Increases and decreases in radiation belt electron content with geomagnetic activity

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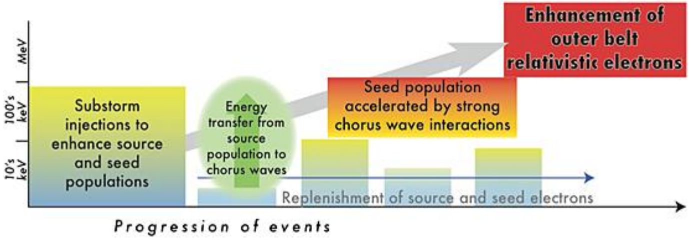
Is geomagnetic activity a good proxy for the physics of the radiation belts?

- Physics tells us that most variations in radiation belts result from wave-particle interactions

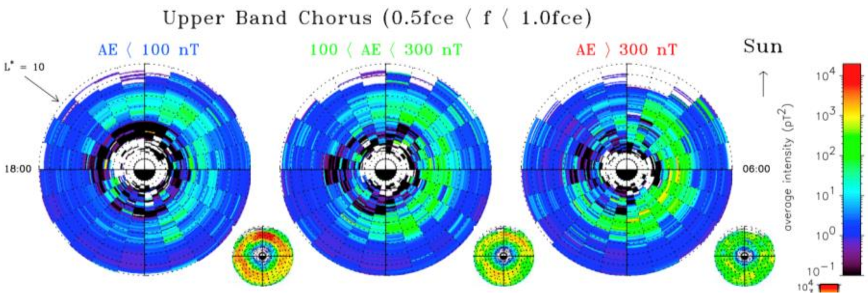
- Wave-power varies with geomagnetic activity levels

  BUT…

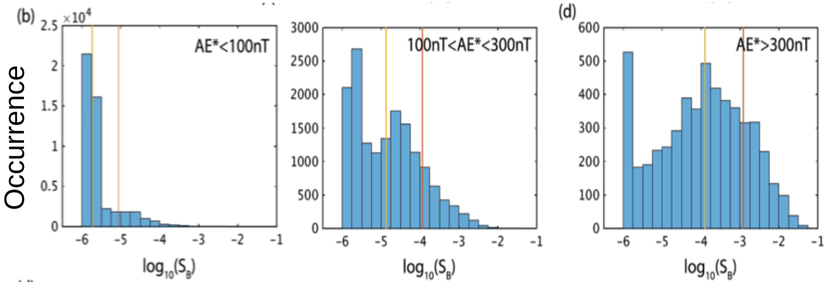
- Distribution of wave power with geomagnetic activity covers many orders of magnitude



Jaynes et al. [2015]



Meredith et al. [2012]



