Use of the IMAGE ground magnetometer network's ULF wave observations to derive radial diffusion coefficients in the radiation belts

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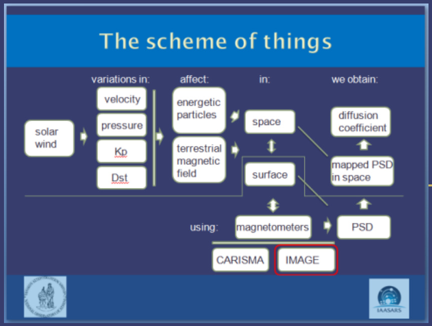
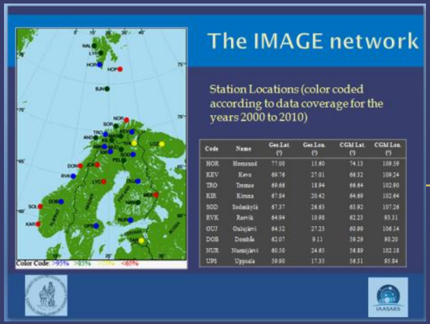
Geospace Revisited, Rhodes, 17/9/2014

Outline

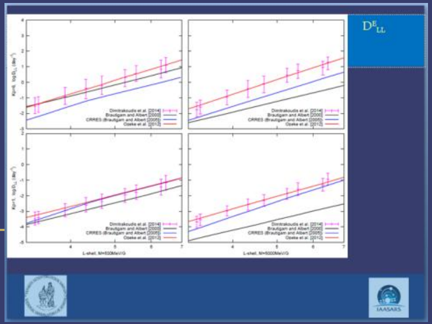


I) Introduction

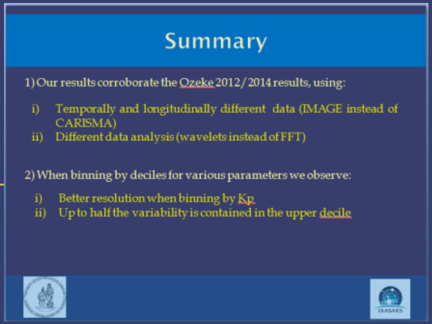


II) Observations

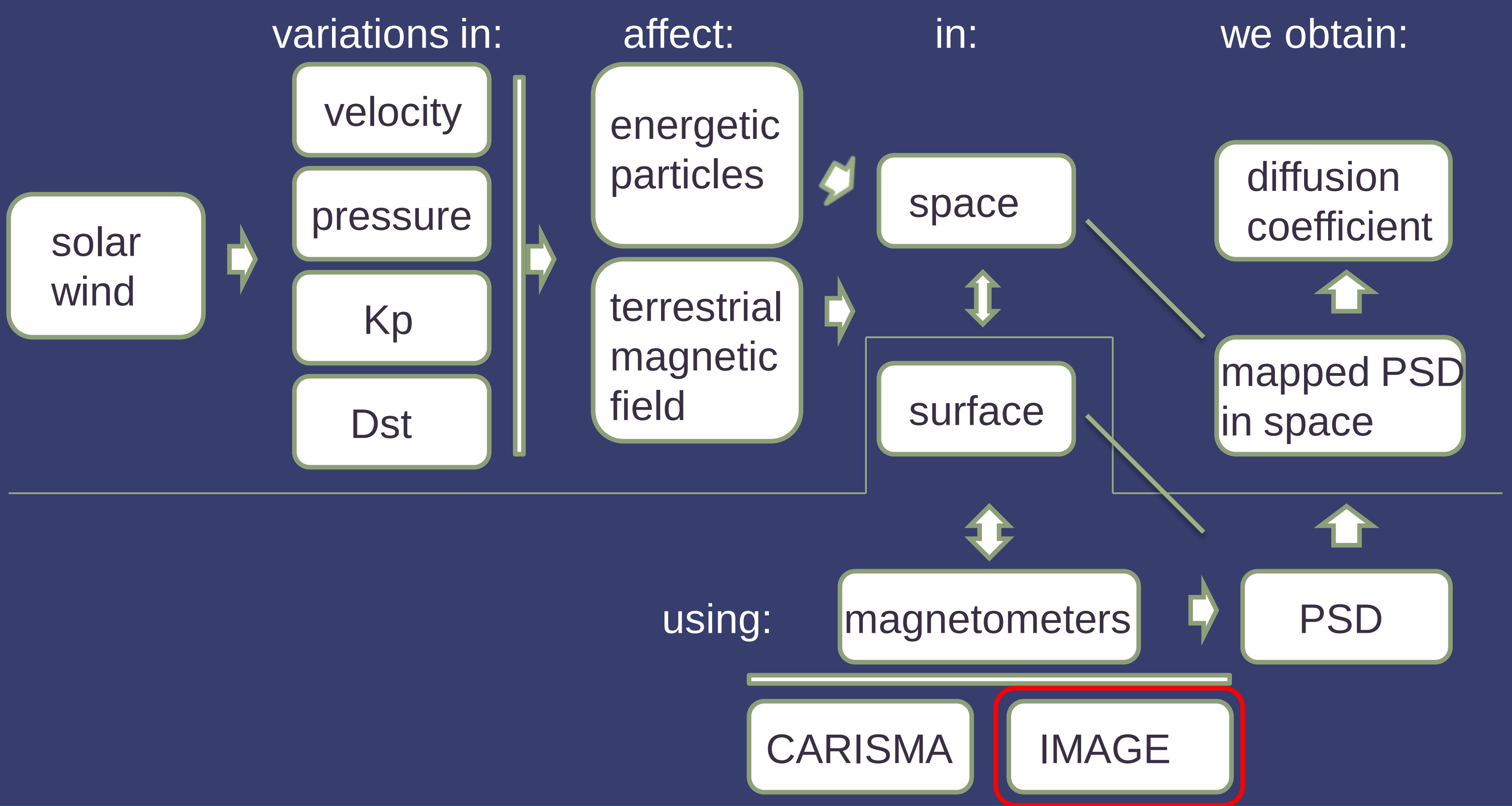
III) Calculations & Results



IV) Summary



The scheme of things



Objectives

1) Calculate the electric field diffusion coefficient using the methodology of Ozeke et al. (2012), using 11 years of European ground observations (IMAGE).

This step will offer a verification of the results of Ozeke et al. (2012), as well as an expansion of the statistical data, since European stations complement the North American ones. Also, a view of the waves at higher L-values.

2) Expand the research by binning the diffusion coefficient according to additional geomagnetic or solar wind parameters; binning by deciles.

With such a study we can ascertain which binning parameter gives the best resolution and, therefore, which parameter is most closely correlated with changes in the diffusion coefficient.

