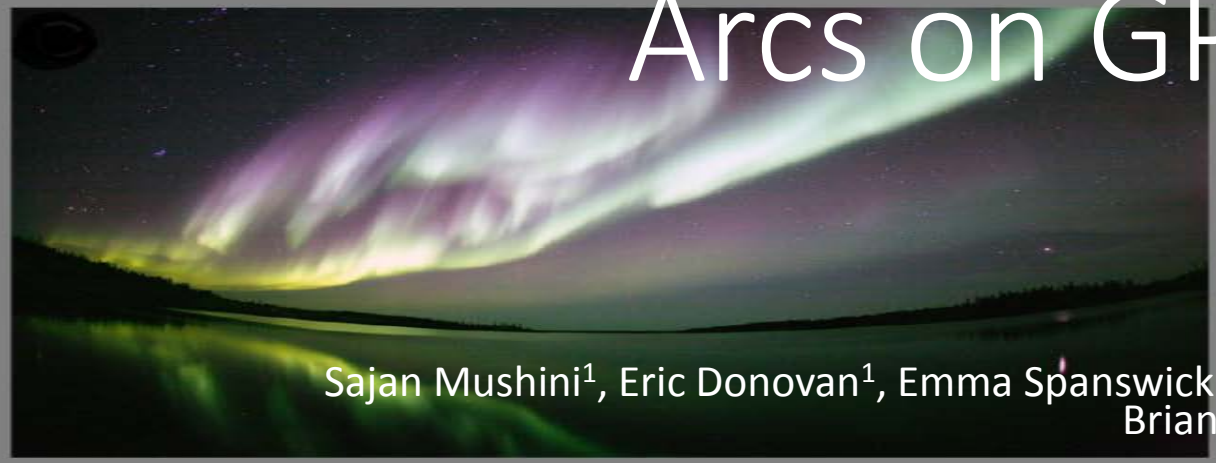


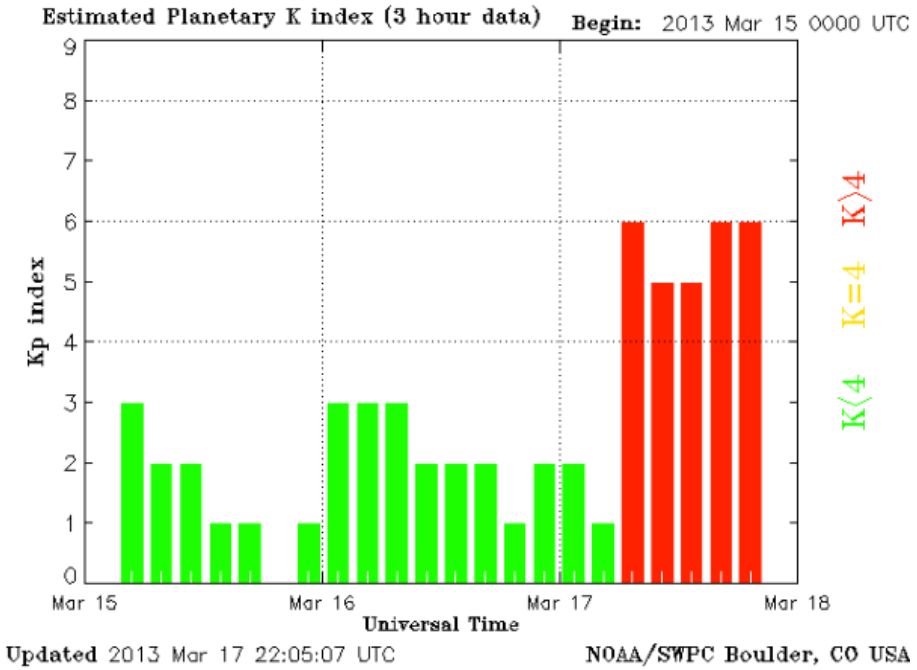
On the Effect of "Patchy Pulsating" Aurora and Auroral Arcs on GPS Signals

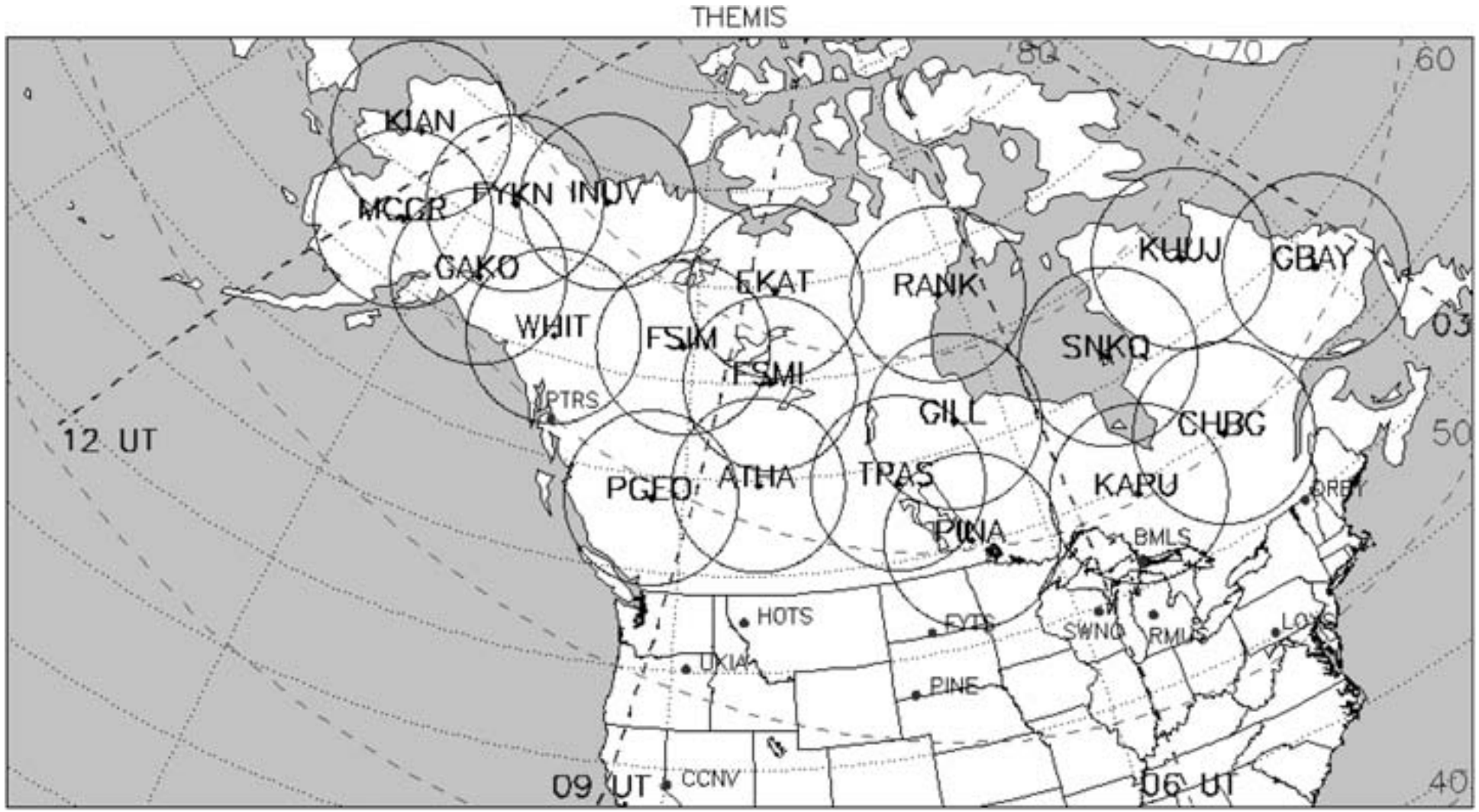
Sajan Mushini[1], Eric Donovan[1], Emma Spanswick[1], Jayachandran PT[2], Richard Langley[2], Paul Prikryl[3], Brian Jackal[1]

1) University of Calgary, Calgary, Canada
2) University of New Brunswick, Fredericton, Canada
3) Geomagnetic Laboratory, Canada