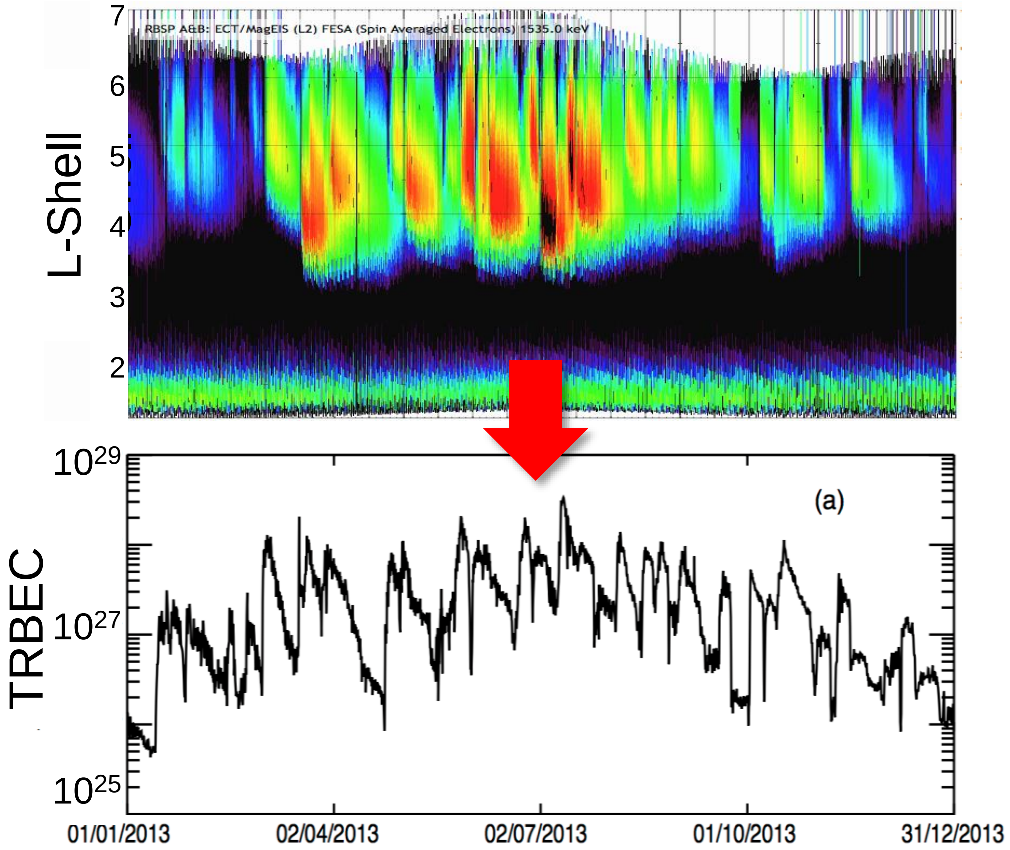
Watt et al. [2017]

Total Radiation Belt Electron Content (TRBEC)

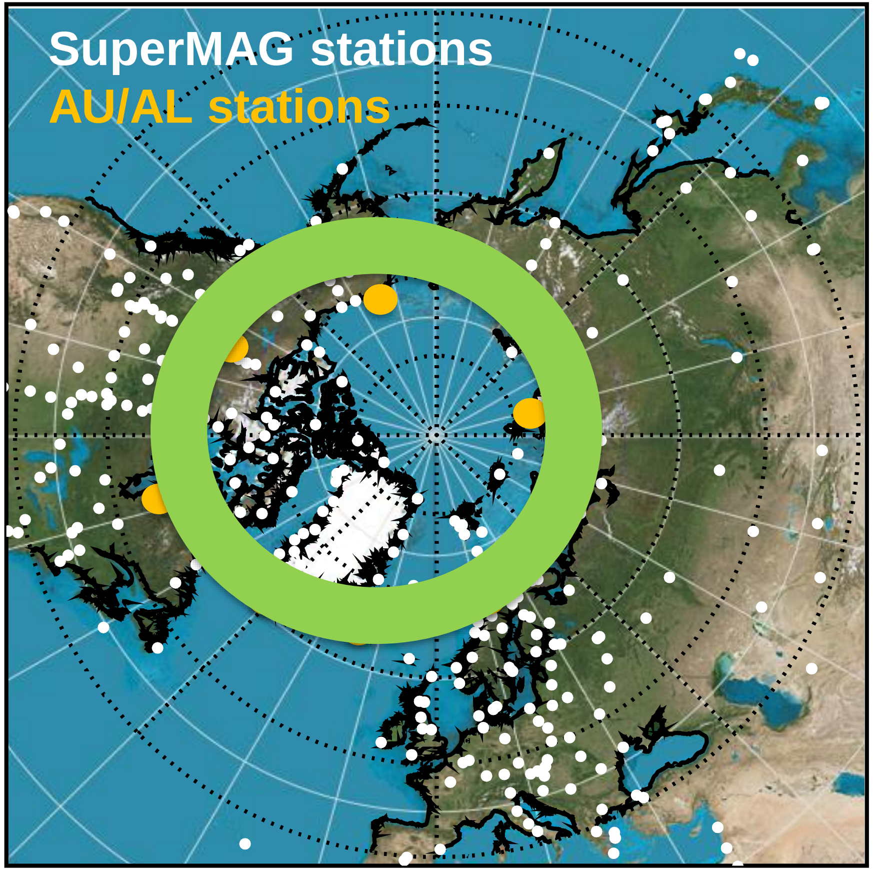
- After Baker et al. [2004], Boyd [2016], Huang et al. [in prep]