The model

Radial diffusion equation: $$\frac{\partial f}{\partial t} = L^2 \frac{\partial}{\partial L}\left[\frac{D_{LL}}{L^2}\frac{\partial f}{\partial L}\right] - \frac{f}{\tau}$$

Ozeke et al. 2012, JGR

Diffusion coefficient: $$D_{LL} = D_{LL}^{E} + D_{LL}^{B}$$

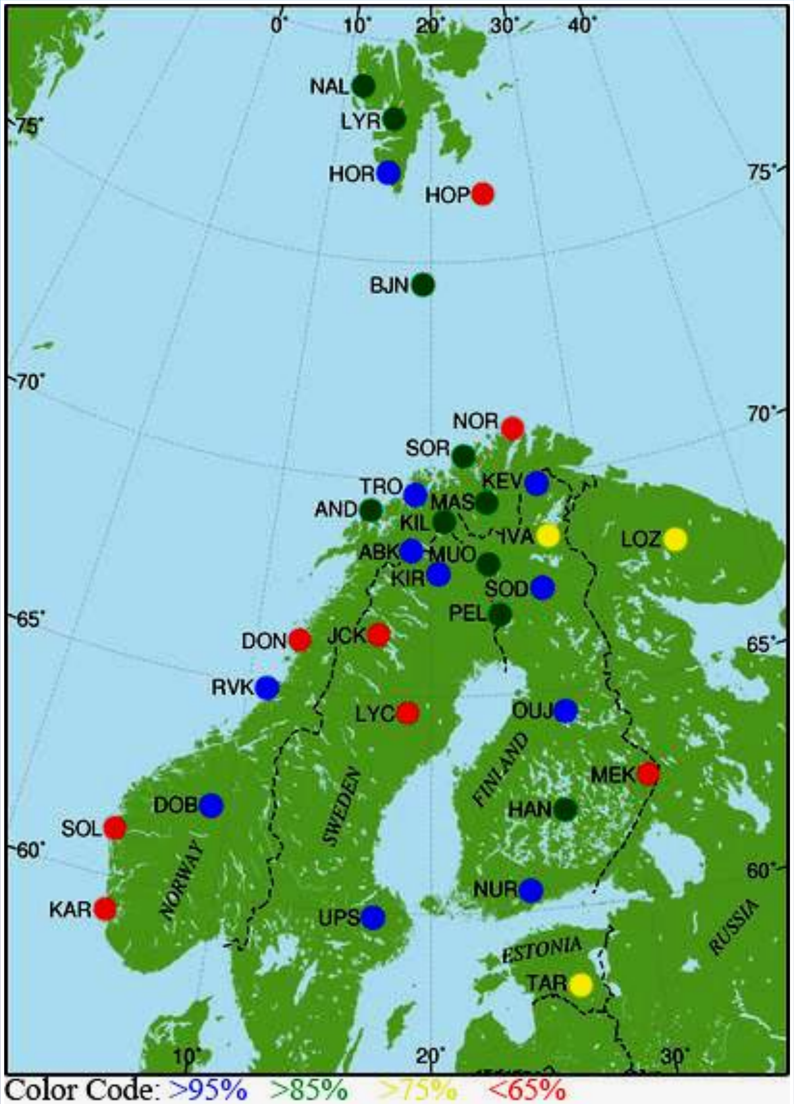
$$D_{LL}^{E} = \frac{1}{8B_E^2 R_E^2} L^6 \sum_m P_m^E(m\omega_d)$$

$$D_{LL}^{B} = \frac{M^2}{8q^2\gamma^2 B_E^2 R_E^4} L^4 \sum_m m^2 P_m^B(m\omega_d)$$

where: $M = \frac{p_\perp^2 L^3}{2m_e B_E}$ is the first adiabatic invariant.

$P_m^E(m\omega_d)$ / $P_m^B(m\omega_d)$: PSD of the electric / magnetic field perturbations, for $\omega - m\omega_d = 0$

The IMAGE network



Station Locations (color coded according to data coverage for the years 2000 to 2010)

Code	Name	Geo.Lat. (°)	Geo.Lon. (°)	CGM Lat. (°)	CGM Lon. (°)	L-shell
HOR	Hornsund	77	15.6	74.13	109.59	13.6
TRO	Tromsø	69.66	18.94	66.64	102.9	6.46
KEV	Kevo	69.76	27.01	66.32	109.24	6.3
KIR	Kiruna	67.84	20.42	64.69	102.64	5.56
SOD	Sodankylä	67.37	26.63	63.92	107.26	5.26
RVK	Rørvik	64.94	10.98	62.23	93.31	4.68
OUJ	Oulujärvi	64.52	27.23	60.99	106.14	4.32
DOB	Dombås	62.07	9.11	59.29	90.2	3.89
NUR	Nurmijärvi	60.5	24.65	56.89	102.18	3.4
UPS	Uppsala	59.9	17.35	56.51	95.84	3.34

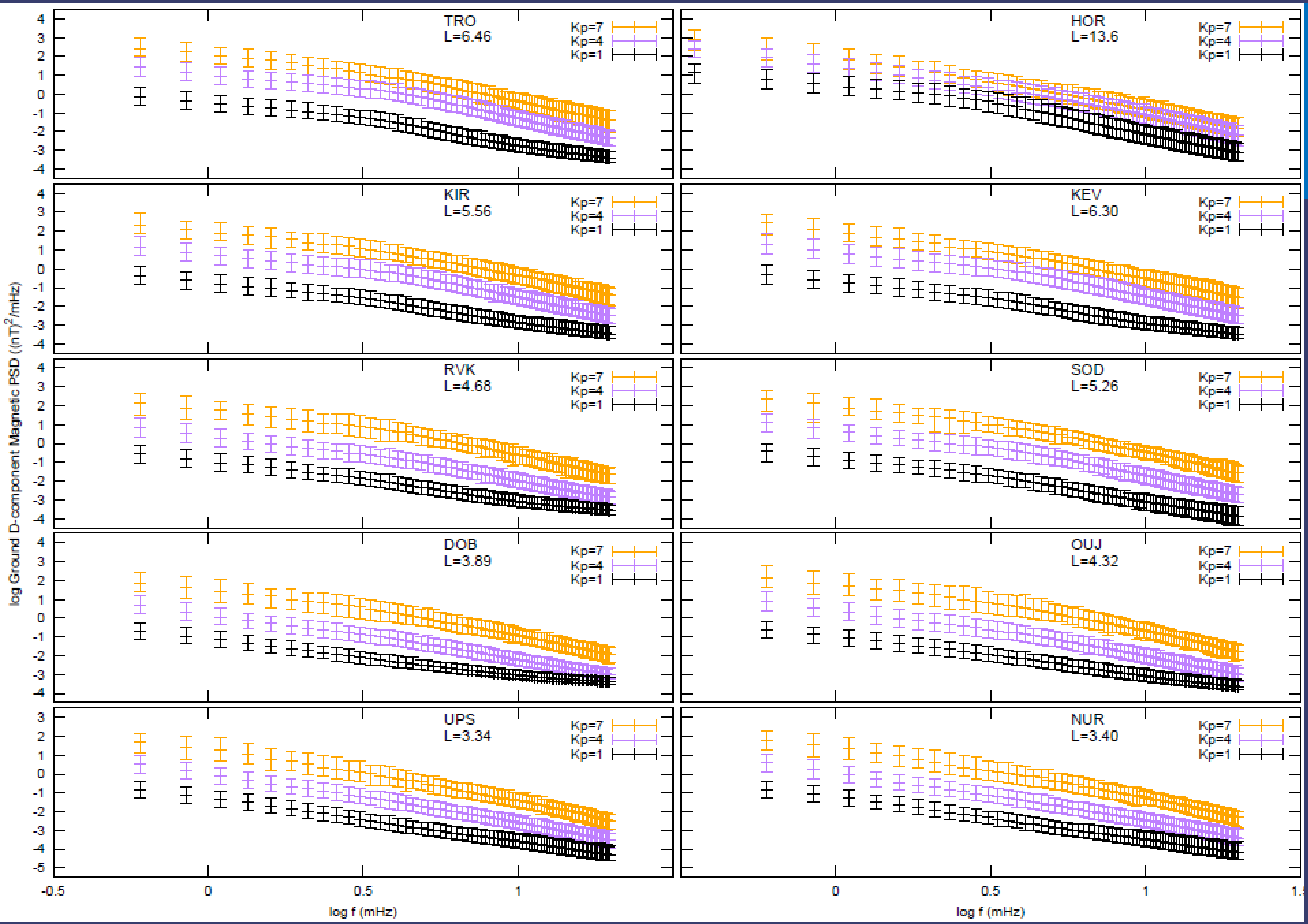
IMAGE data processing steps (TFA tool)