Effect of Aurora on GPS

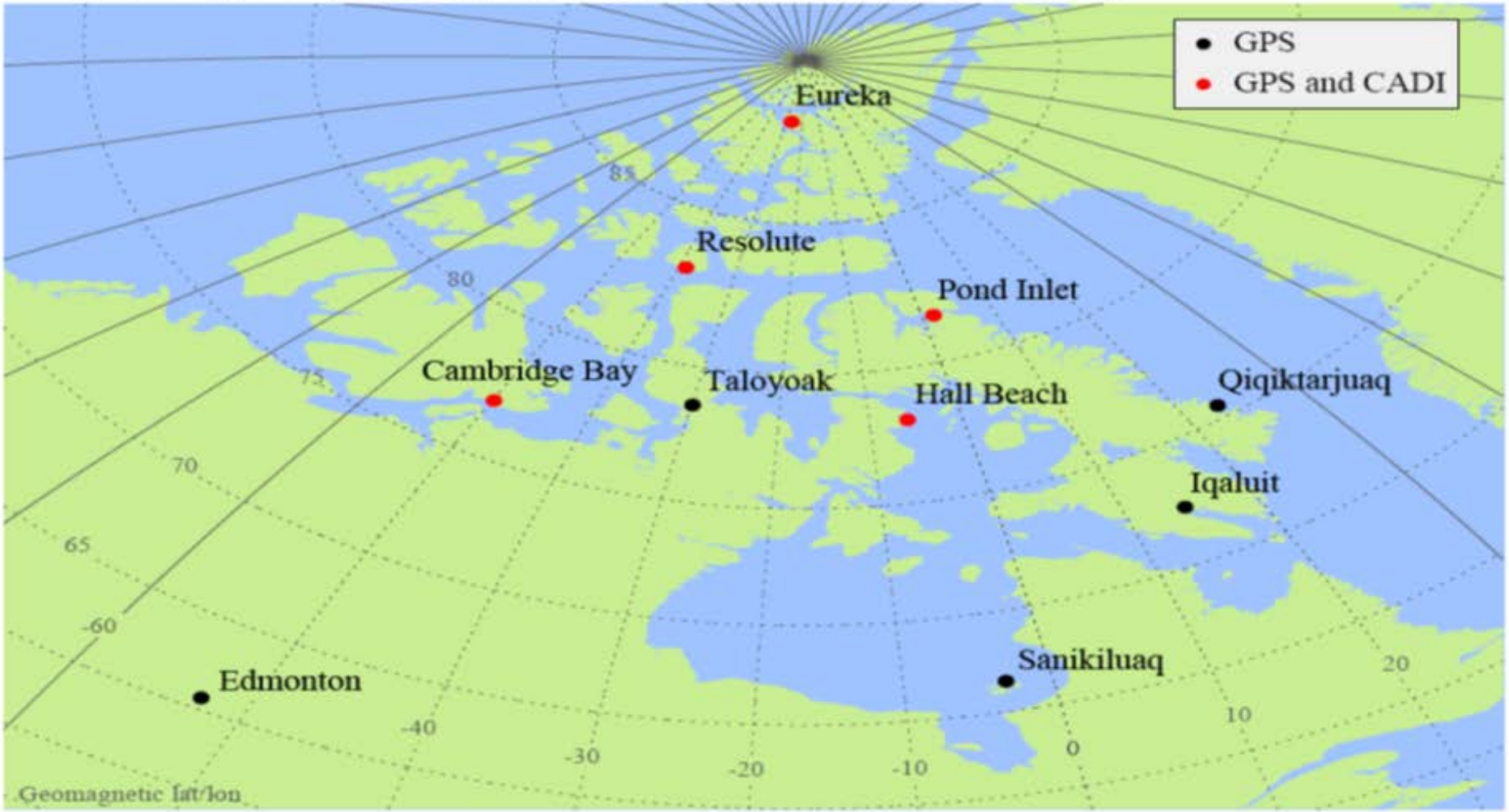
17 March 2013. 6:00 UT to 12:00 UT



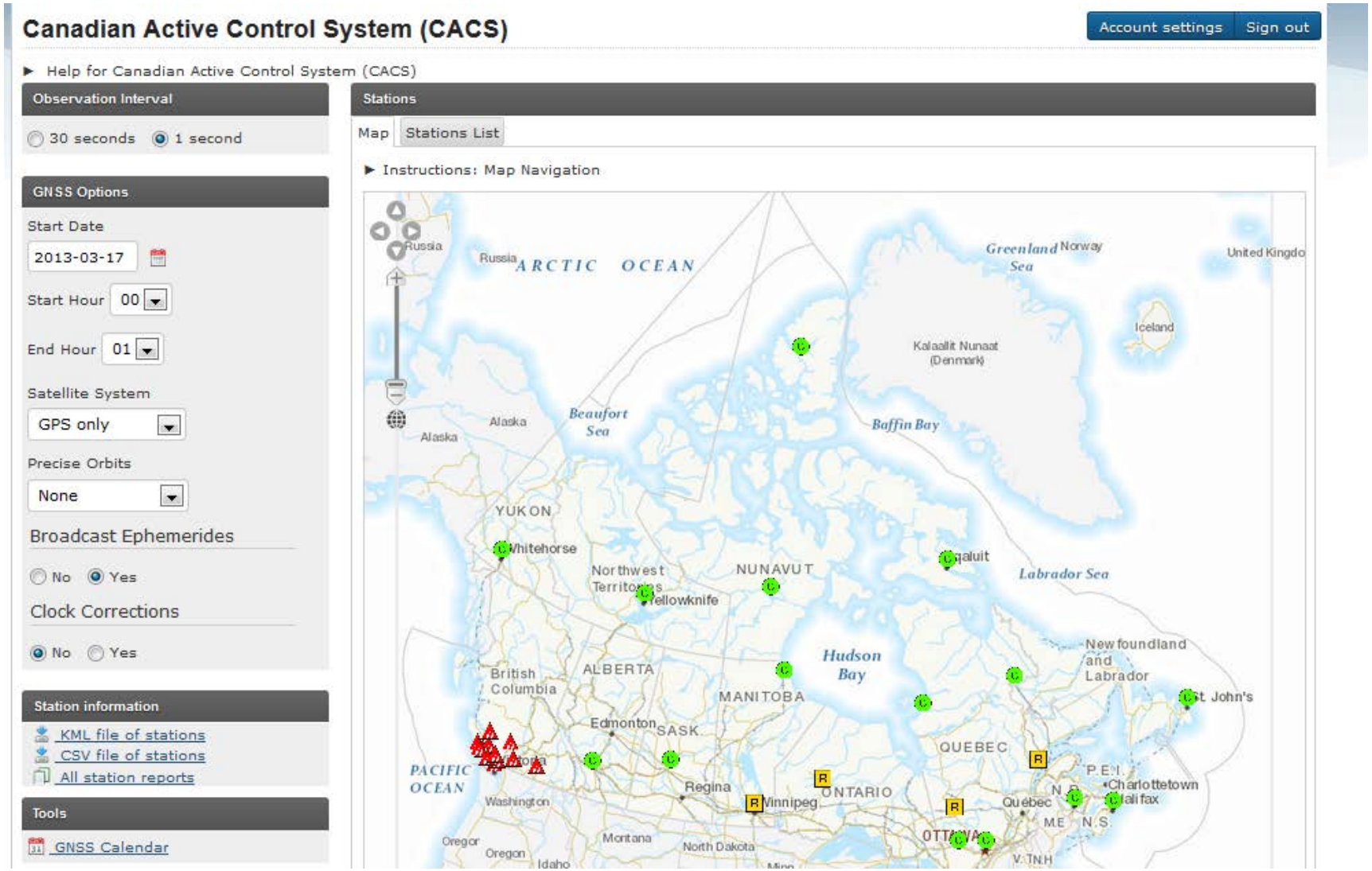


S. Mende et al., "The THEMIS array of ground-based observatories for the study of auroral substorms", *Space Science Review*, 2008, 10.1007/s11214-008-9380-x

Canadian High Arctic Ionospheric Network (CHAIN) - station map



Jayachandran, P. T., R. B. Langley, J. W. MacDougall, S. C. Mushini, D. Pokhotelov, A. M. Hamza, I. R. Mann, D. K. Milling, Z. C. Kale, R. Chadwick, T. Kelly, D. W. Danskin, and C. S. Carrano (2009), The Canadian high arctic ionospheric network (CHAIN), Radio Sci., 44, RS0A03, doi:10.1029/2008RS004046, 2009



http://webapp.geod.nrcan.gc.ca/geod/data-donnees/cacs-scca.php

ROTI

$$TEC_{\Phi} = 9.52(\Phi_1 - \Phi_2)TECU$$

$$ROT = \frac{\Delta TEC}{\Delta t}$$

$$ROTI = \sqrt{\langle ROT^2 \rangle - \langle ROT \rangle^2}$$

Color Coding :

ROTI < 0.02

0.02 < ROTI < 0.06

ROTI > 0.06

```
     2.10           Observation        G (GPS)             RINEX VERSION / TYPE
DiscFix v.5.0 ,5.3  ARL:UT/SGL/GPSTk    20140127 174509 UTC PGM / RUN BY / DATE
BAIE RACS-GSD M012001 Baie Comeau QC Canada                 MARKER NAME
OPERATOR            NRCan/GEODETIC SURVEY OF CANADA         OBSERVER / AGENCY
1116                AOA BENCHMARK ACT   3.3.32.2N           REC # / TYPE / VERS
467                 AOAD/M_T        NONE                    ANT # / TYPE
  1546824.0300 -3879766.5300  4804185.0600                  APPROX POSITION XYZ
        0.1000        0.0000        0.0000                  ANTENNA: DELTA H/E/N
     1     1                                                WAVELENGTH FACT L1/2
     4    L1    L2    P1    P2                             # / TYPES OF OBSERV
     1.000                                                  INTERVAL
  2013     3    17     6     0    0.0000000     GPS         TIME OF FIRST OBS
40151M001                                                   MARKER NUMBER
    16                                                      LEAP SECONDS
Linux 2.4.21-27.ELsmp|Opteron|gcc -static|Linux x86_64|=+   COMMENT
teqc  2013Mar15                      20140124 22:12:46UTCCOMMENT
teqc  2009Mar23                      20130317 06:18:08UTCCOMMENT
Linux 2.4.20-8|Pentium IV|gcc -static|Linux|486/DX+         COMMENT
P1 =    P1  TurboRogue; =    Y1  Benchmark                  COMMENT
L1 = L1(CA)                                                 COMMENT
P2 =    P2  TurboRogue; =    Y2  Benchmark                  COMMENT
L2 = L2(P2) TurboRogue; = L2(Y2) Benchmark                  COMMENT
SNR is mapped to RINEX snr flag value [0-9]                 COMMENT
L1 & L2: min(max(int(snr_dBHz/6), 0), 9)                    COMMENT
teqc edited: all GLONASS satellites excluded                COMMENT
                                                            END OF HEADER
 13  3 17  6  0  0.0000000  0  8G01G04G09G11G17G20G28G32
112508393.34516  87668869.88816  21409641.781    21409642.807
125938692.6351   98134070.41212  23965313.937    23965315.298
117210917.45315  91333191.07614  22304489.305    22304487.799
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111432464.13117  86830481.05917  21204898.610    21204896.264
116413955.23515  90712175.10014  22152832.604    22152831.894
108274949.00416  84370110.72817  20604026.784    20604024.300
119080439.66914  92789901.50414  22660291.189    22660289.856
 13  3 17  6  0  1.0000000  0  8G01G04G09G11G17G20G28G32
112510630.527 6  87670613.150 6  21410067.780    21410068.446
125934878.972    98131098.726 3  23964591.559    23964590.388
117212796.186 5  91334655.024 4  22304846.463    22304844.987
```
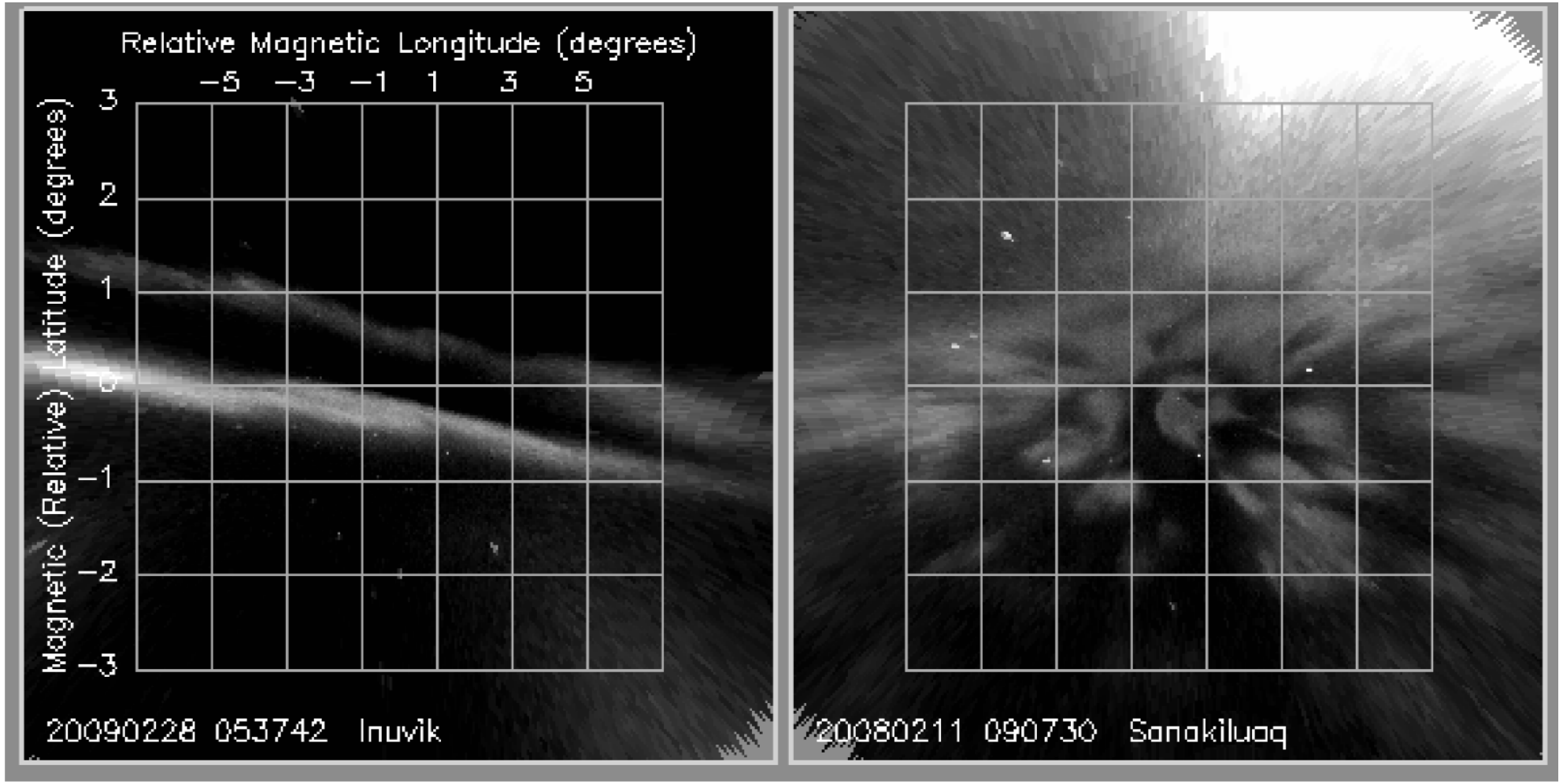
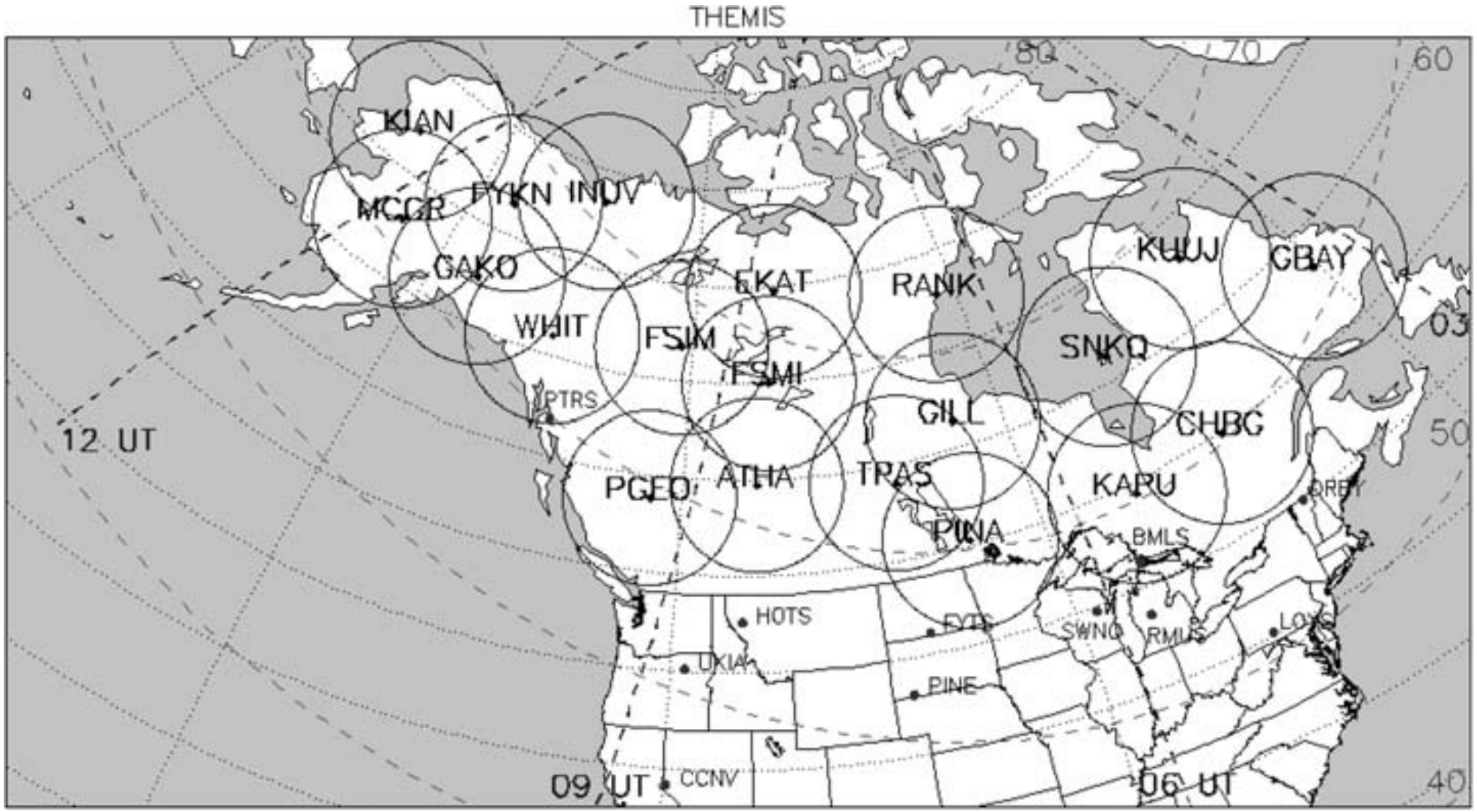
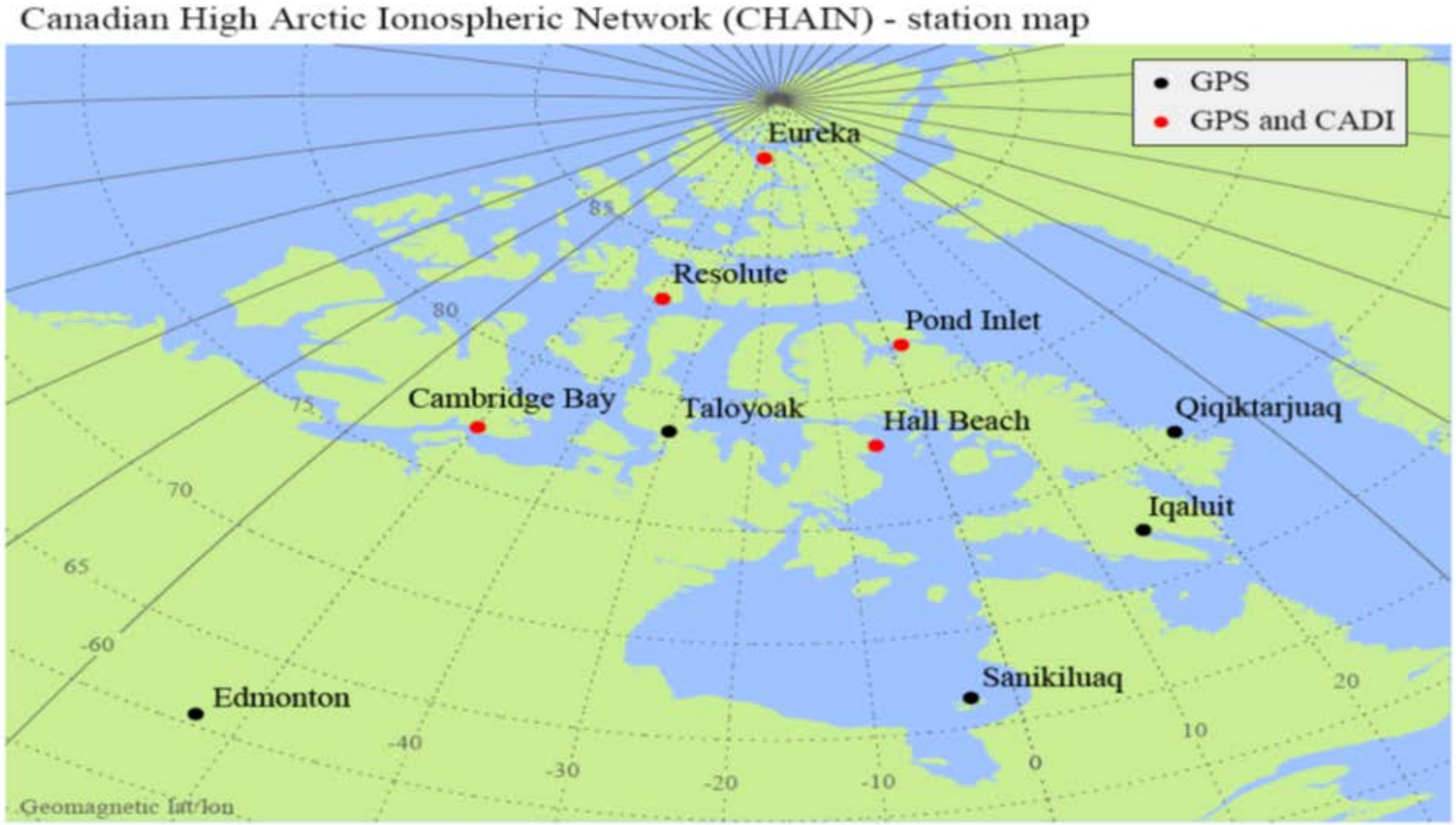