- Integrate MagEIS PSD from RBSP-A and RBSP-B for:
  - μ=1000-2000 MeV/G ("core" population)
  - across L and K
  - every half orbit of Van Allen Probes

- Interpolate onto 3 h time-series



Auroral indices with reduced latitudinal dependence



- AL takes minimum H deflection from 12 auroral zone stations
- If auroral currents move away from AL latitudes, same currents will give different AL
  - Particular issue for large events
  - c.f. using L or L*
- SuperMAG AL (SML) uses >100 latitudinally scattered stations
  - Newell & Gjerloev, [2011]; Gjerloev, [2012]

Contingency table analysis of the radiation belts

- Contingency tables compare to independent categories to check for a link

- **No information on size of change or level of activity is used**

	TRBEC DECREASE	TRBEC INCREASE
QUIET	a	b
ACTIVE	c	d

Analysis of Predictive Skill from contingency tables

	TRBEC DECREASE	TRBEC INCREASE
QUIET	97 (a)	1 (b)
ACTIVE	1 (c)	1 (d)

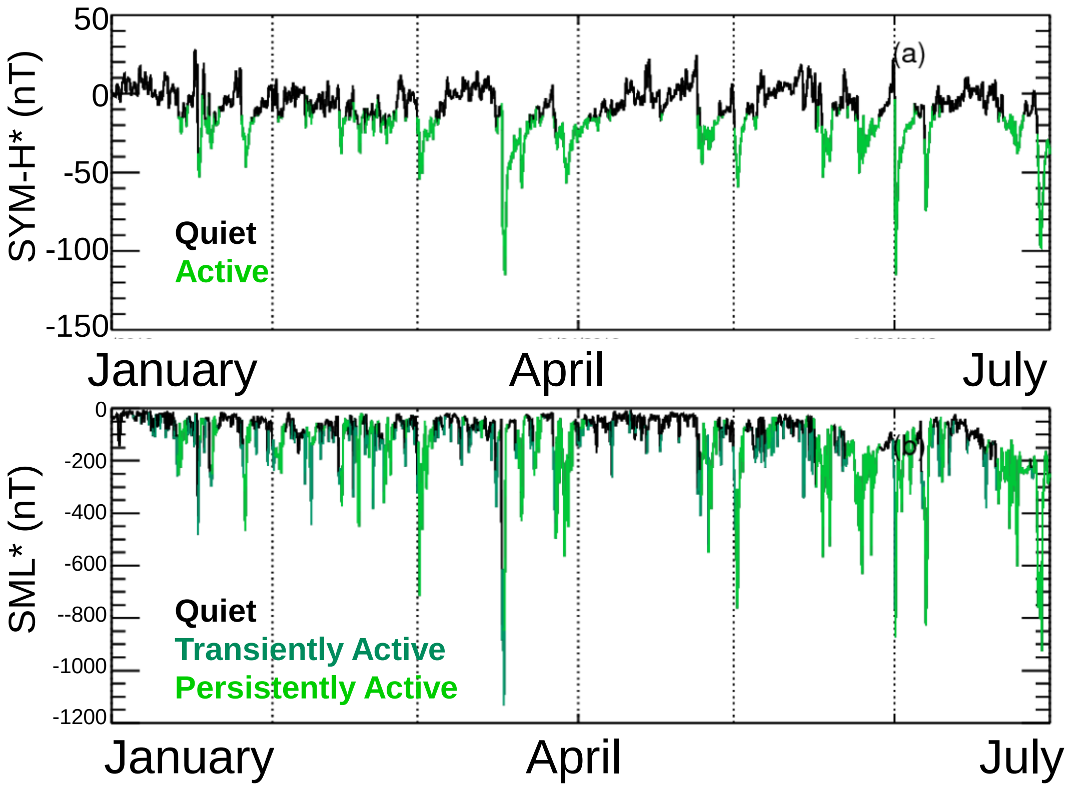
Accuracy = 97%
HSS = 0.49

- Quantitative assessment of Skill can be calculated
- Simplest is accuracy: $$Acc = \frac{(a+d)}{(a+b+c+d)}$$
- Heidke [1926] Skill Score uses all components:

$$HSS = \frac{2(ad - bc)}{(a+c)(c+d) + (a+b)(b+d)}$$

- HSS ranges from -∞ to 1
  - 0 indicates no skill
  - 1 indicates perfect skill
- Used to show substorms have significant influence on radiation belts for up to 6 days [Forsyth et al. 2016]