- Reading data (extended time interval to avoid edge effects)
- Checking for Data Gaps (set to NaN)
- Checking for FILL VALUES (set to NaN)
- Calculating Wavelet Power Spectral Density matrix at frequencies from 0.6 to 19.85 mHz (linearly spaced with a step of 0.25 mHz)
- Remove extended intervals
- Segment to hourly intervals
- Discard intervals with excessive NaNs
- Keep only daytime values

Balasis et al. 2012,
Annales Geophysicae

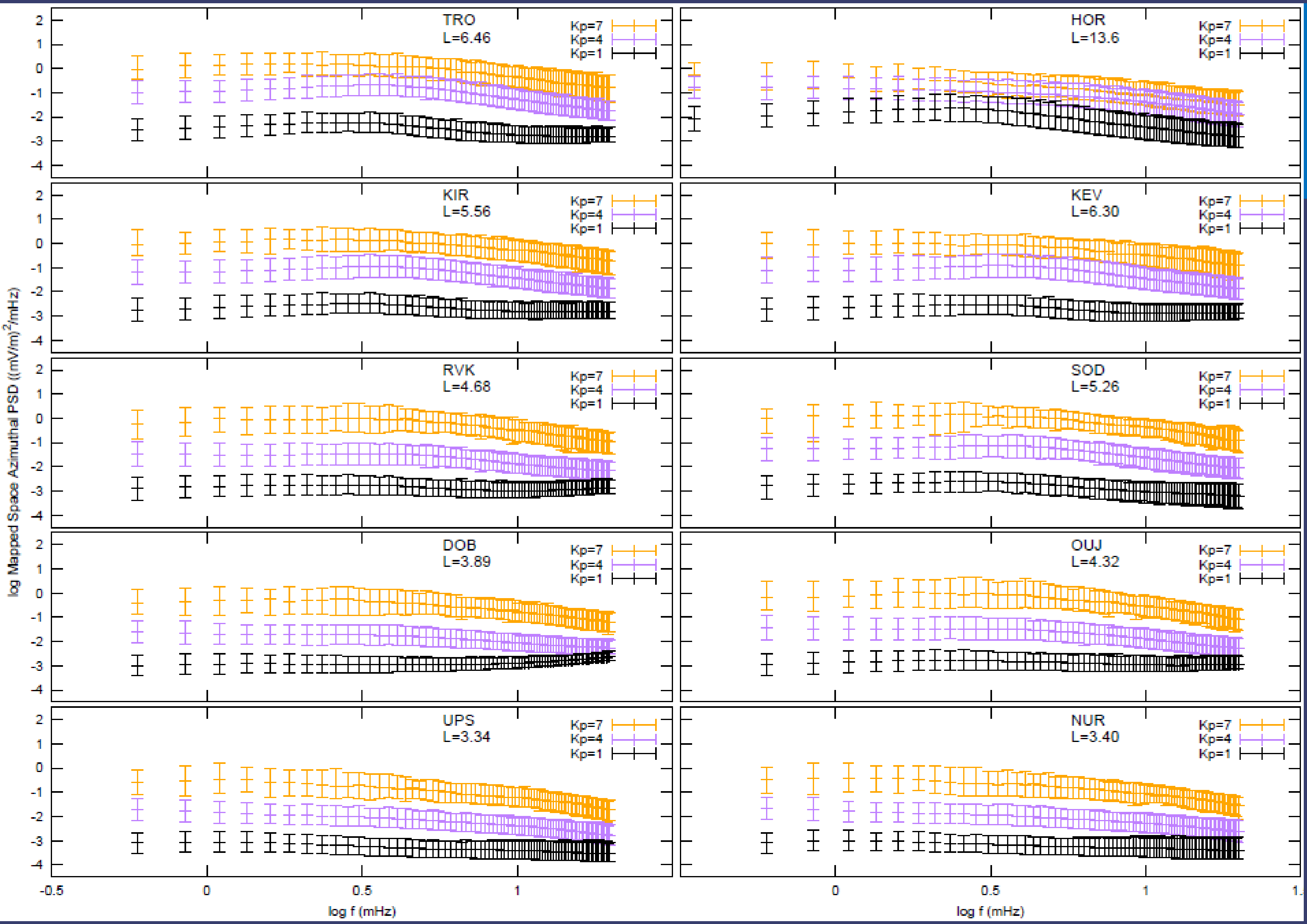
Balasis et al. 2013,
Earth, Planets and Space