Types of Aurora



Kyle Rae., "Pathcy Pulsating Aurora and its relation to cold plasma in the magnetospheric Equitorial Plane", *Master Thesis, Univ. Of Calgary*, 2014

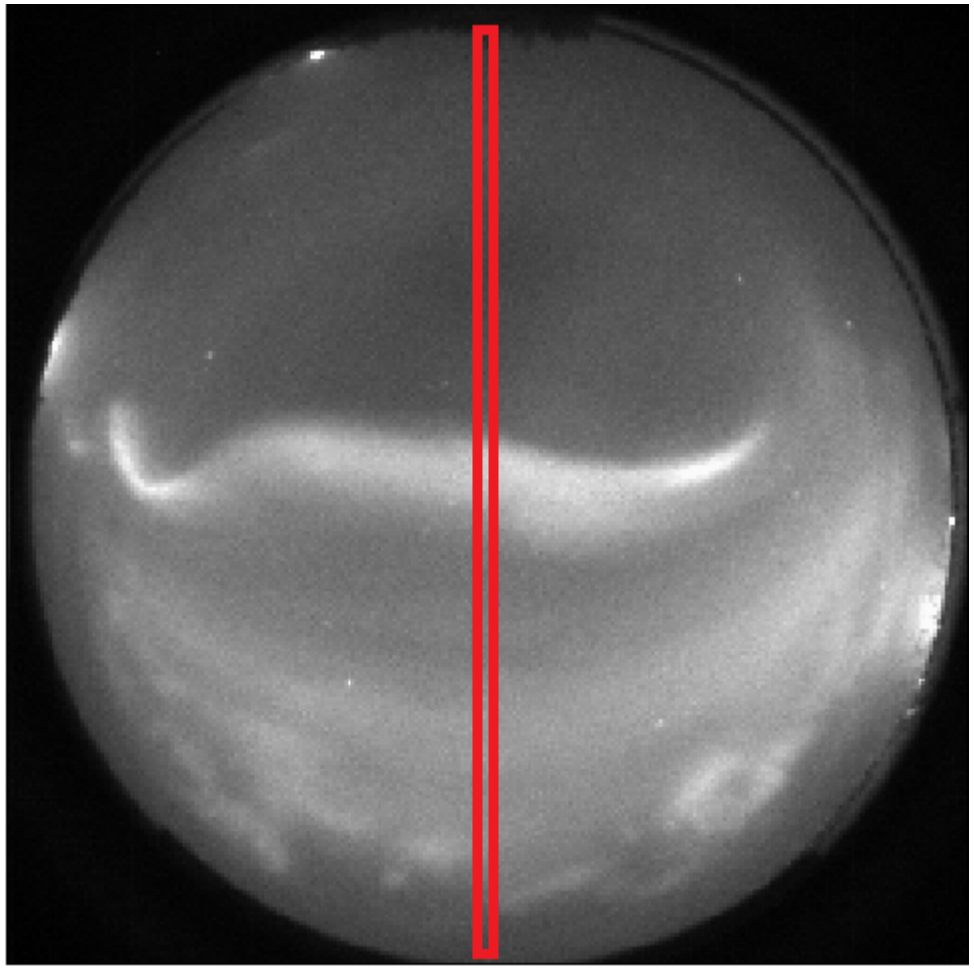


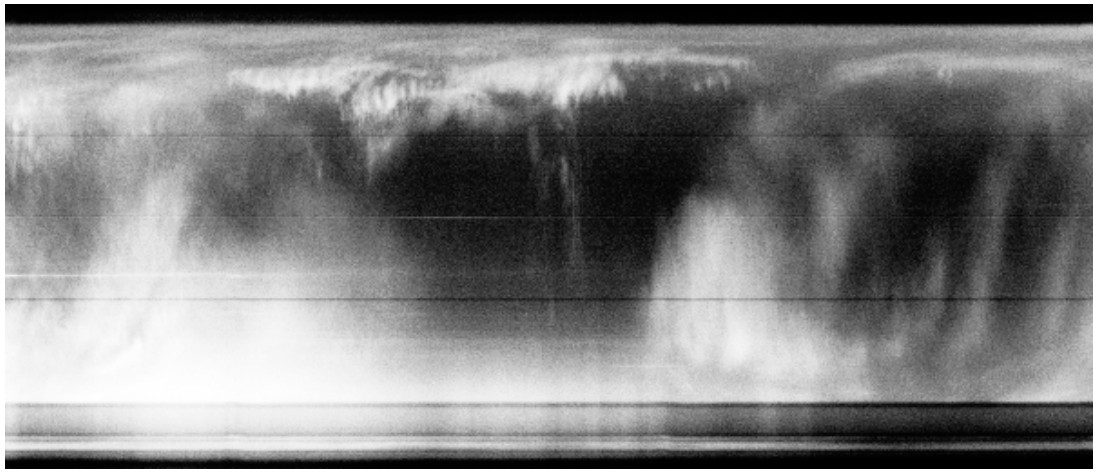
S. Mende et al., "The THEMIS array of ground-based observatories for the study of auroral substorms", *Space Science Review*, 2008, 10.1007/s11214-008-9380-x



Jayachandran, P. T., R. B. Langley, J. W. MacDougall, S. C. Mushini, D. Pokhotelov, A. M. Hamza, I. R. Mann, D. K. Milling, Z. C. Kale, R. Chadwick, T. Kelly, D. W. Danskin, and C. S. Carrano (2009), The Canadian high arctic ionospheric network (CHAIN), Radio Sci., 44, RS0A03, doi:10.1029/2008RS004046, 2009

