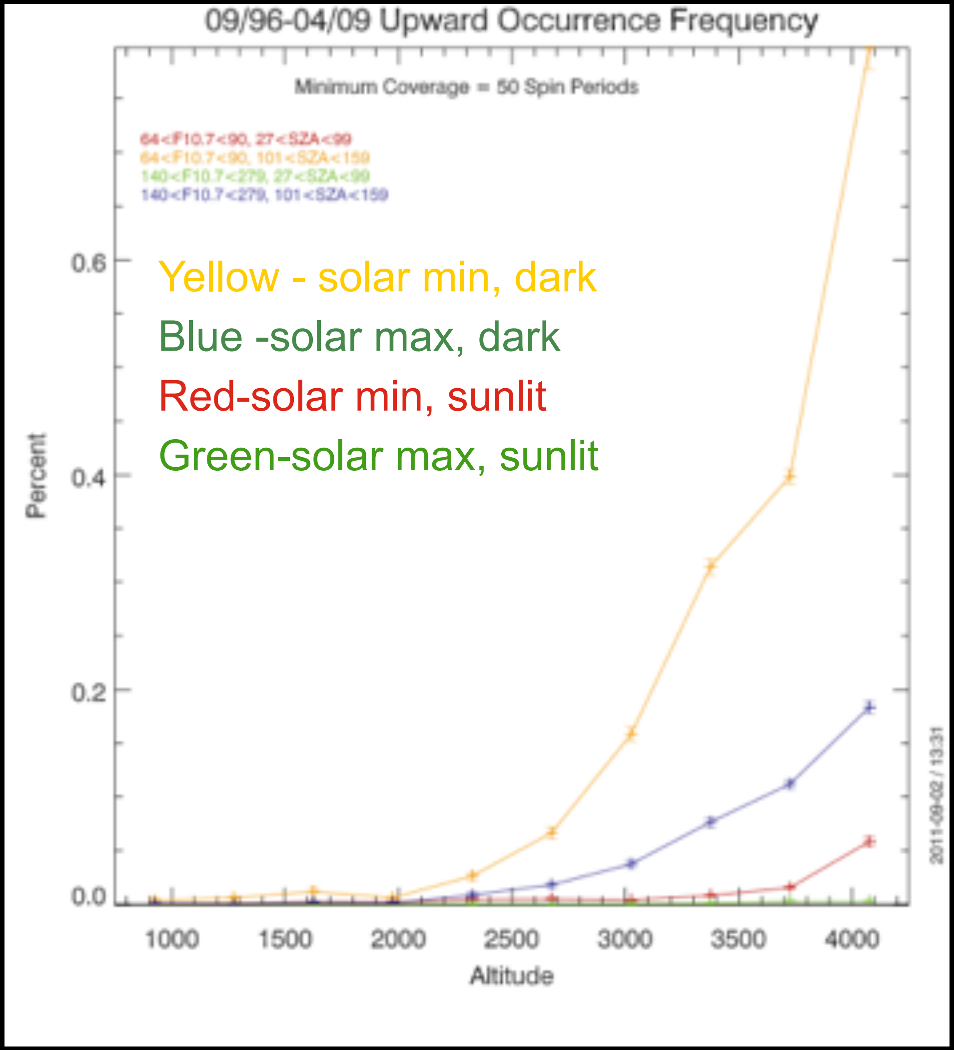
Factor of ~10



Sunlit

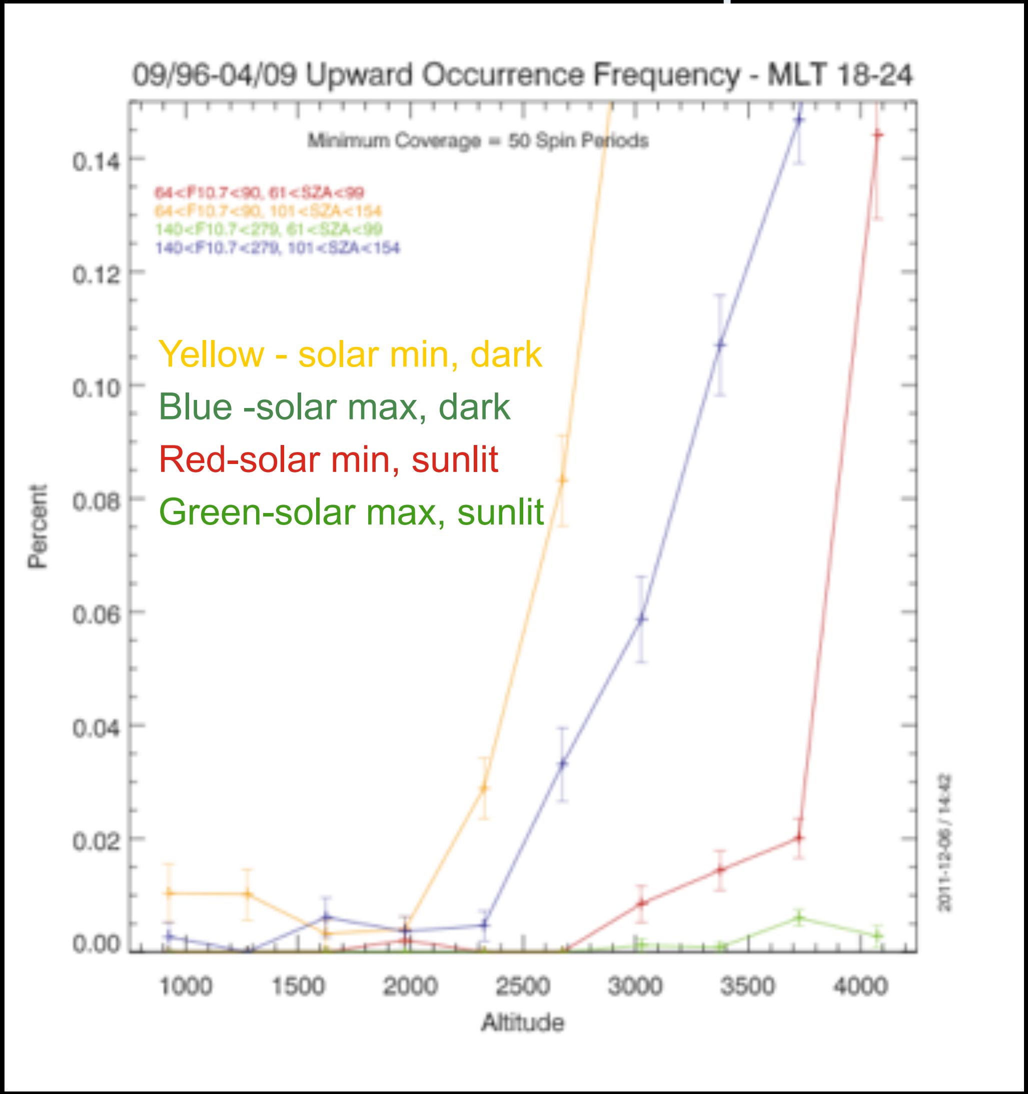


Ion beams: Altitude dependence



- Ion beams rare below ~2000 km
- For dark footpoints, high F10.7 suppresses beams by factor of ~>2 at ~4000km, ~4 at 3500, ~6 at 3000km
- For low F10.7, illumination suppresses beams by ~10 at high altitudes

Altitude dependence, 18-24 MLT



Expanded scale shows altitude where beams are first seen increases with increasing solar flux:

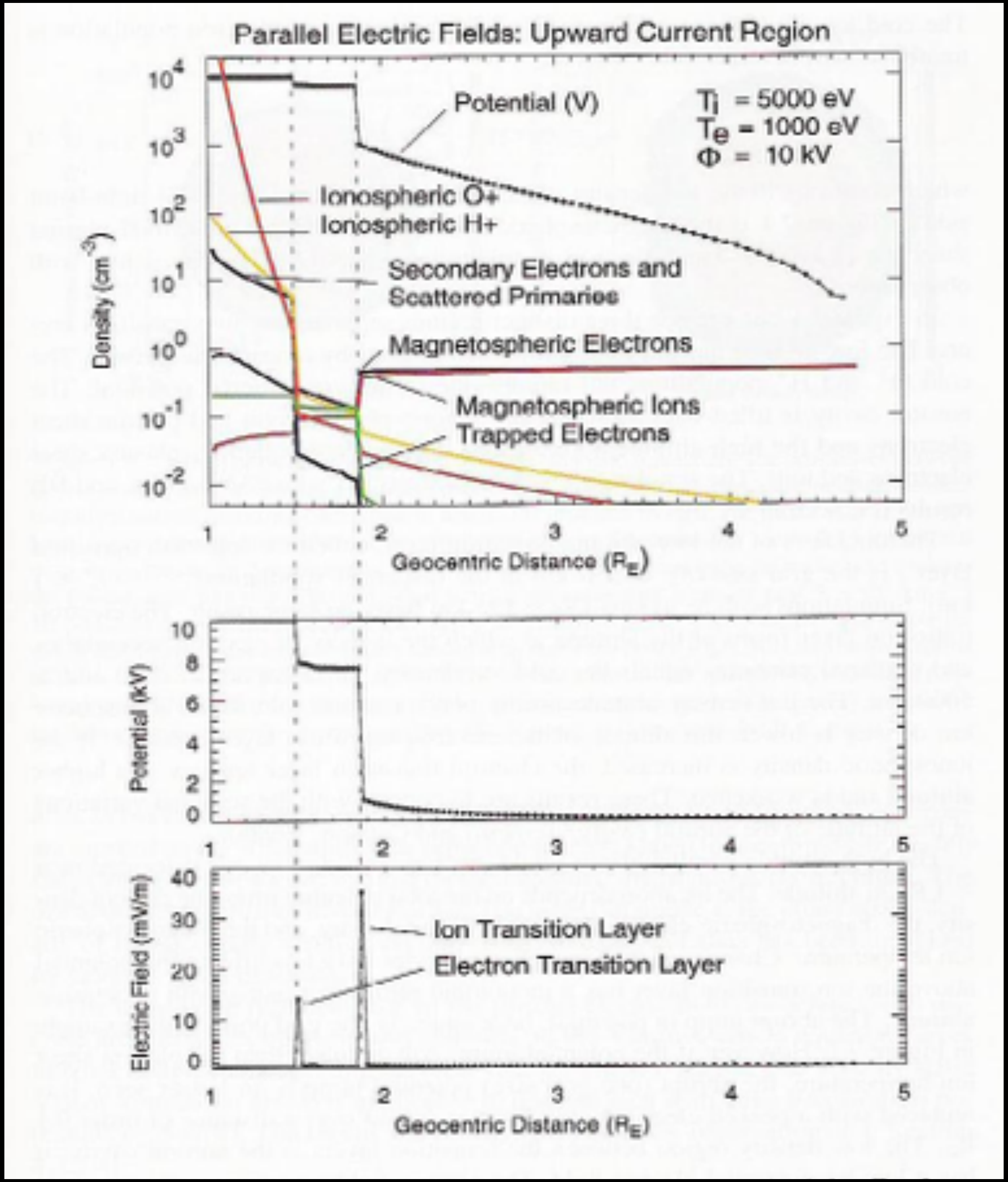
Dark, minimum - ~2000 km, with beams to lowest altitude bin