PSDs on the ground

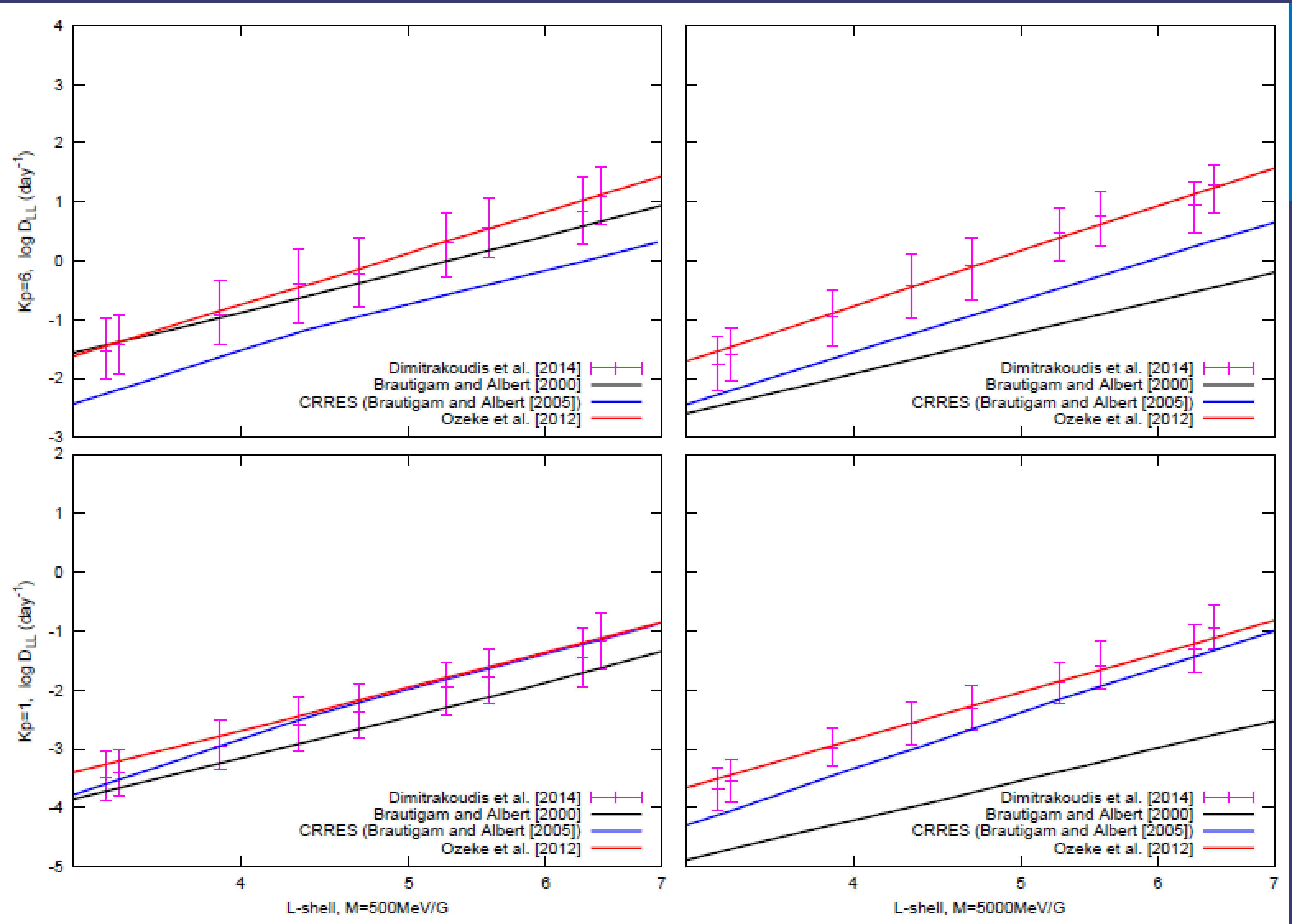


IAASARS

PSDs mapped to space



D^{E}_{LL}


Kp=6, log D_LL (day^-1)
Kp=1, log D_LL (day^-1)
Dimitrakoudis et al. [2014]
Brautigam and Albert [2000]
CRRES (Brautigam and Albert [2005])
Ozeke et al. [2012]
L-shell, M=500MeV/G
L-shell, M=5000MeV/G

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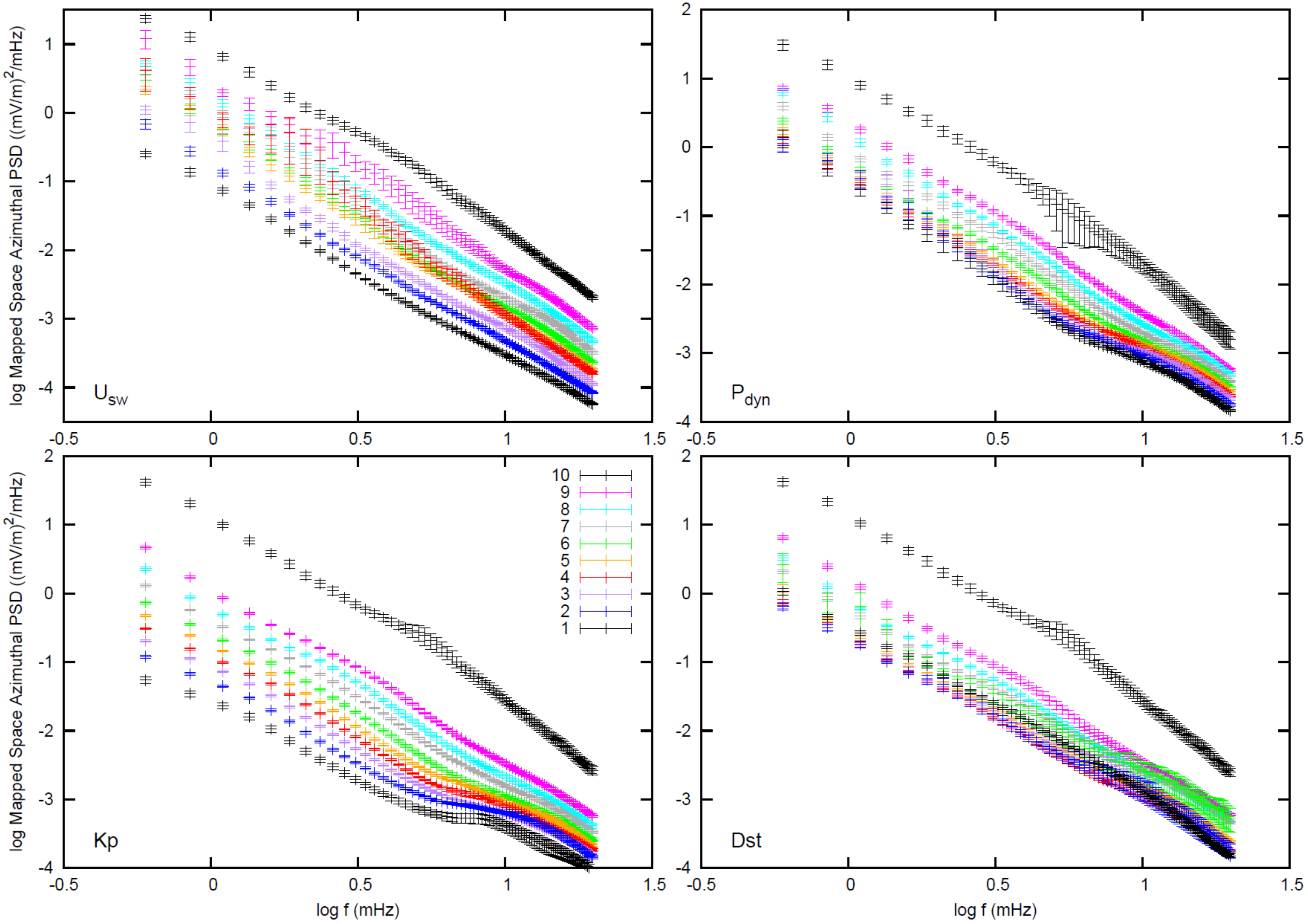
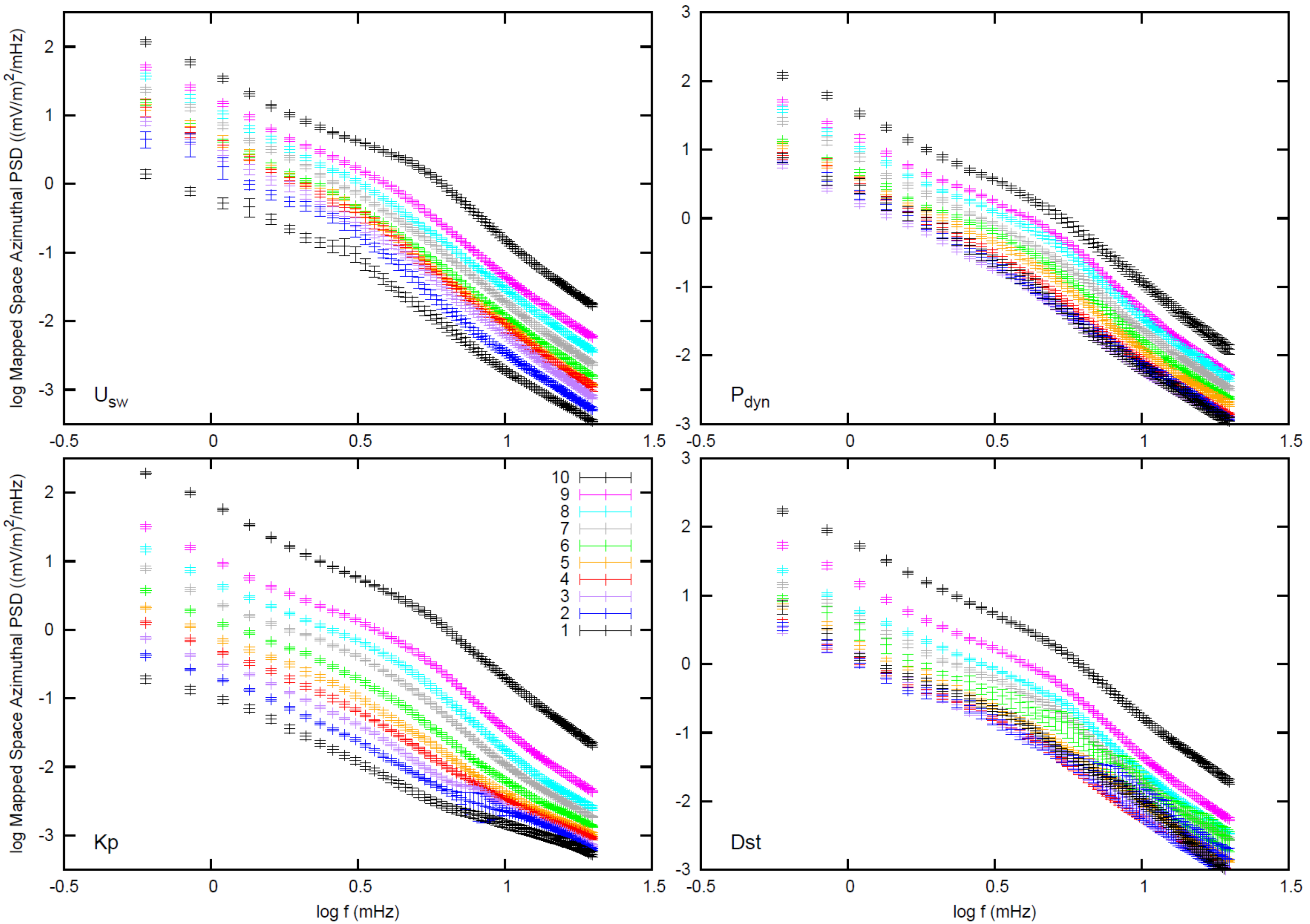
Binning with other parameters