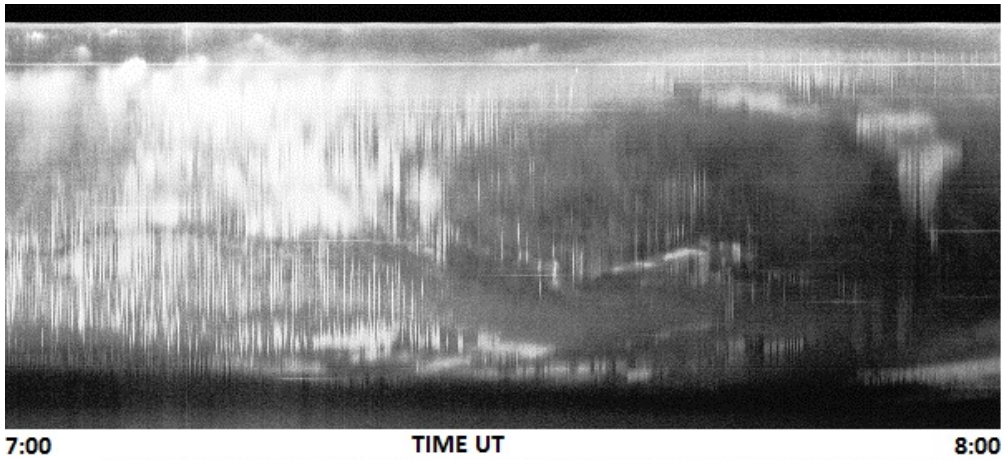
KEOGRAMS





Source: aig.rtemp.ca

Types of Aurora as seen in a Keogram

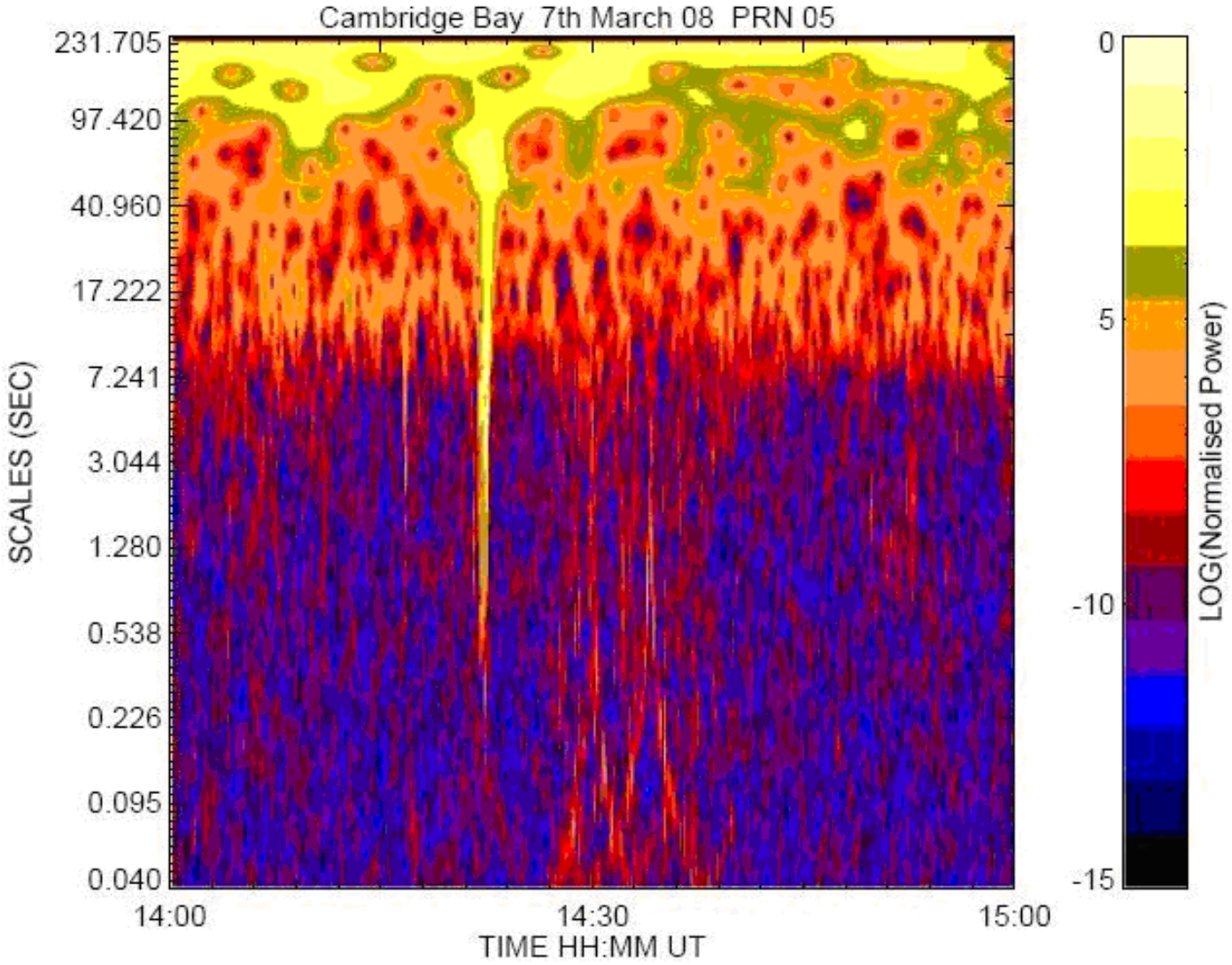


Patchy Pulsating Aurora- 2009 Jan 01

Auroral Arcs- 2011 Mar 02

Sigma Phi Signature

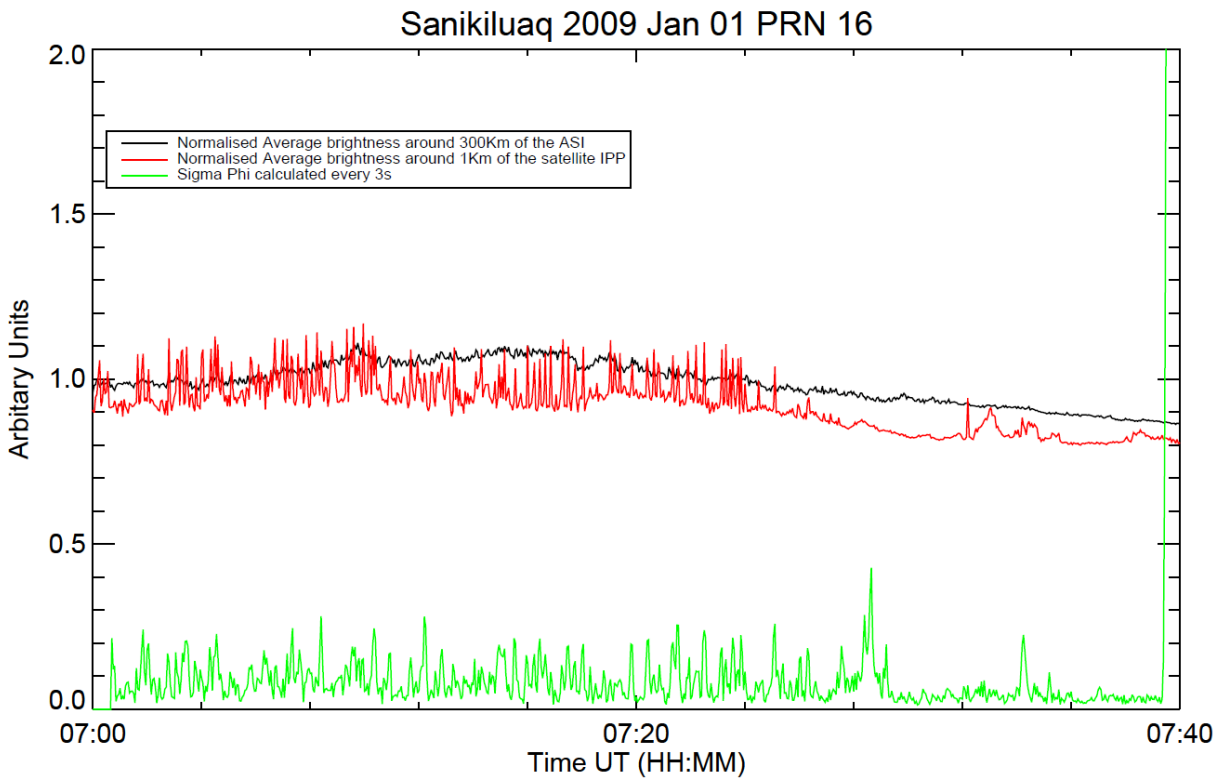
Wavelet Filtering



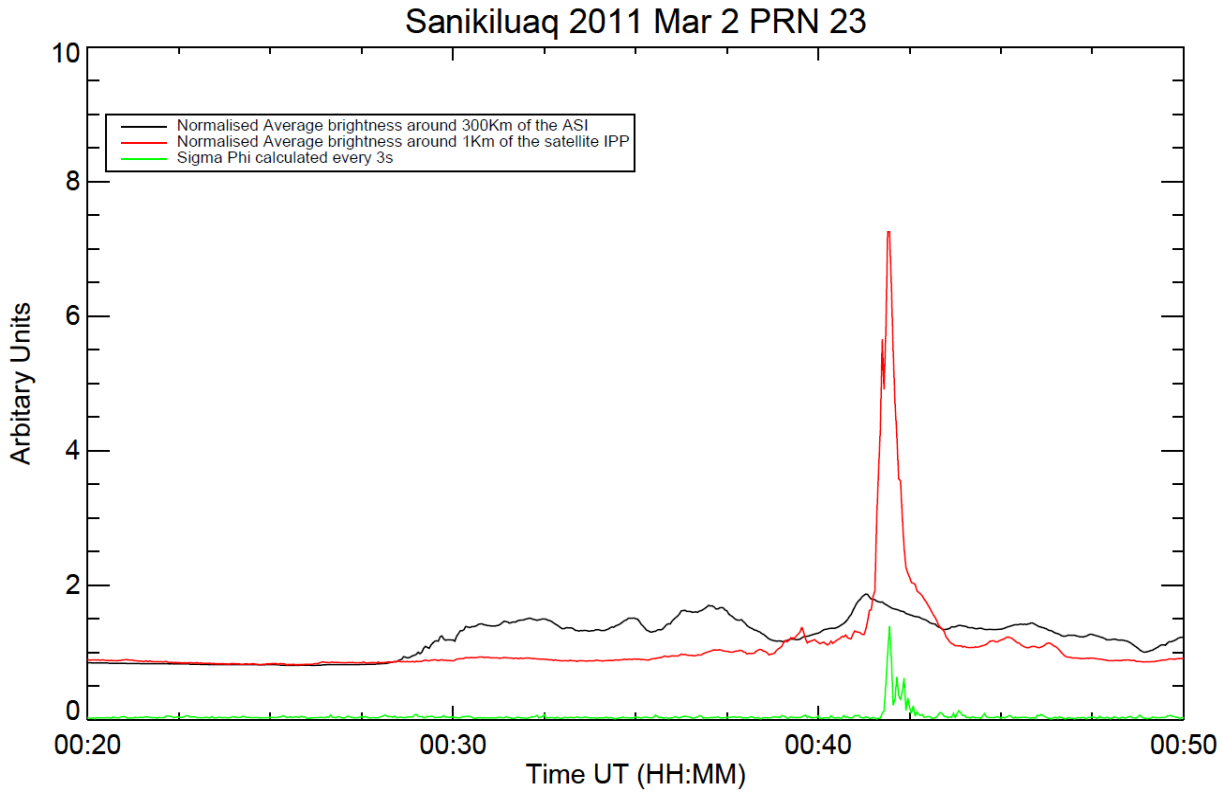
- Mushini. S. C, et al. (2012), Improved amplitude and phase scintillation indices derived from wavelet - detrended high latitude GPS data., GPS solutions, Vol 16(3), 363-373