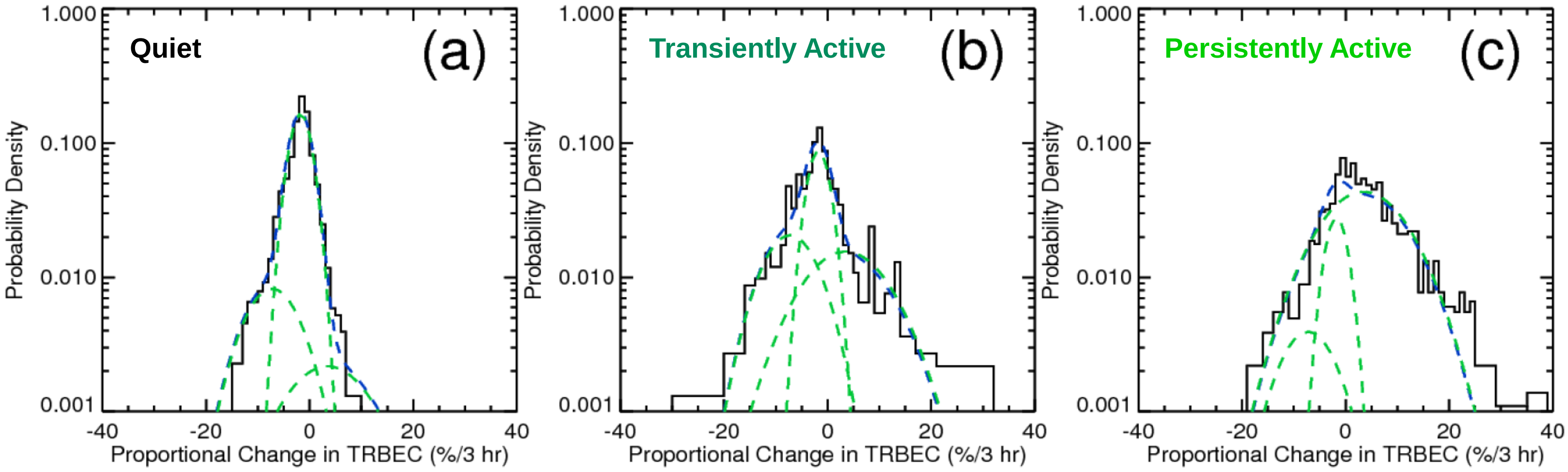
Defining activity based on skill



- Vary threshold of SML or SYM-H *and* time threshold broken to maximise HSS
- Best SYM-H skill (HSS = 0.392):
  > 42 mins/3 h, SYM-H < -16 nT
- Best SML skill (HSS = 0.294):
  > 1 mins/3 h, SML < -251 nT
- **BEST SKILL- SML with persistence:**
  > 1 mins/3 h, SML < -251 nT
  4 out of previous 7 intervals active

  (HSS=0.421; Accuracy=74%)