Decile border	Kp	V_{sw}(km/s)	P_{dyn}(nPa)	Dst(nT)
0	0	233	0.03	67
1	0.3	320	0.81	6
2	0.7	346	1.01	1
3	1	369	1.19	-2
4	1.3	393	1.36	-6
5	1.7	418	1.57	-9
6	2	448	1.81	-13
7	2.7	485	2.14	-18
8	3	537	2.61	-25
9	3.7	607	3.54	-35
10	9	1189	79.05	-422

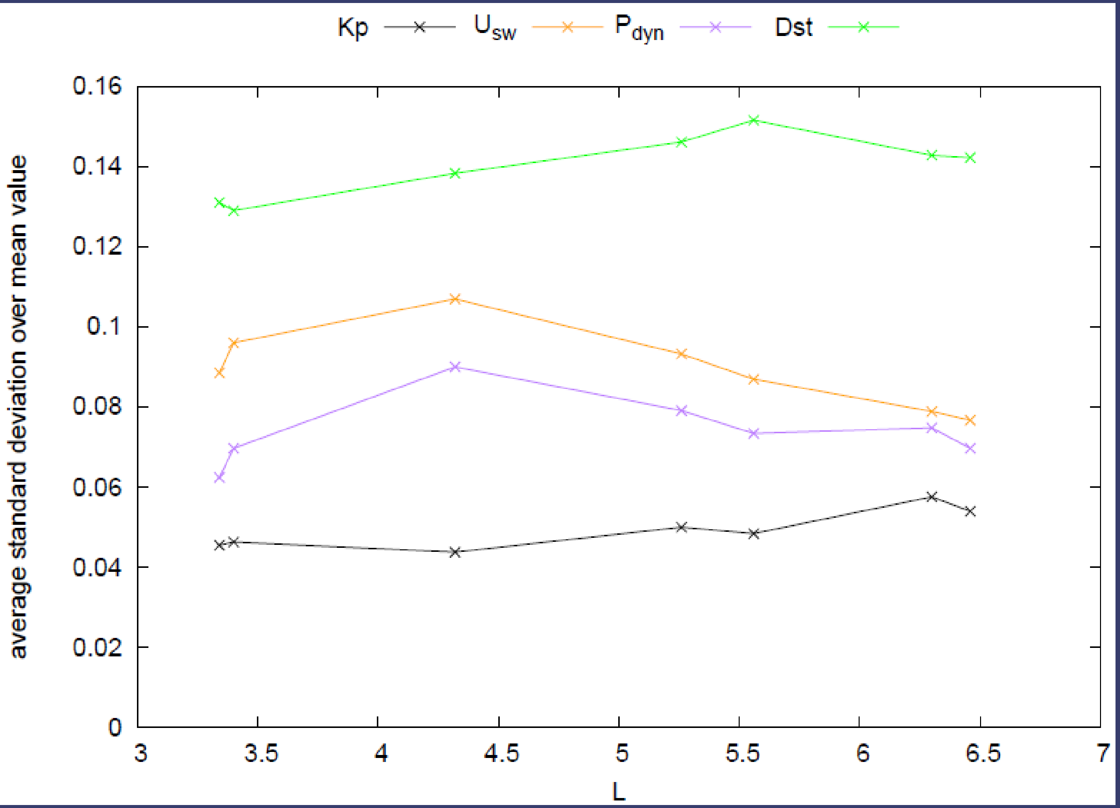
UPS
L=3.34


log Mapped Space Azimuthal PSD ((mV/m)^2/mHz)
U_{sw}
P_{dyn}
Kp
Dst
10
9
8
7
6
5
4
3
2
1
log f (mHz)

KEV
L=6.3


log Mapped Space Azimuthal PSD ((mV/m)^2/mHz)
log f (mHz)
U_sw
P_dyn
Kp
Dst
10
9
8
7
6
5
4
3
2
1
-0.5
0
0.5
1
1.5
3
2
1
0
-1
-2
-3