Sigma Phi

Patchy Pulsating Aurora

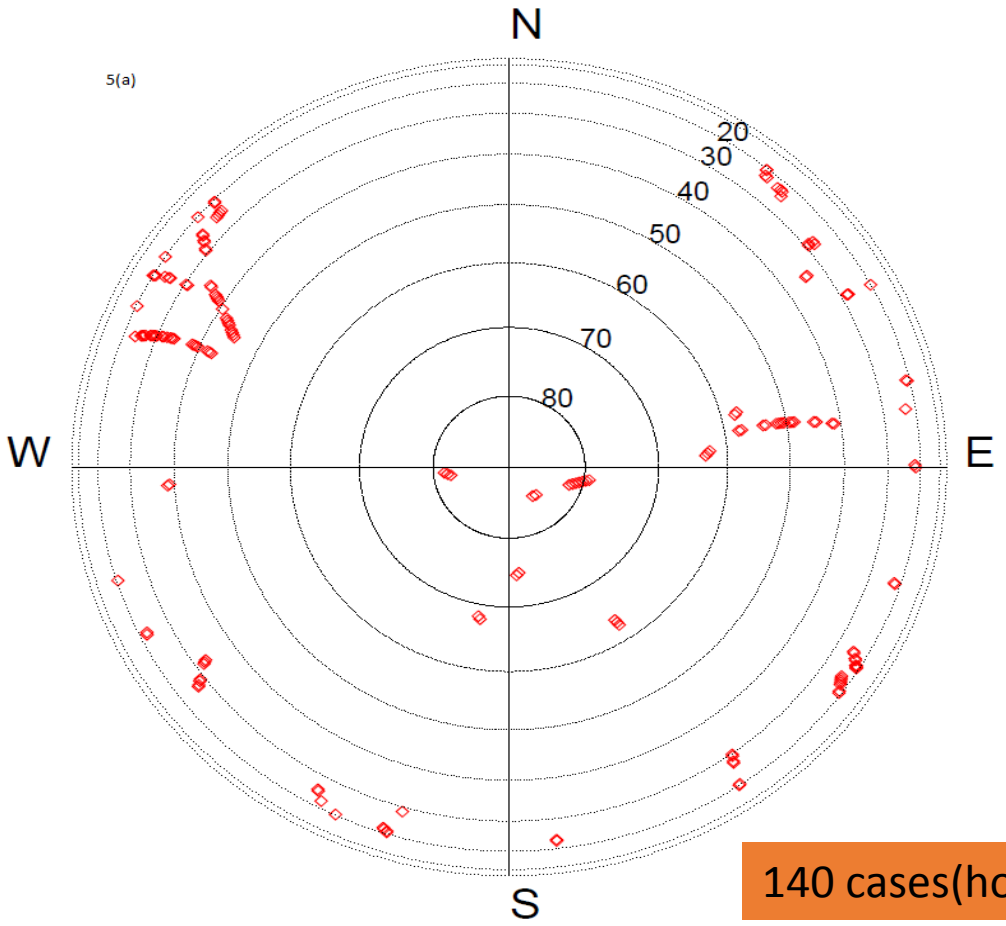


Auroral Arcs

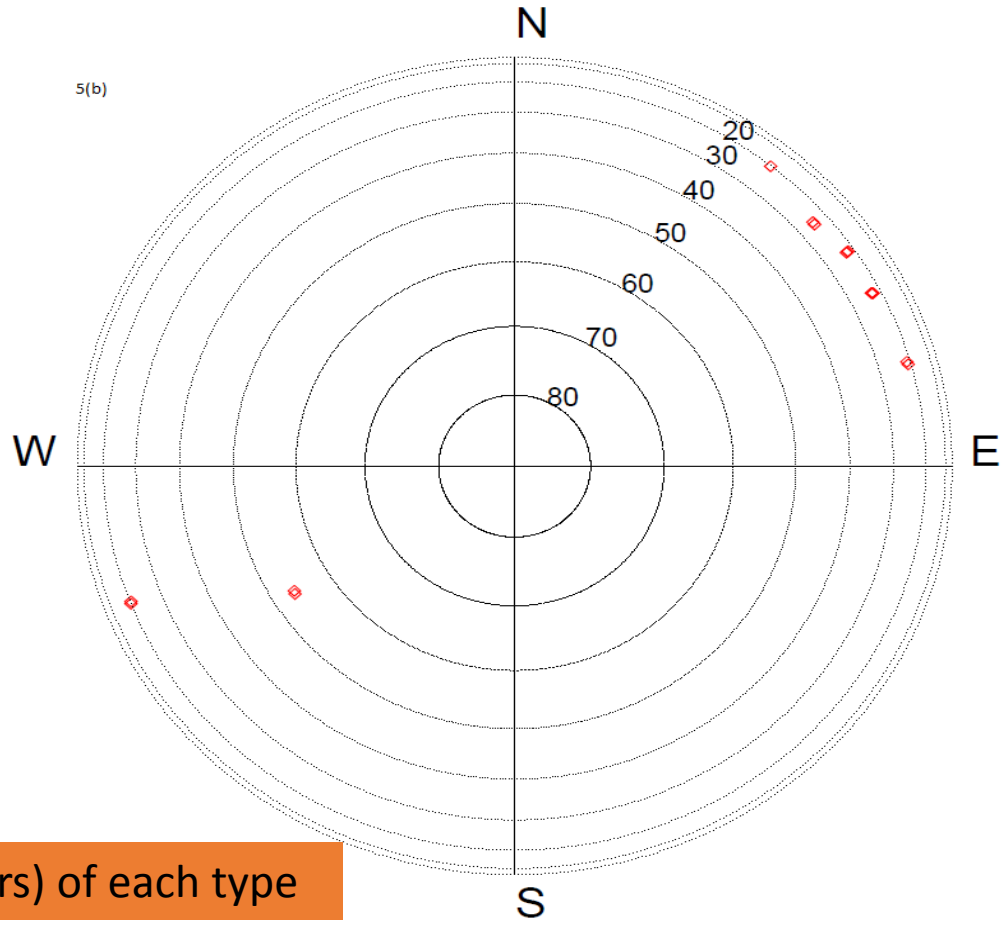


Cycle slips associated with PPA and Arcs

(a) PPA



(b) Arcs

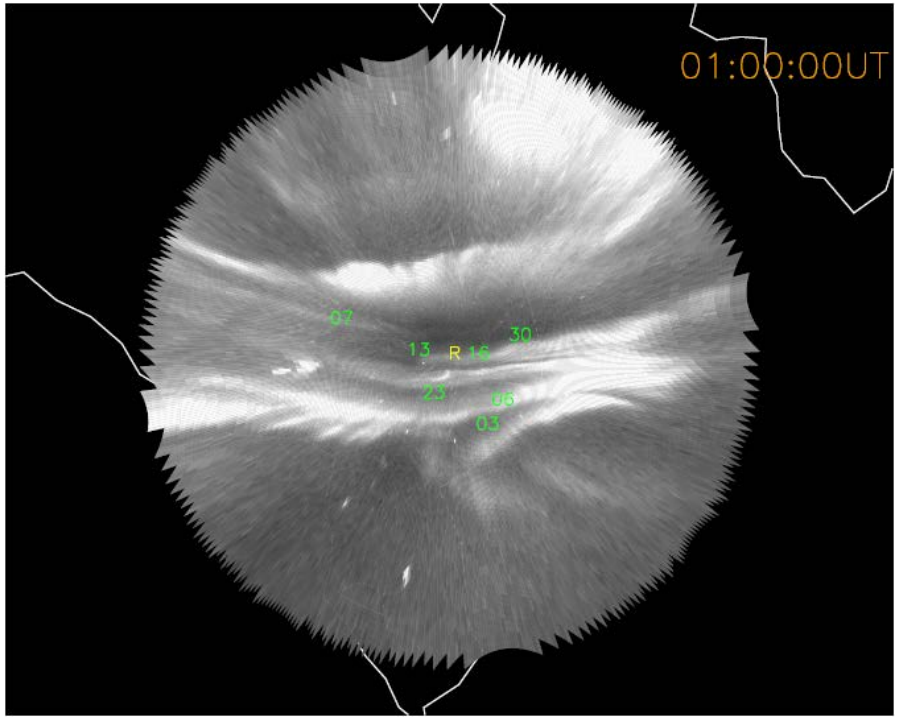


140 cases(hours) of each type

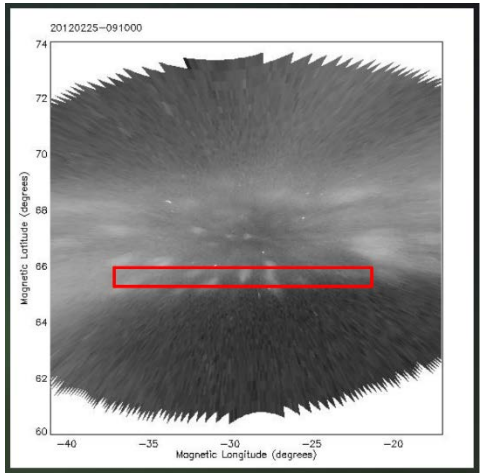
Characteristic Irregularity Scale Size

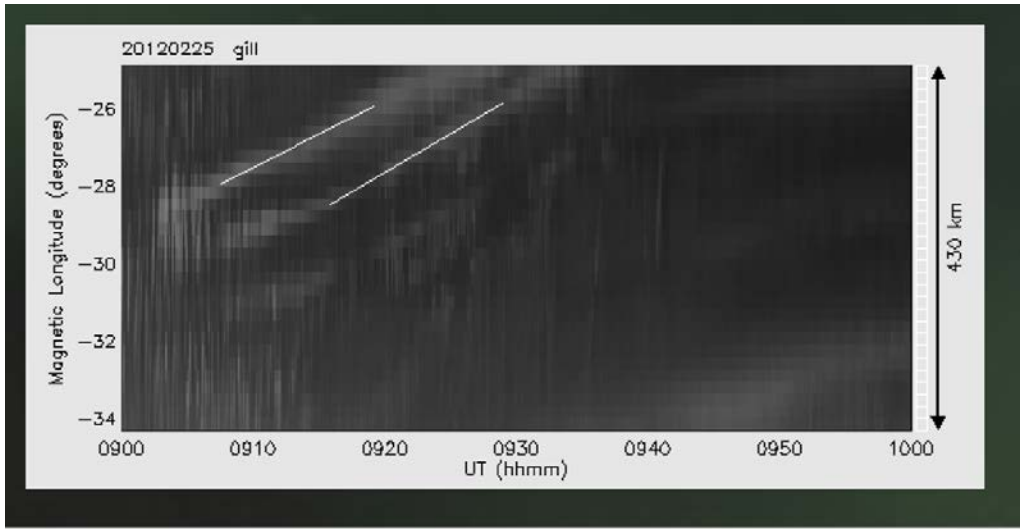
Velocity Calculations

Auroral Arc



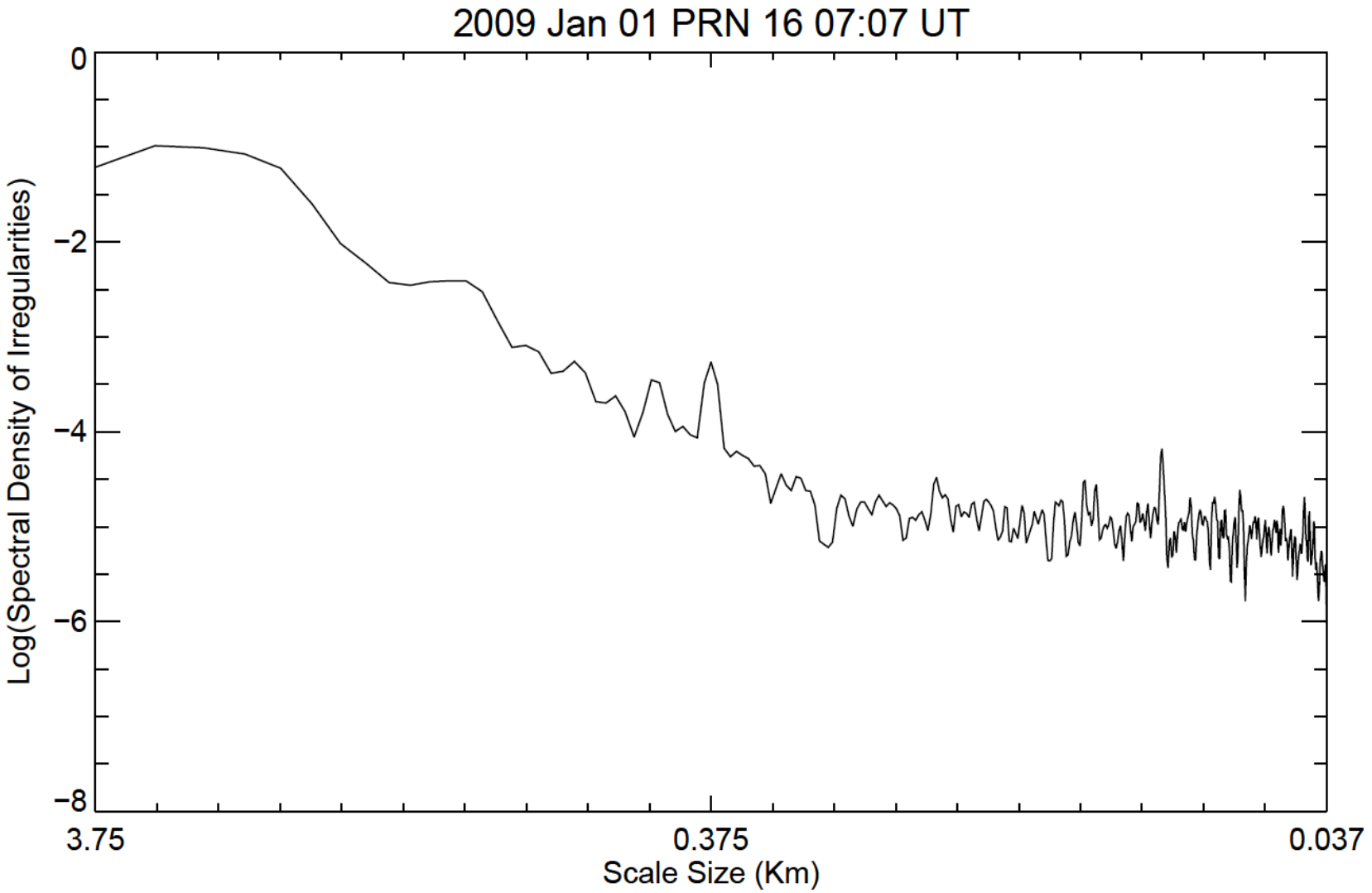
Patchy Pulsating Aurora





Bing Yang (2013), Using Patchy Pulsating Aurora to remote sense Magnetospheric Convection, AGU Fall Meeting, USA.