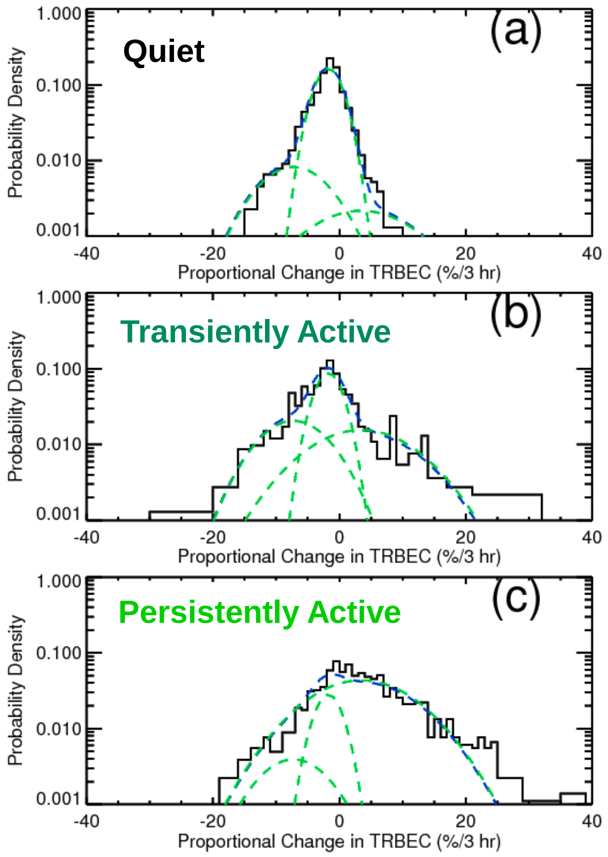
Proportional changes described by three Gaussians



- Triple-Gaussians fit give χ^2<0.08, p-value~1
- Fitted Gaussians are:
  - Narrow: μ_N = -1.75, σ_N =2.07 (% per 3 h)
  - Wide +: μ_{W+} = 3.47, σ_N =8.84 (% per 3 h)
  - Wide - : μ_{W-} = -7.26, σ_N =5.14 (% per 3 h)

- Contribution of each Gaussian varies with activity:
  - **85% Quiet from Narrow (loss dominant)**
  - **85% Persistently Active times from Wide+**
  - **Transiently Active times mixed (45%/ 30%/25%)**

Changes in radiation belt content are stochastic



- Quiet Gaussian is sufficiently narrow that most changes are decreases, thus losses dominate
  - Mean loss rate equivalent to 13.5% per day
  - E-folding of 6.88 days, comparable to GEO [Meredith et al., 2006]
  - ‘Calms before storms’ [Borovsky & Denton, 2009] appear at μ-σ
  - Wave-particle interactions with hiss or outward diffusion? Physics is missing in our study

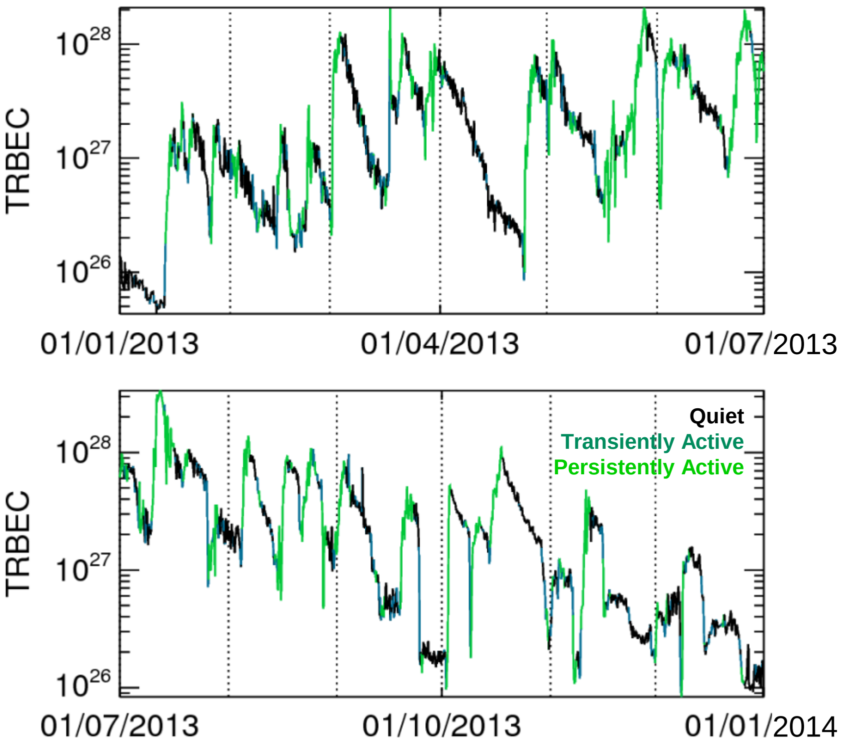
- Transiently Active times show mostly losses, but a greater proportion of large losses