Standard deviation comparison



Summary

1) Our results corroborate the Ozeke 2012/2014 results, using:

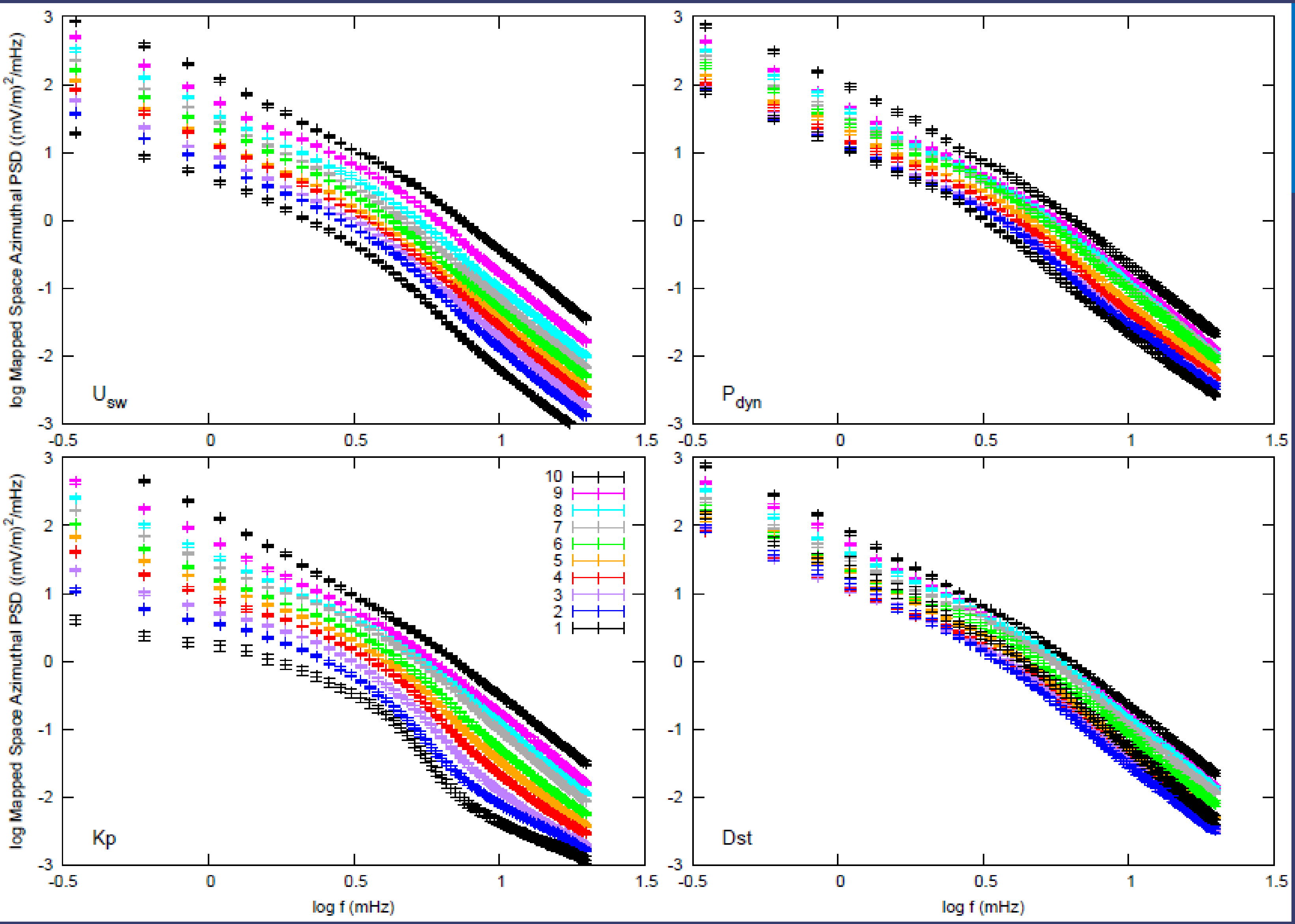
i) Temporally and longitudinally different data (IMAGE instead of CARISMA)
ii) Different data analysis (wavelets instead of FFT)

2) After binning by deciles for various parameters, we observe:

i) Better resolution when binning by Kp
ii) Up to half of the variability is contained in the upper decile

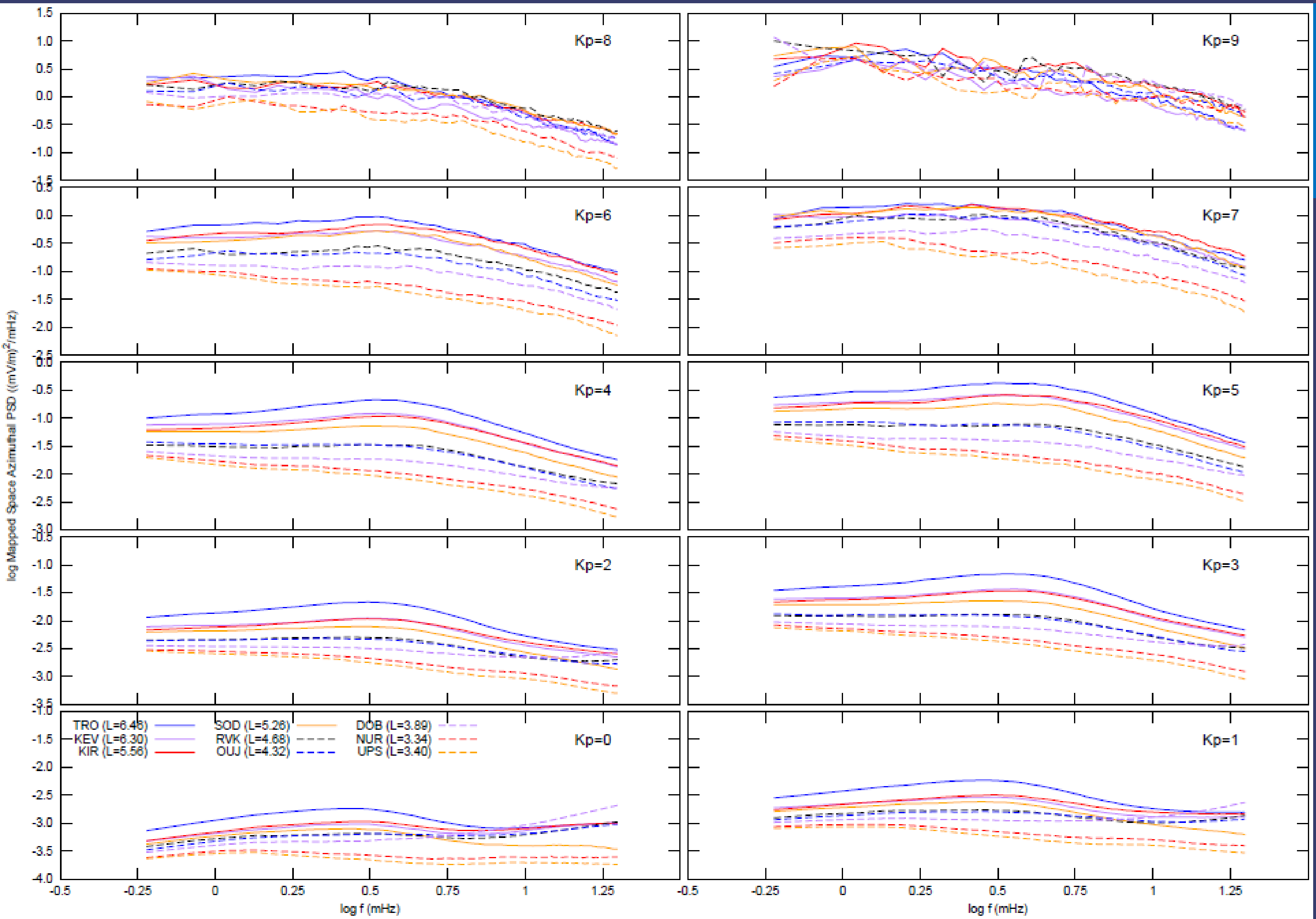
Thank you!