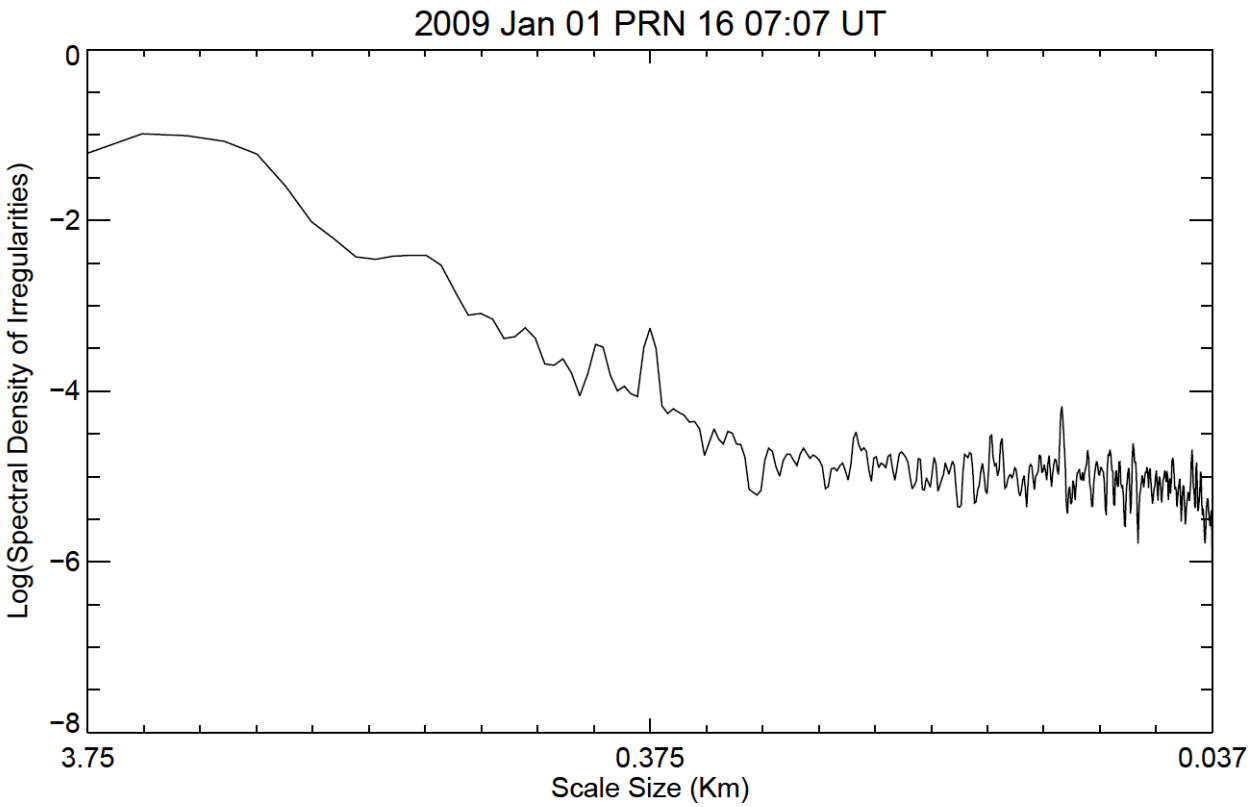
Scale Size



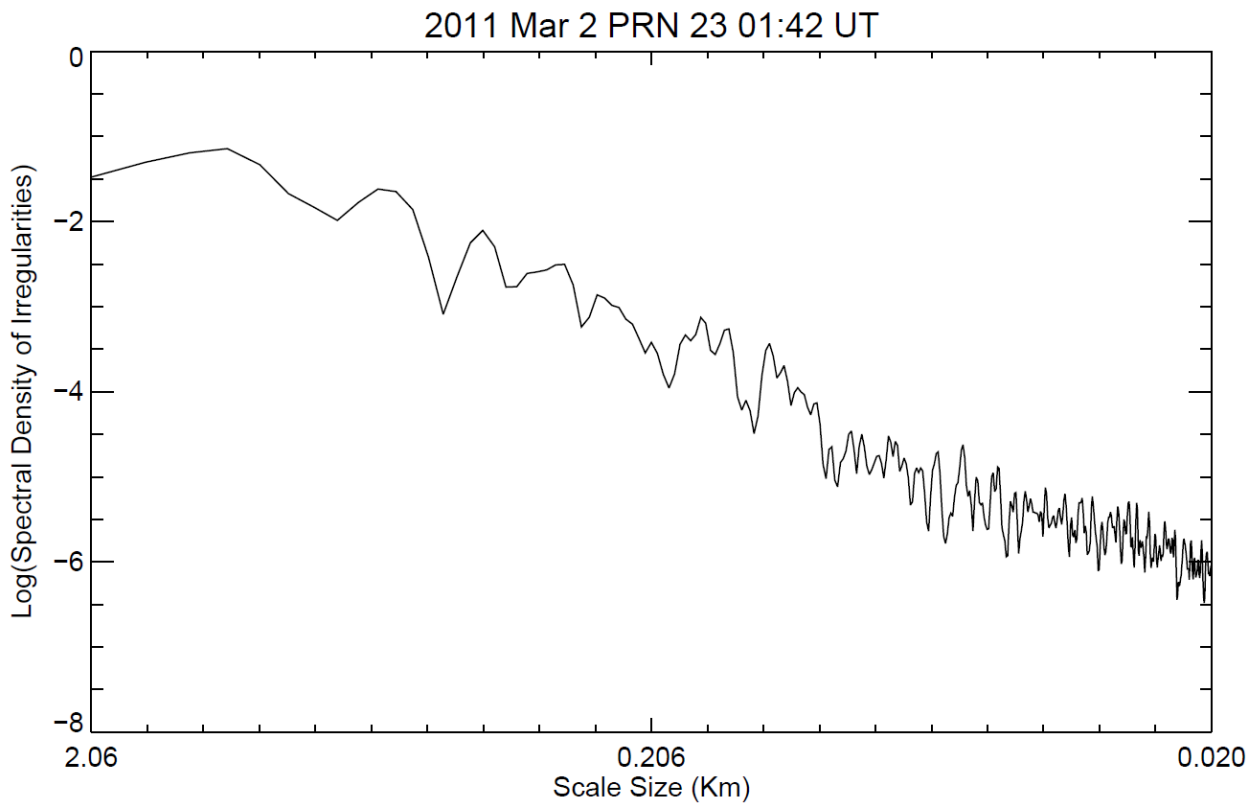
Scale Size = Relative Vel./ frequency

Irregularity Scale Size

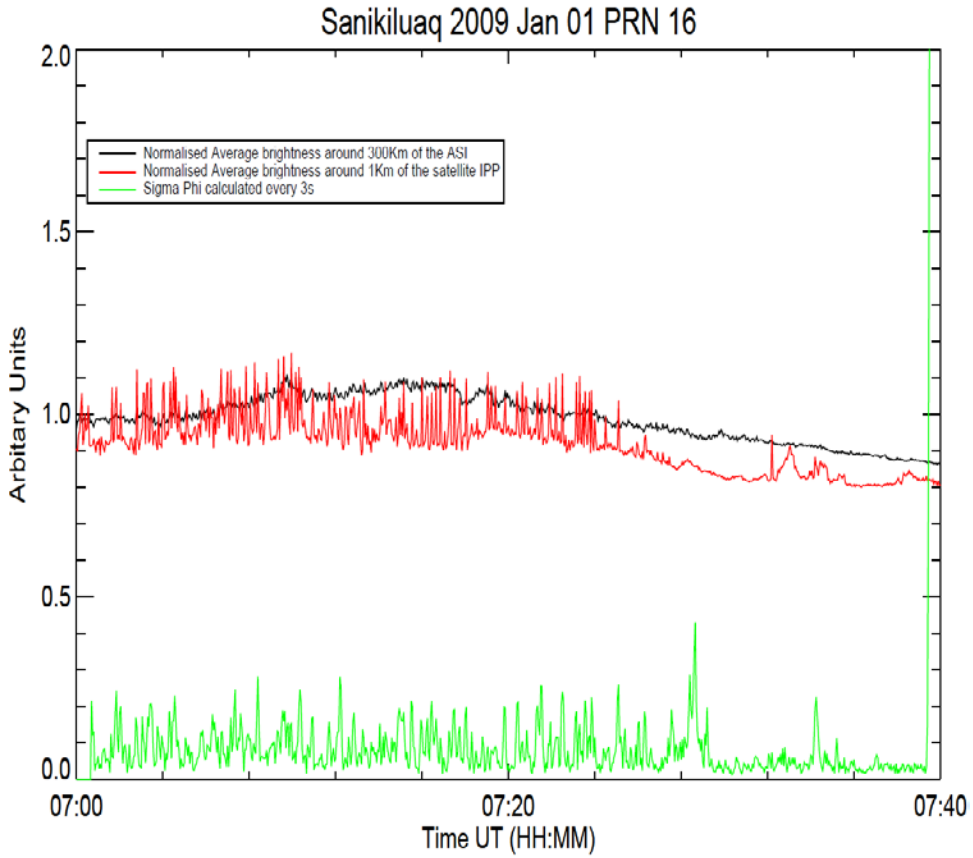
Patchy Pulsating Aurora

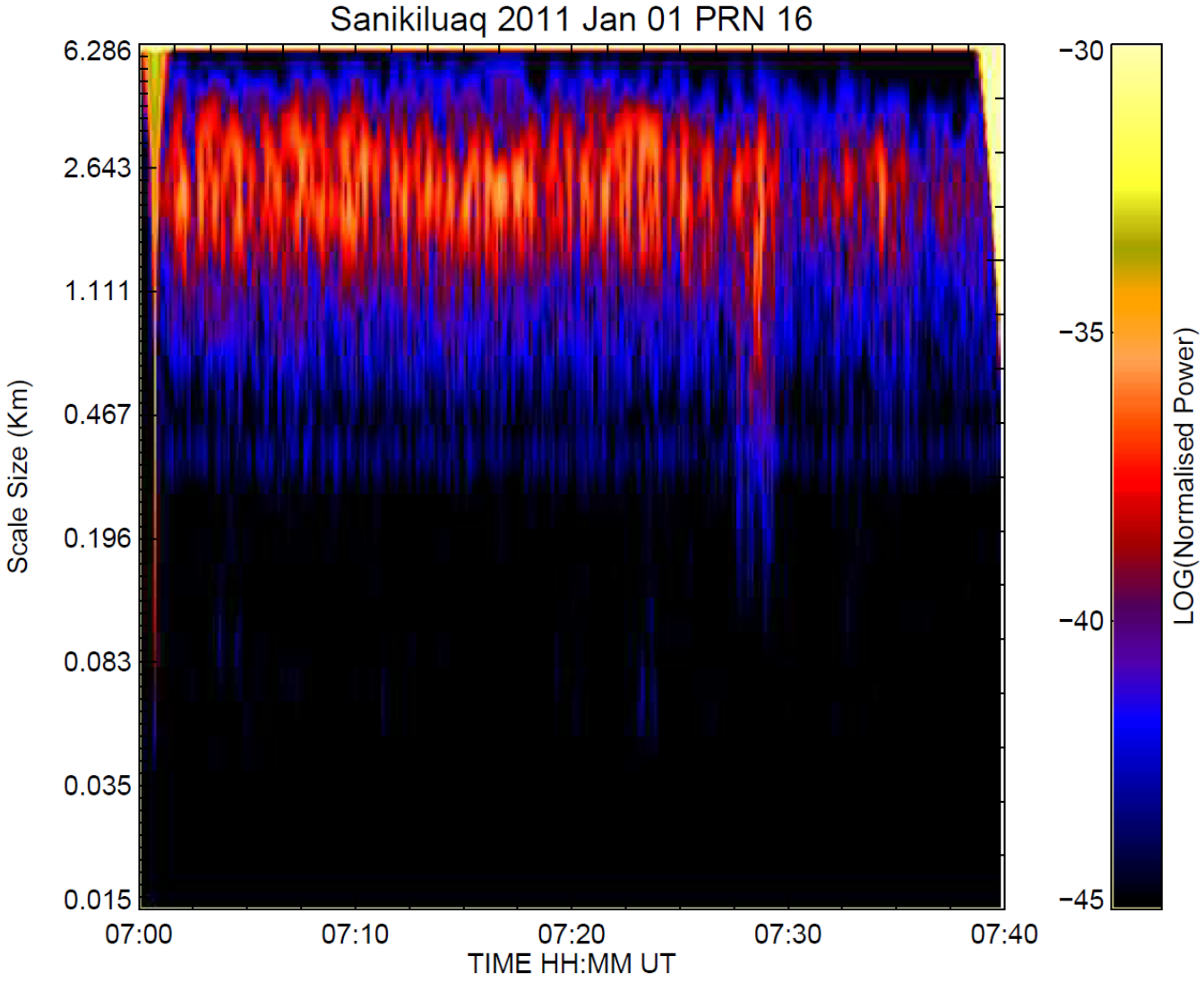


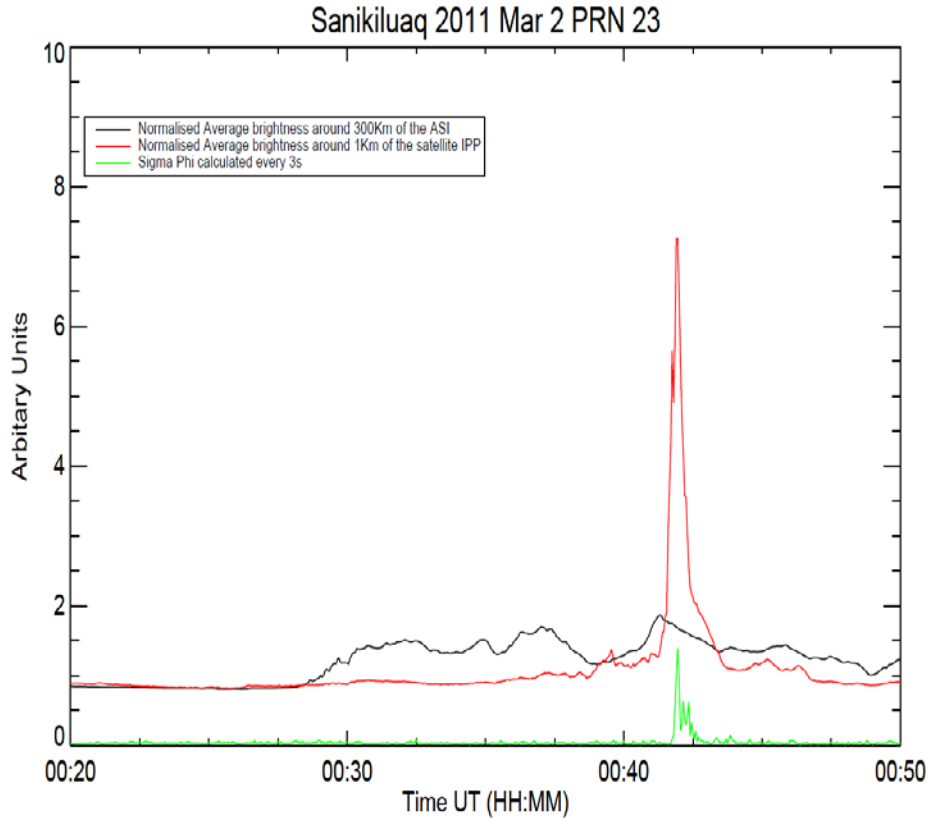
Auroral Arc

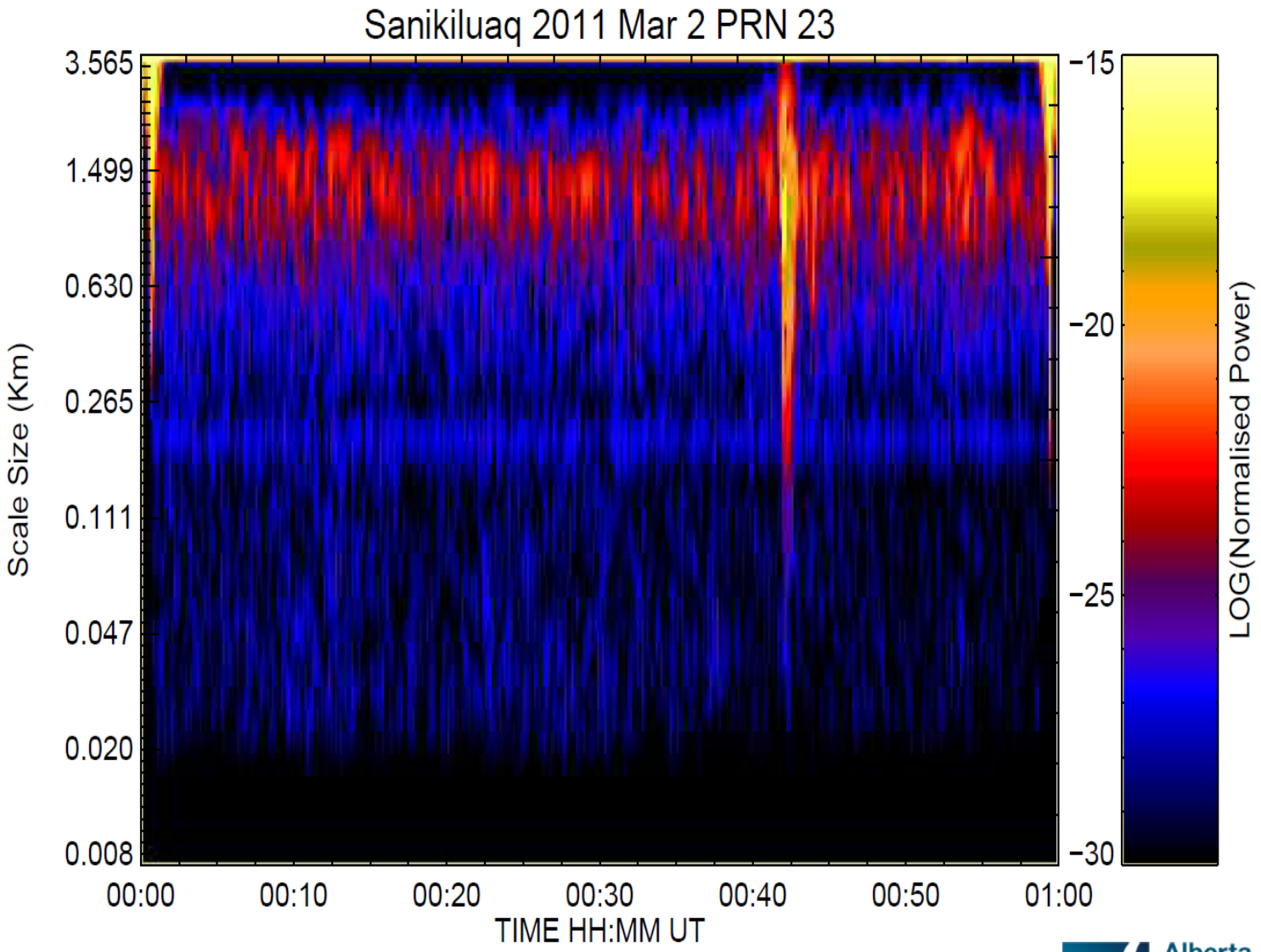


“Spatialograms”