- Persistently Active Gaussian is so wide that both losses and gains appear naturally
  - 25% of losses of more than -4% in 3 h;
  - 25% show changes of between $\pm$4% per 3 h
  - 50% show increases of more than 4% per 3 h

Changes in radiation belt content are Gaussian; Distributions are separated by geomagnetic activity

- **SML can indicate increases or decreases in radiation belt content with 74% accuracy and moderate skill**
  - SML < -251 nT for four of seven 3 h intervals

- **Changes in TRBEC are described by a combination of three Gaussians**
  - Quiet times dominated by narrow, loss dominant Gaussian
  - Persistently active times dominated by wide, gain dominant Gaussian
  - Transiently active times are a mix, but loss dominant



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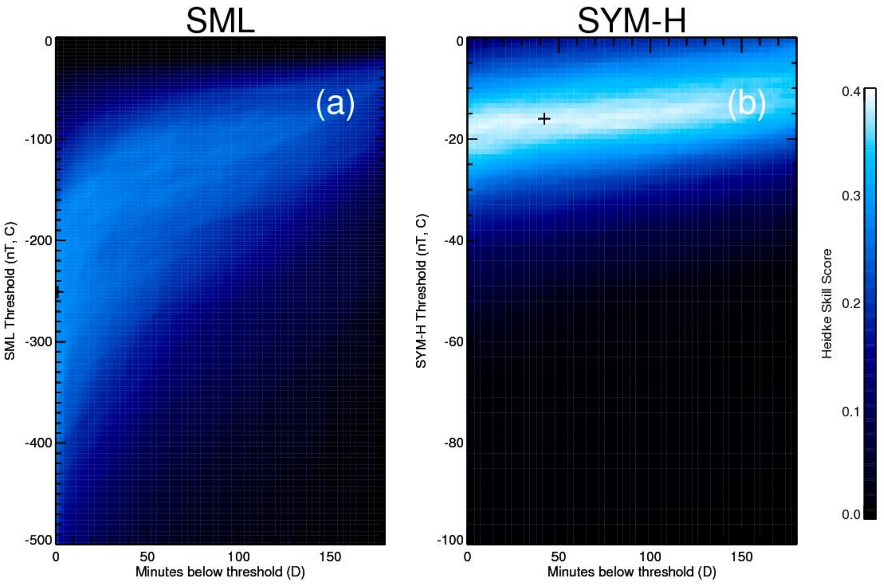
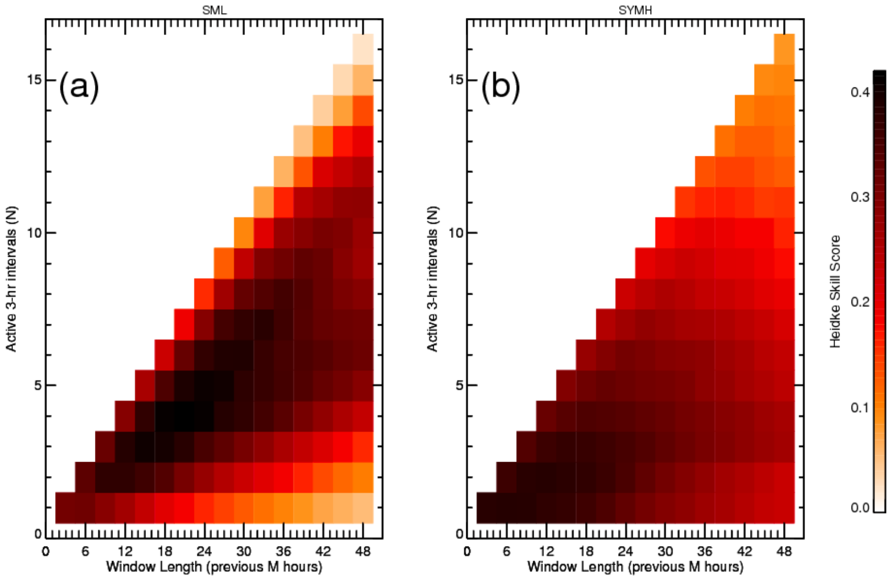
Backup slides