HOR
L=13.6

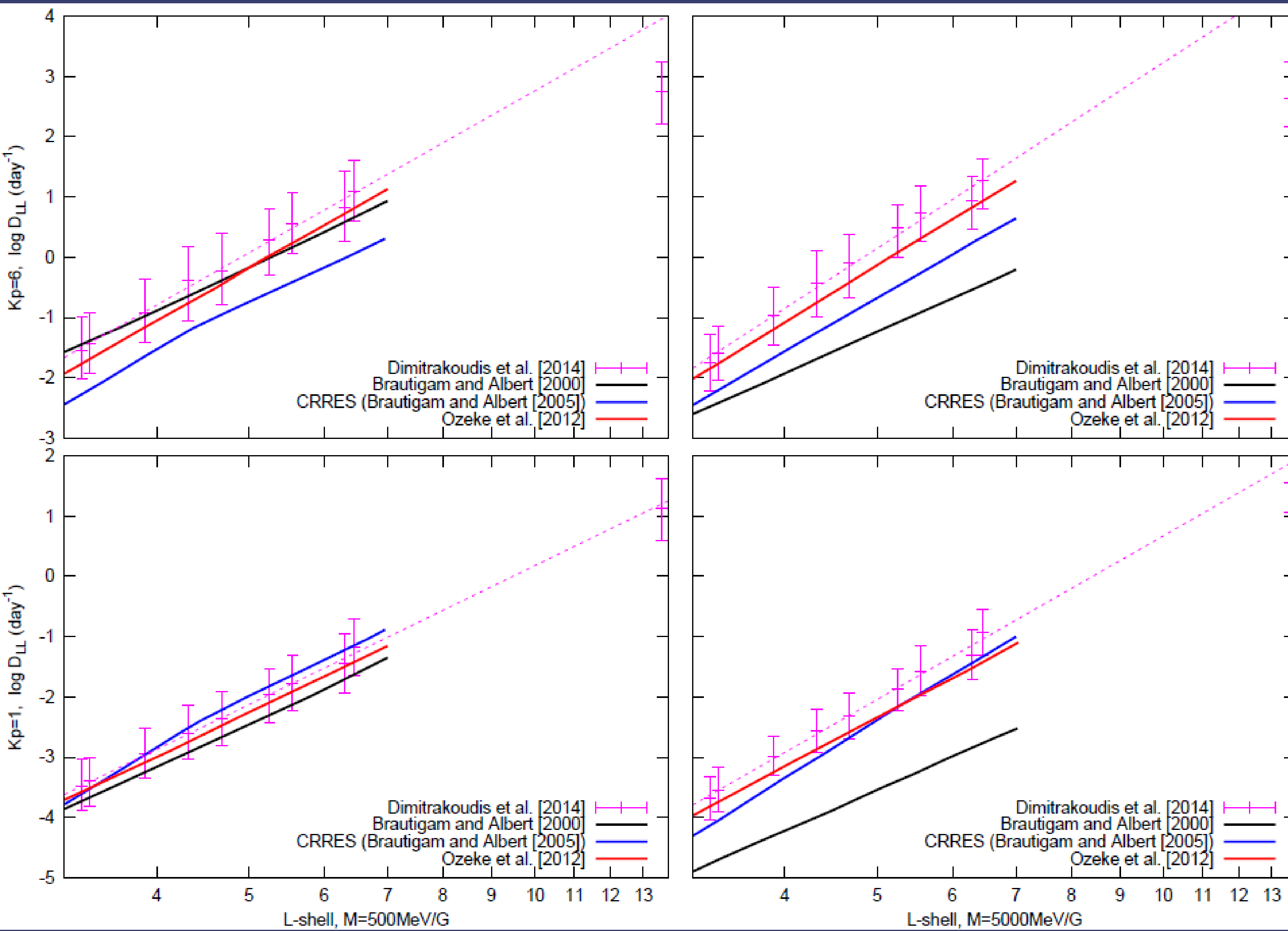


log Mapped Space Azimuthal PSD ((mV/m)^2/mHz)
U_{sw}
P_{dyn}
Kp
Dst
10
9
8
7
6
5
4
3
2
1
log f (mHz)