Dark, maximum - ~2300 km

Sunlit minimum - ~3500 km, with beams down to ~3000 km

Sunlit maximum - ?, few seen, only above 3500 km

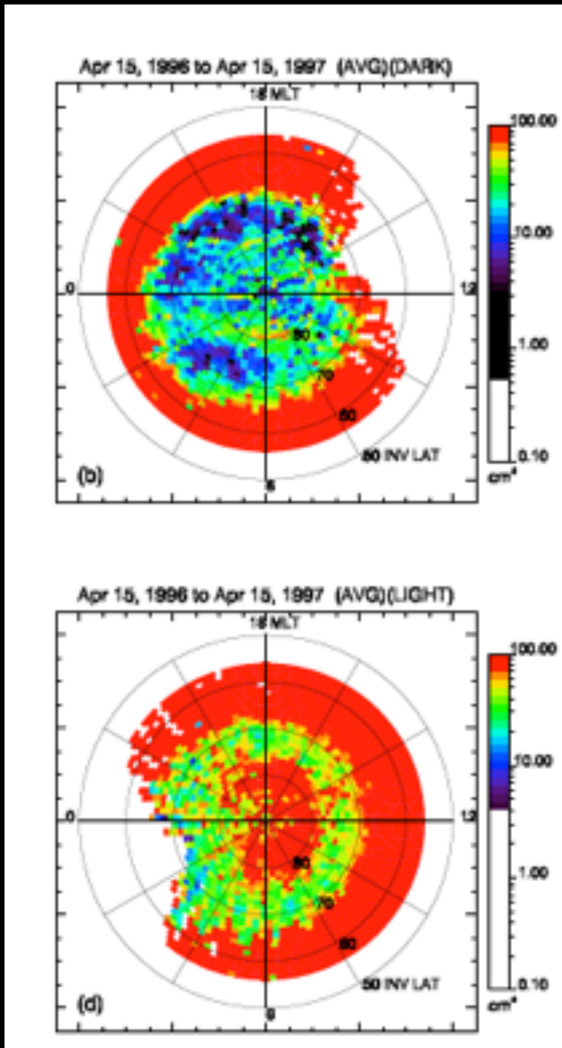
Ergun et al, 2000 Vlasov-Poisson model



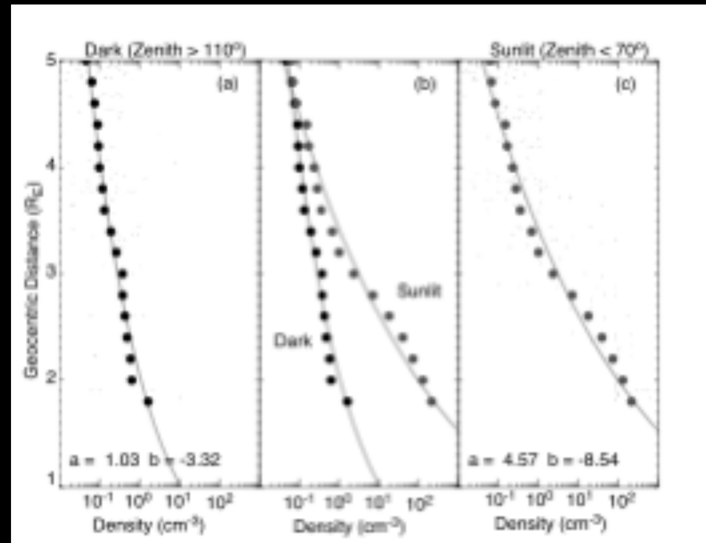
Size and location of potential drop depends on density/ temperature/composition of ionospheric particles

All 3 parameters are modified by solar EUV

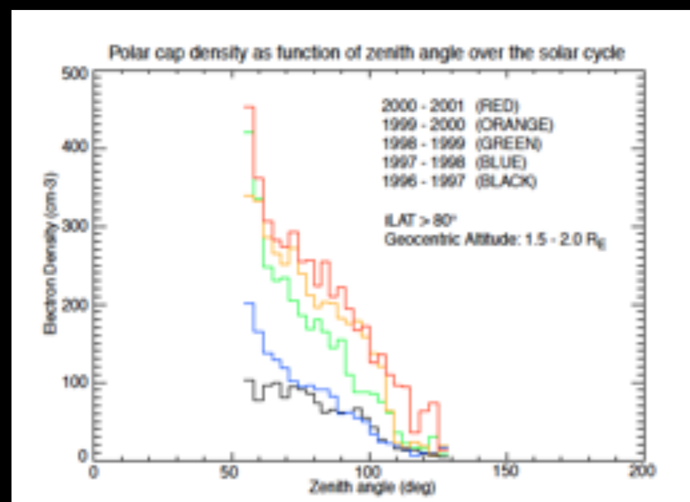
Density dependence on illumination and solar cycle



Density at ~2 Re (Johnson et al., 2002)



Altitude dependence of polar cap density showing increased density to 5 Re for illuminated footpoint compared to dark footpoint (Johnson and Wygant, 2003).



Solar zenith angle dependence of polar cap density by year from solar minimum (1996-black) to maximum (2000-red), showing enhanced density at solar maximum compared to solar minimum for the same solar zenith angle (Johnson, 2002).