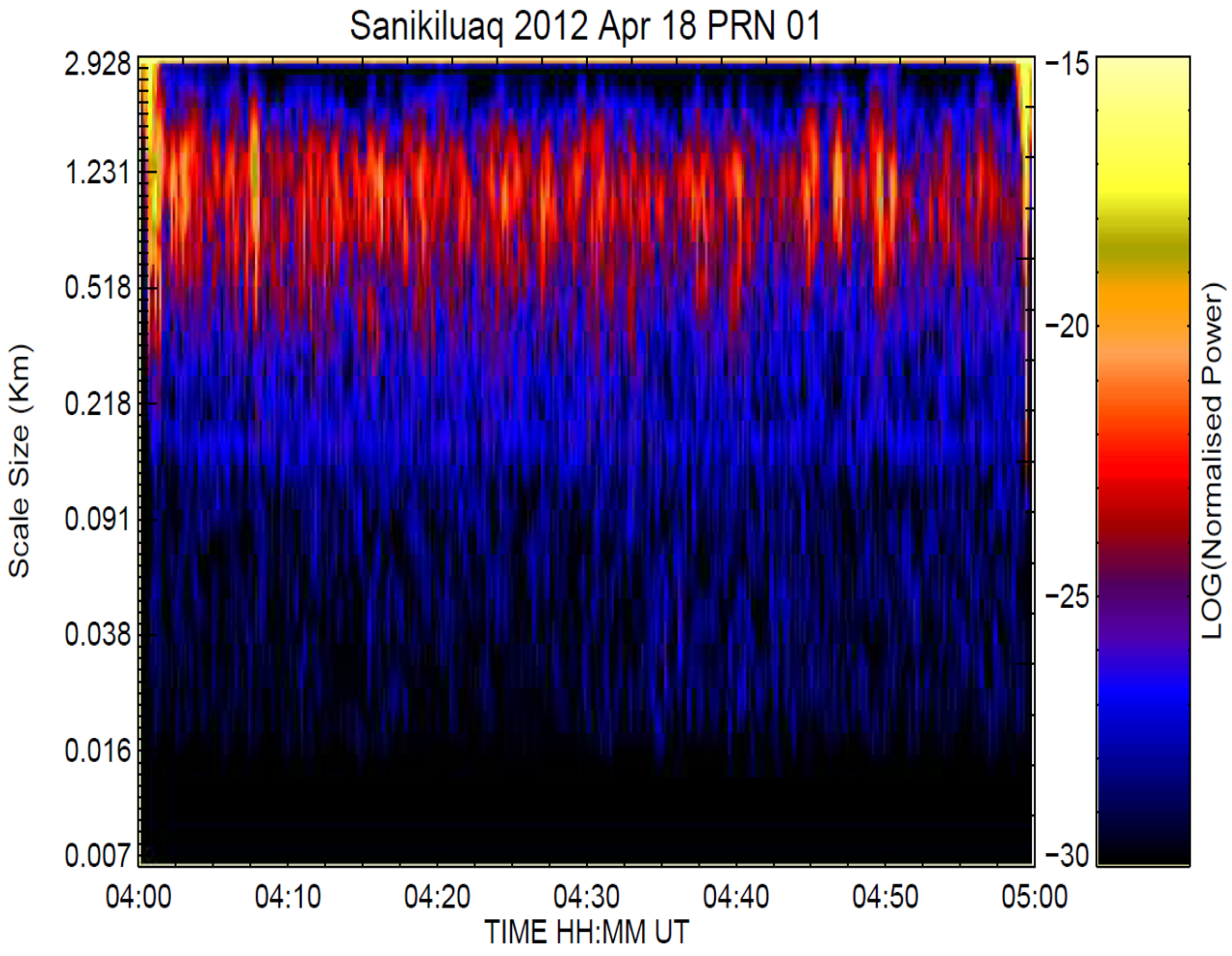


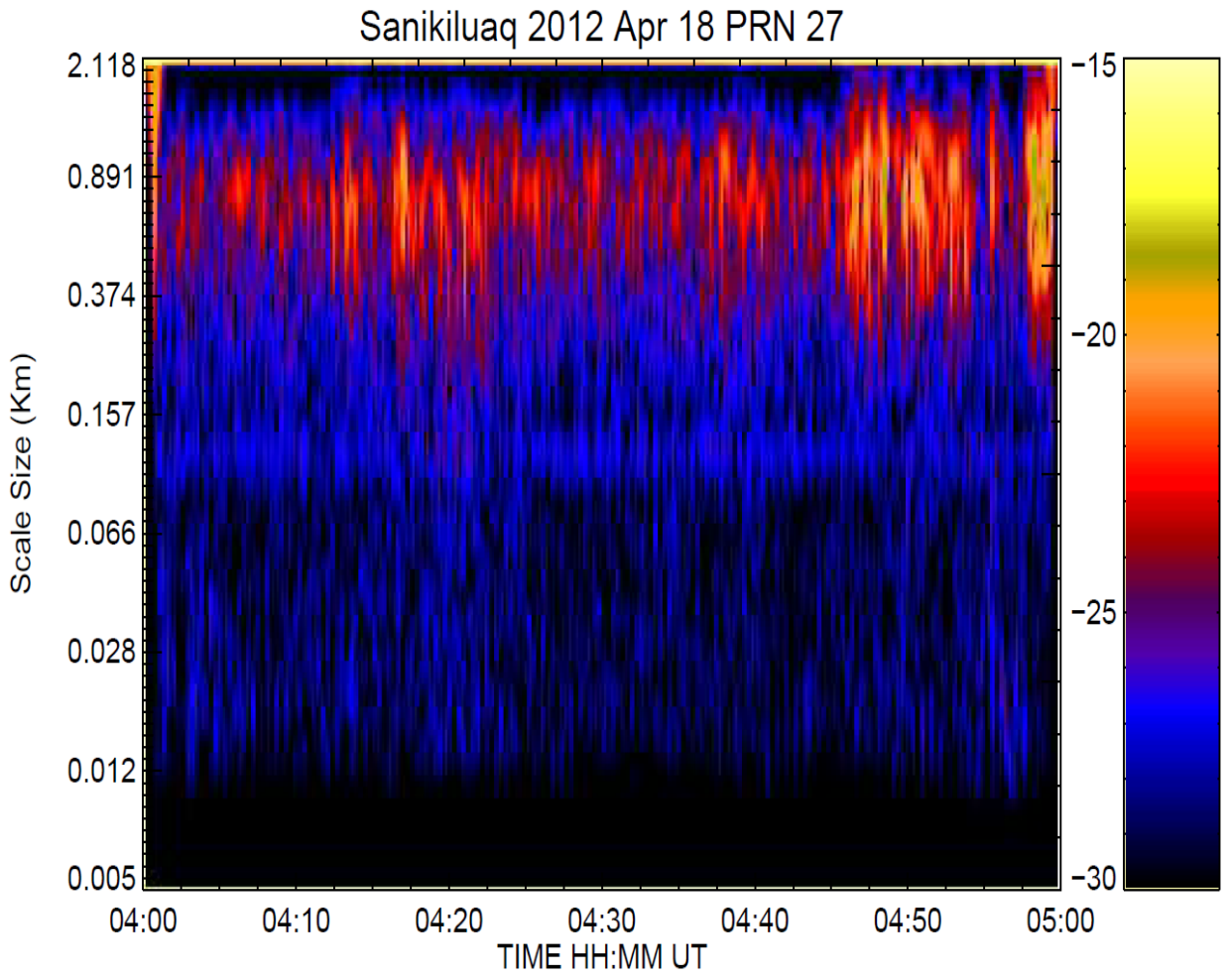

Sanikiluaq 2011 Mar 2 PRN 23
Normalised Average brightness around 300Km of the ASI
Normalised Average brightness around 1Km of the satellite IPP
Sigma Phi calculated every 3s
Arbitary Units
Time UT (HH:MM)
00:20
00:30
00:40
00:50

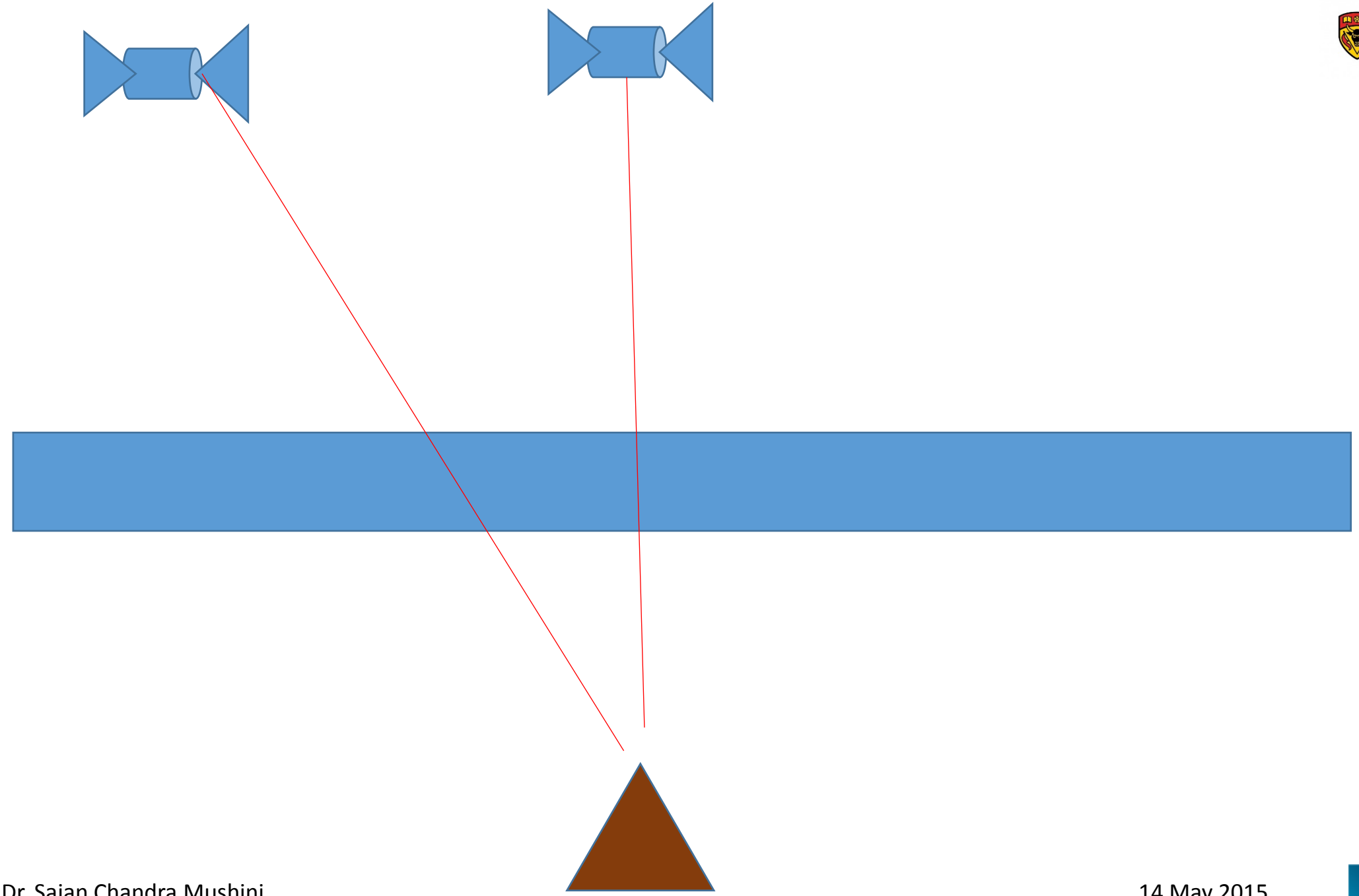

Sanikiluaq 2011 Mar 2 PRN 23
Scale Size (Km)
3.565
1.499
0.630
0.265
0.111
0.047
0.020
0.008
TIME HH:MM UT
00:00
00:10
00:20
00:30
00:40
00:50
01:00
LOG(Normalised Power)
-15
-20
-25
-30