all stations for all Kp



D^{E}_{LL}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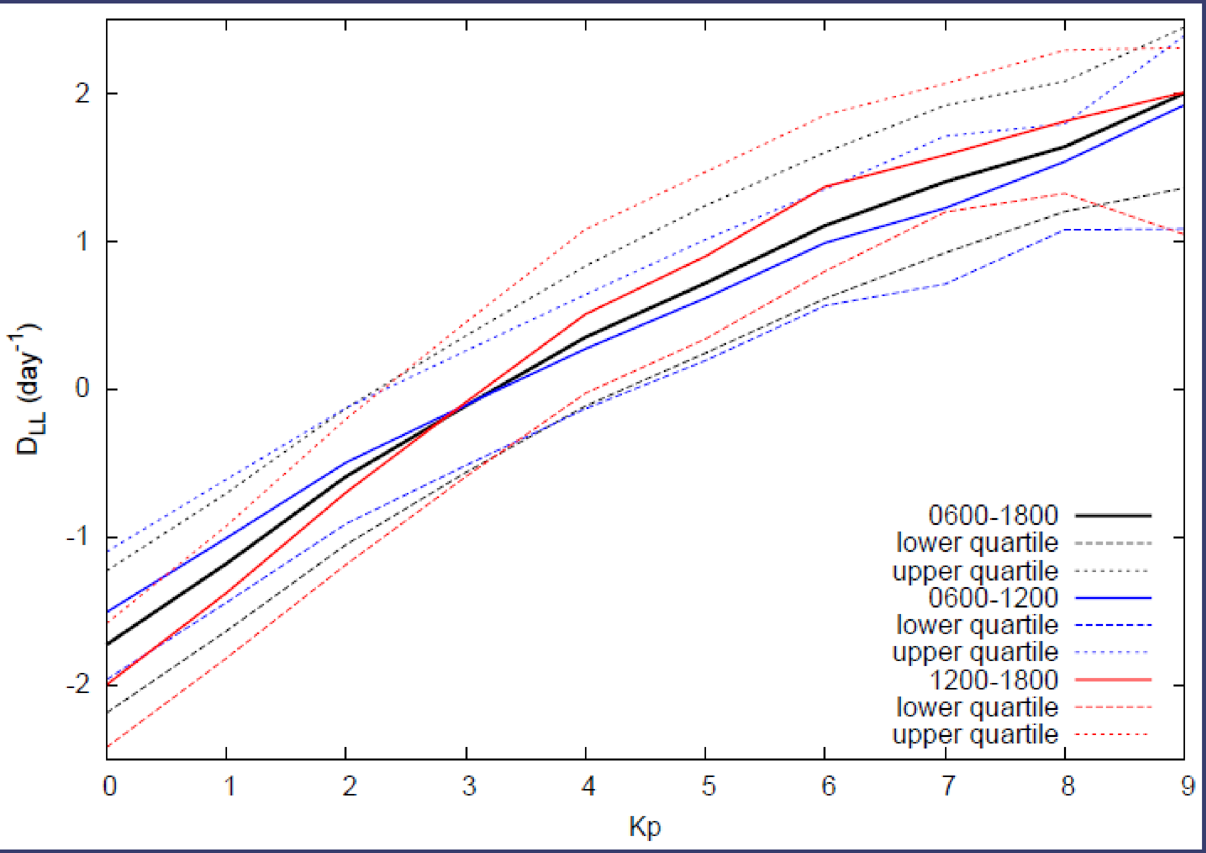
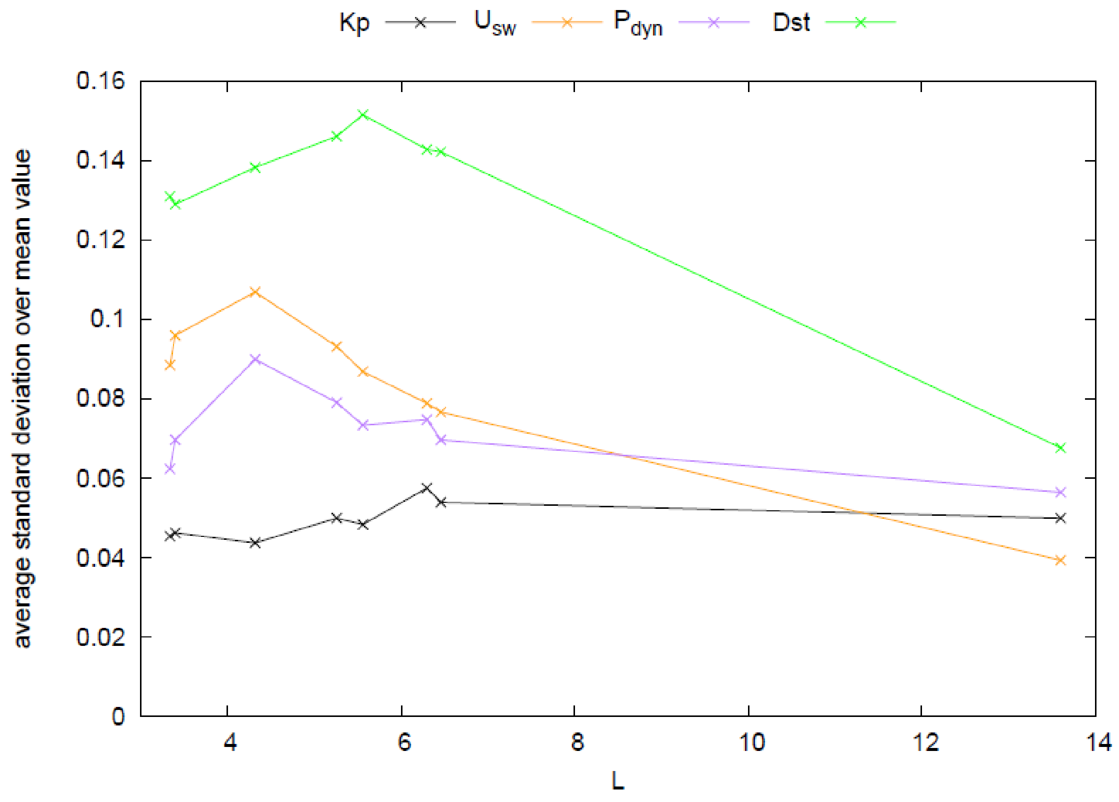
Ozeke et al. [2012]
L-shell, M=500MeV/G
L-shell, M=5000MeV/G
4
3
2
1
0
-1
-2
-3
-4
-5
5
6
7
8
9
10
11
12
13

Does time of measurement affect the discrepancy with CRRES?



(probably not)

Standard deviation comparison



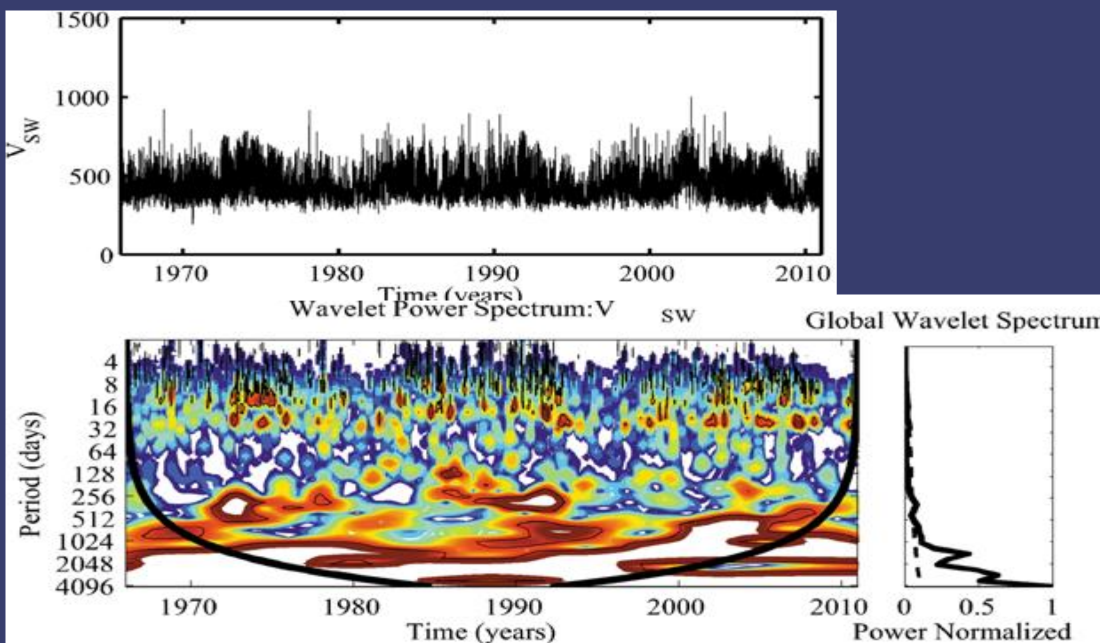
Wavelet analysis method

Morlet Wavelet

$$y\left(t,t',f\right) = \exp\left(2i\pi f t\right)\exp\left(-f^2\frac{\left(t-t'\right)^2}{2}\right)$$

Global Spectrum

$$\overline{W}^2(s) = 1/N \sum_{n=0}^{N-1}\left|W_n(s)\right|^2$$



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