Results consistent with dependence on density and scale height, not just conductivity, long-term effects, not just short

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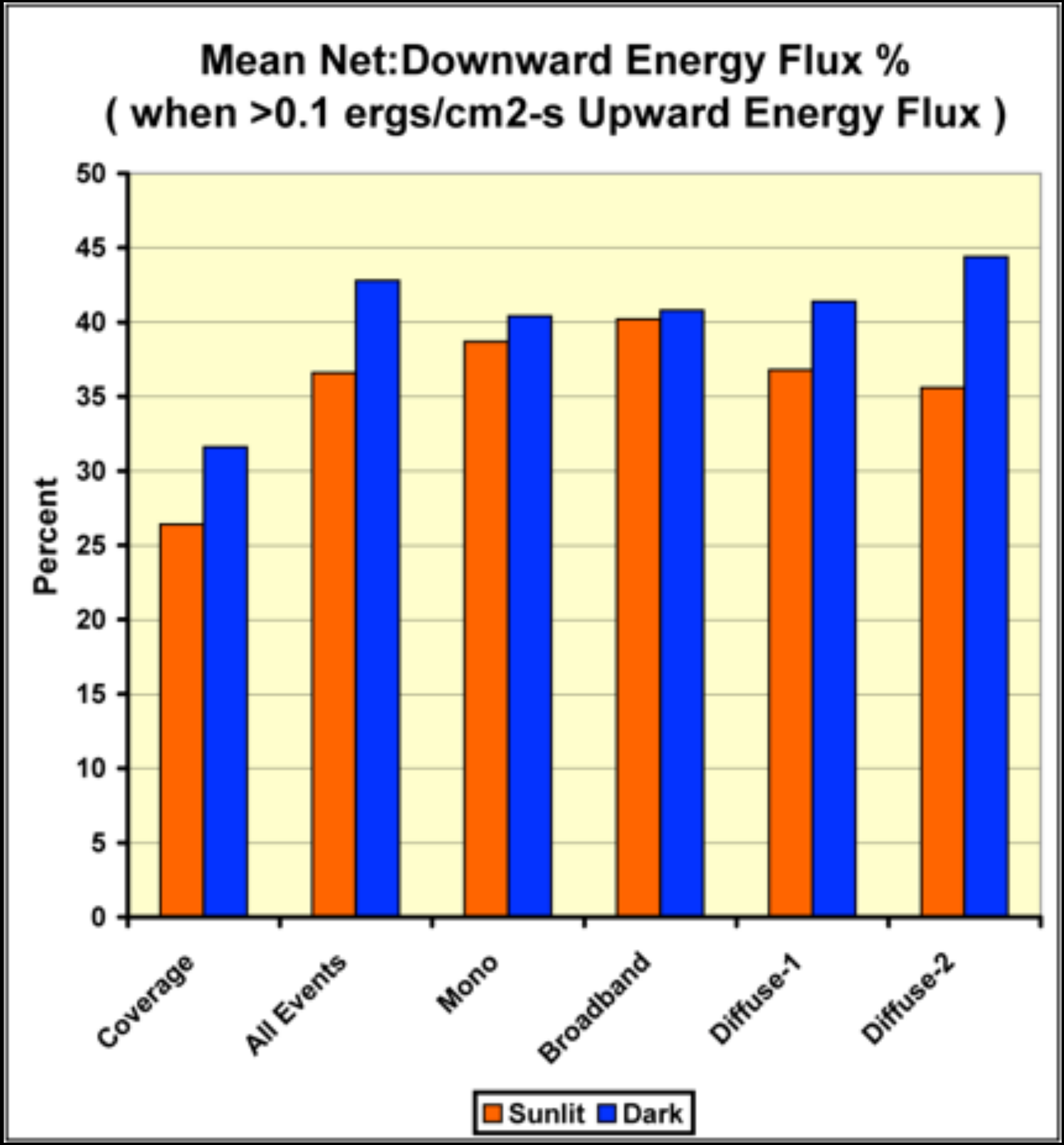
Comparison of Downgoing and Upgoing Energy Flux for Various Event Types

66-74°ILat, 21-03 MLT



Questions for Discussion

How accurate can our general understanding/application/prediction of shorter-term physics be without understanding/accounting for long-term effects?

How do we determine (separate out) these long-term effects without averaging over many solar cycles?

What are the limits on predictability of the SW-M-I-T system due to limitations in solar cycle detail predictability?

How is energy transfer from M to I-T affected by I-T conditions and response, and on what scales?

End