Irregularity Orientation

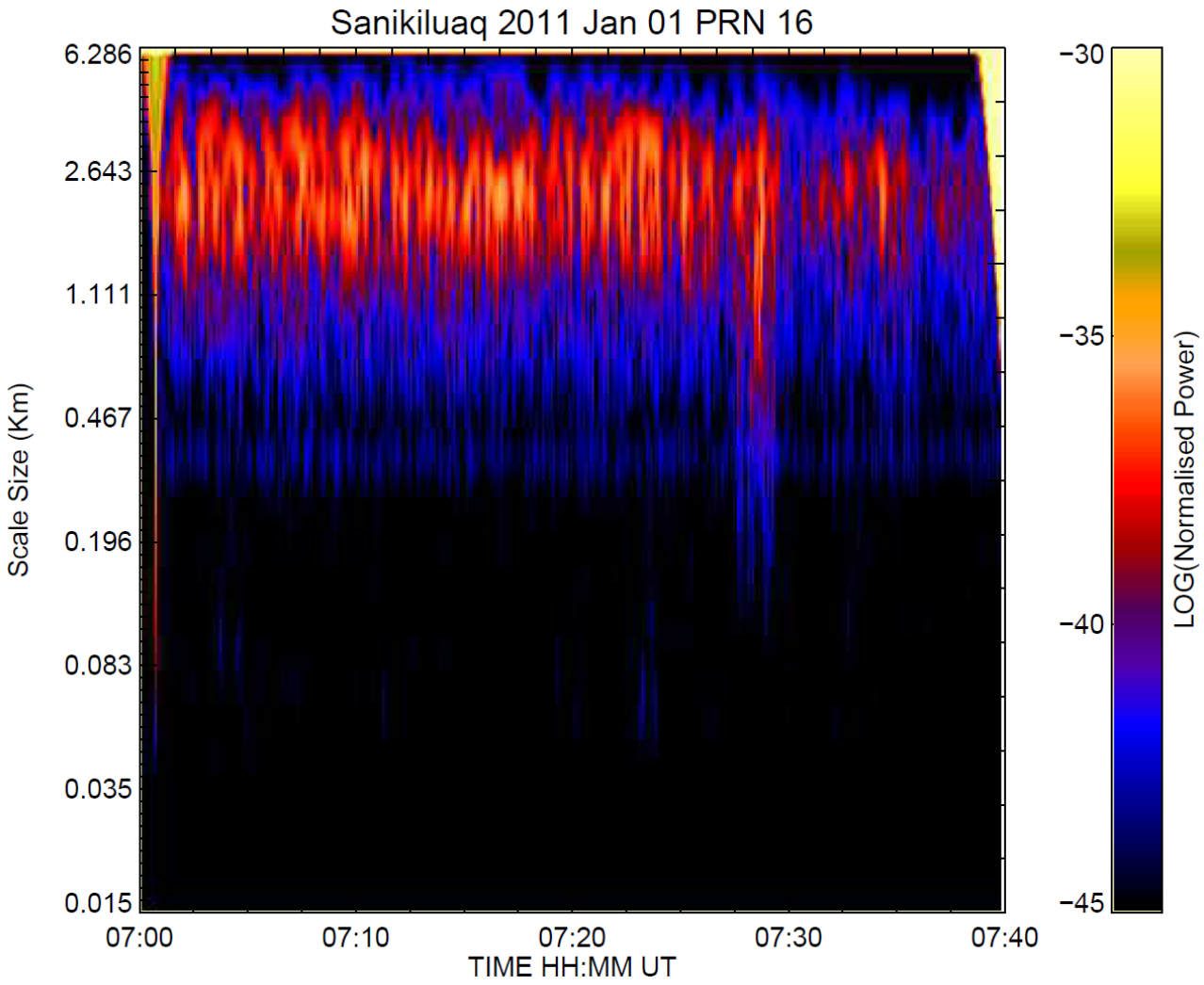
Sanikiluaq 2012 April 18

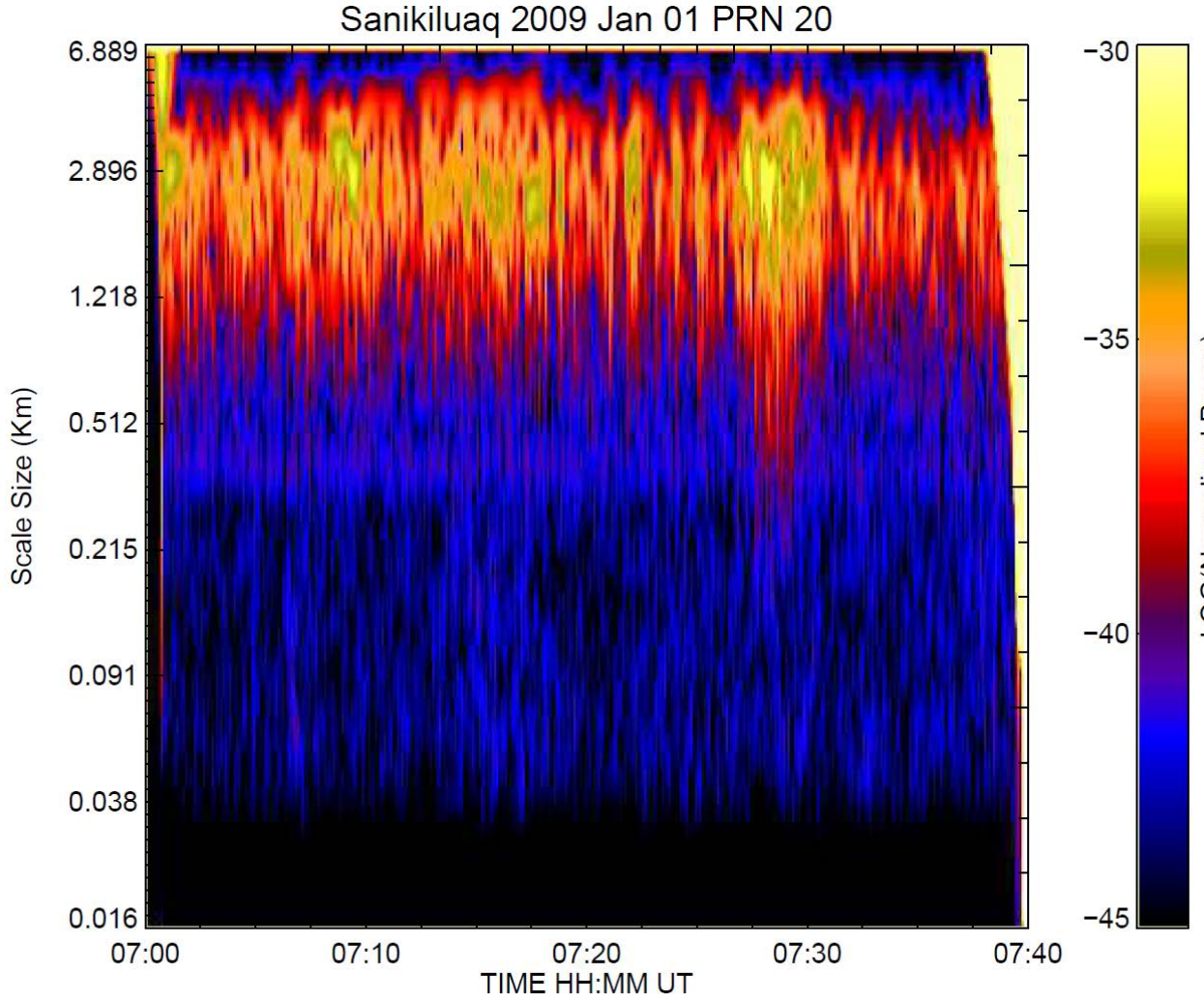

Sanikiluaq 2012 Apr 18 PRN 01
Scale Size (Km)
2.928
1.231
0.518
0.218
0.091
0.038
0.016
0.007
04:00
04:10
04:20
04:30
04:40
04:50
05:00
TIME HH:MM UT
−15
−20
−25
−30
LOG(Normalised Power)

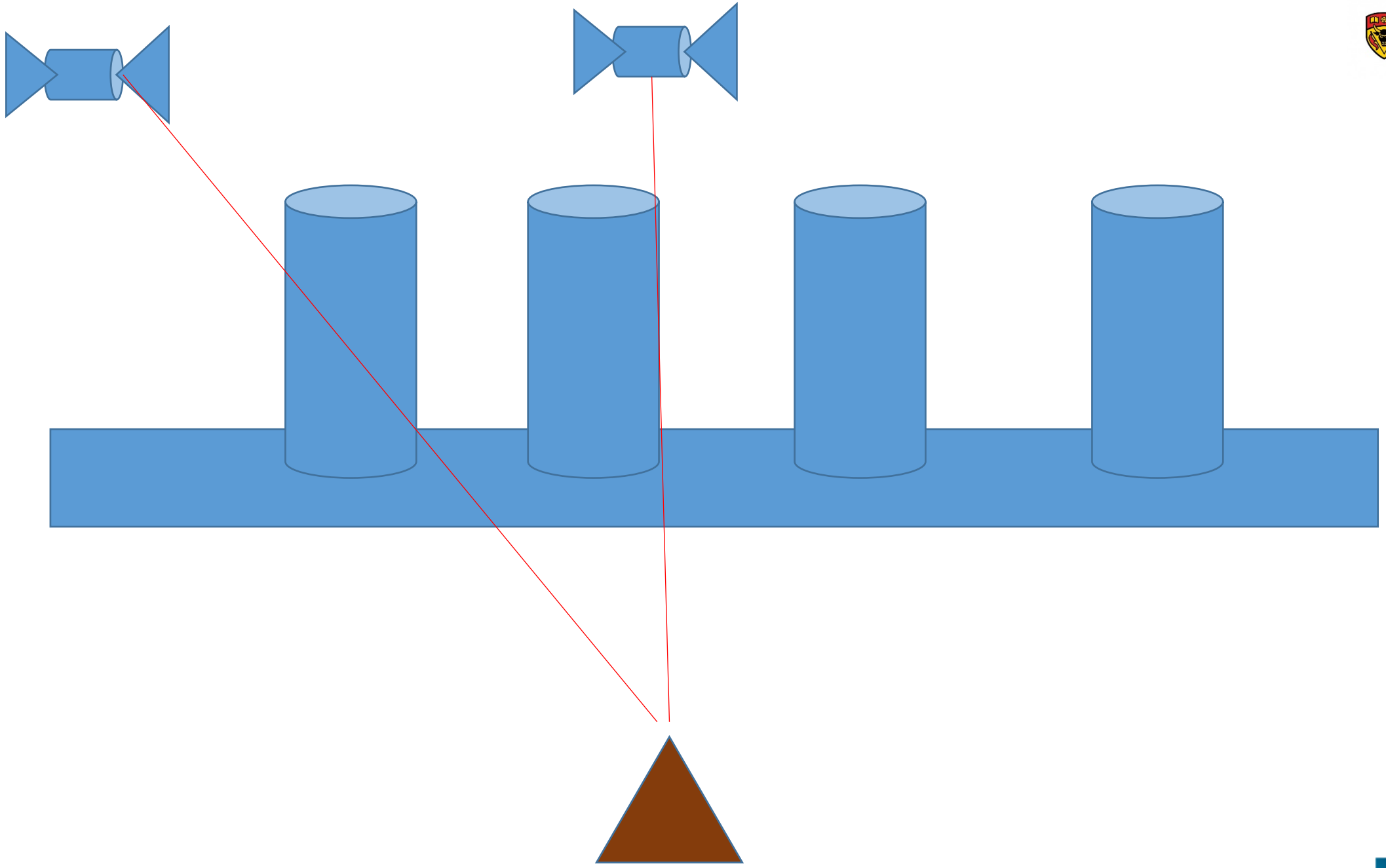

Sanikiluaq 2012 Apr 18 PRN 27
Scale Size (Km)
2.118
0.891
0.374
0.157
0.066
0.028
0.012
0.005
04:00
04:10
04:20
04:30
04:40
04:50
05:00
TIME HH:MM UT
−15
−20
−25
−30
LOG(Normalised Power)



Sanikiluaq 2009 Jan 01


Sanikiluaq 2011 Jan 01 PRN 16
6.286
2.643
1.111
0.467
0.196
0.083
0.035
0.015
Scale Size (Km)
07:00
07:10
07:20
07:30
07:40
TIME HH:MM UT
−30
−35
−40
−45
LOG(Normalised Power)


Sanikiluaq 2009 Jan 01 PRN 20
6.889
2.896
1.218
0.512
0.215
0.091
0.038
0.016
Scale Size (Km)
07:00
07:10
07:20
07:30
07:40
TIME HH:MM UT
−30
−35
−40
−45



Conclusions and Future work

- PPA seem to be one effecting GPS signals more than Arcs
- PPA's larger spatial scale and longer fluctuations can be attributed to this effect
- Arcs seem to have contribution from smaller irregularity scales compared to PPA
- Elevation dependence in scale lengths is more pronounced in PPA rather than Auroral Arcs pointing towards vertical orientation of irregularities in PPA (initial work, need to further studied)
- More cases and methods are being considered to remove some assumptions that were made.

Acknowledgements

- Darren Chaddoc, THEMIS, Univ. of Calgary, Canada
- Bing Yang, Univ. of Calgary, Canada
- Richard Chadwick, CHAIN, Univ. of New Brunswick, Canada
- NRCAN, Govt. of Canada
- Eyes High Fellowship, Univ. of Calgary, Canada
- Alberta Innovates Technology Fund (AITF) Fellowship, Alberta, Canada

Suggestions appreciated!