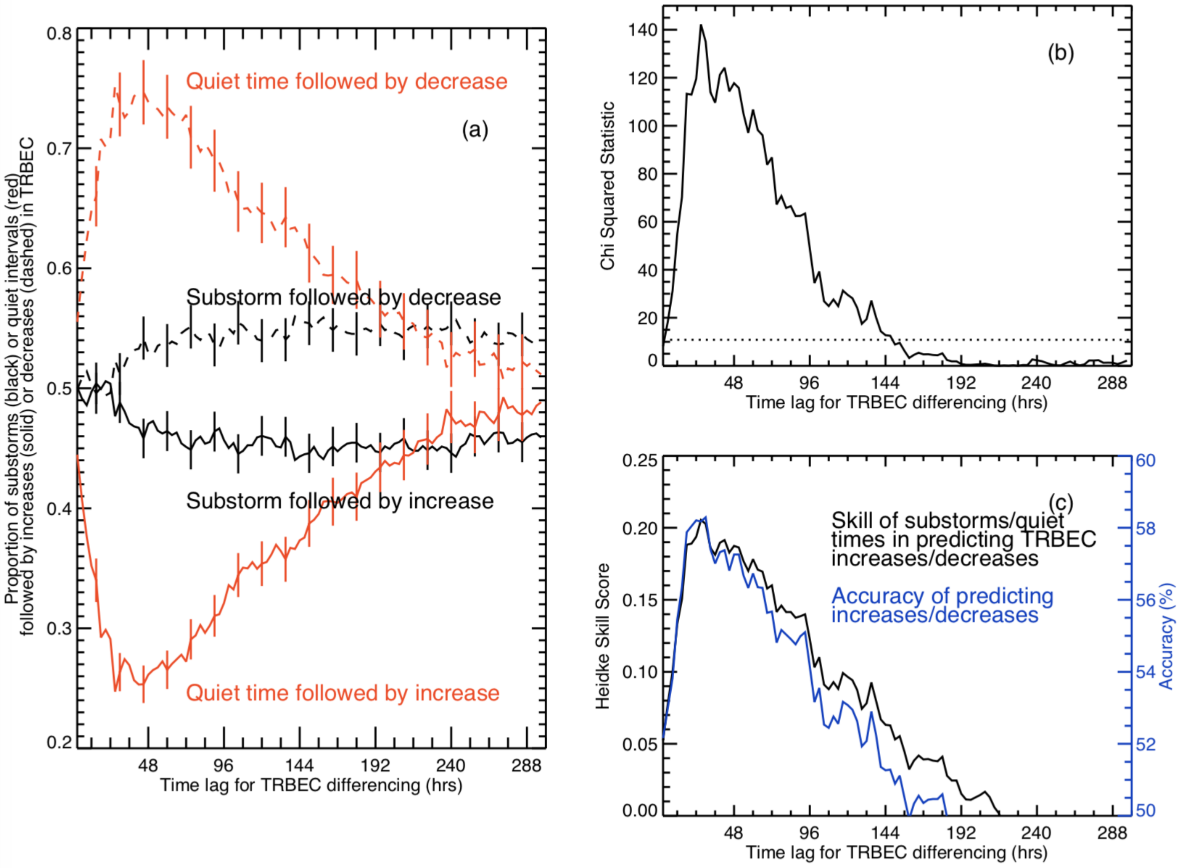
Examination of parameter space of geomagnetic indices





Forsyth et al. [under review]

Substorm impact on the radiation belts



Forsyth et al. [2016]

Best skill contingency table

	TRBEC DECREASE	TRBEC INCREASE
QUIET	1550	447
ACTIVE	311	608