Winter Polar Vortex Statistical Studies

PAHA/CANDAC Workshop

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http://homepage.usask.ca/~cem600

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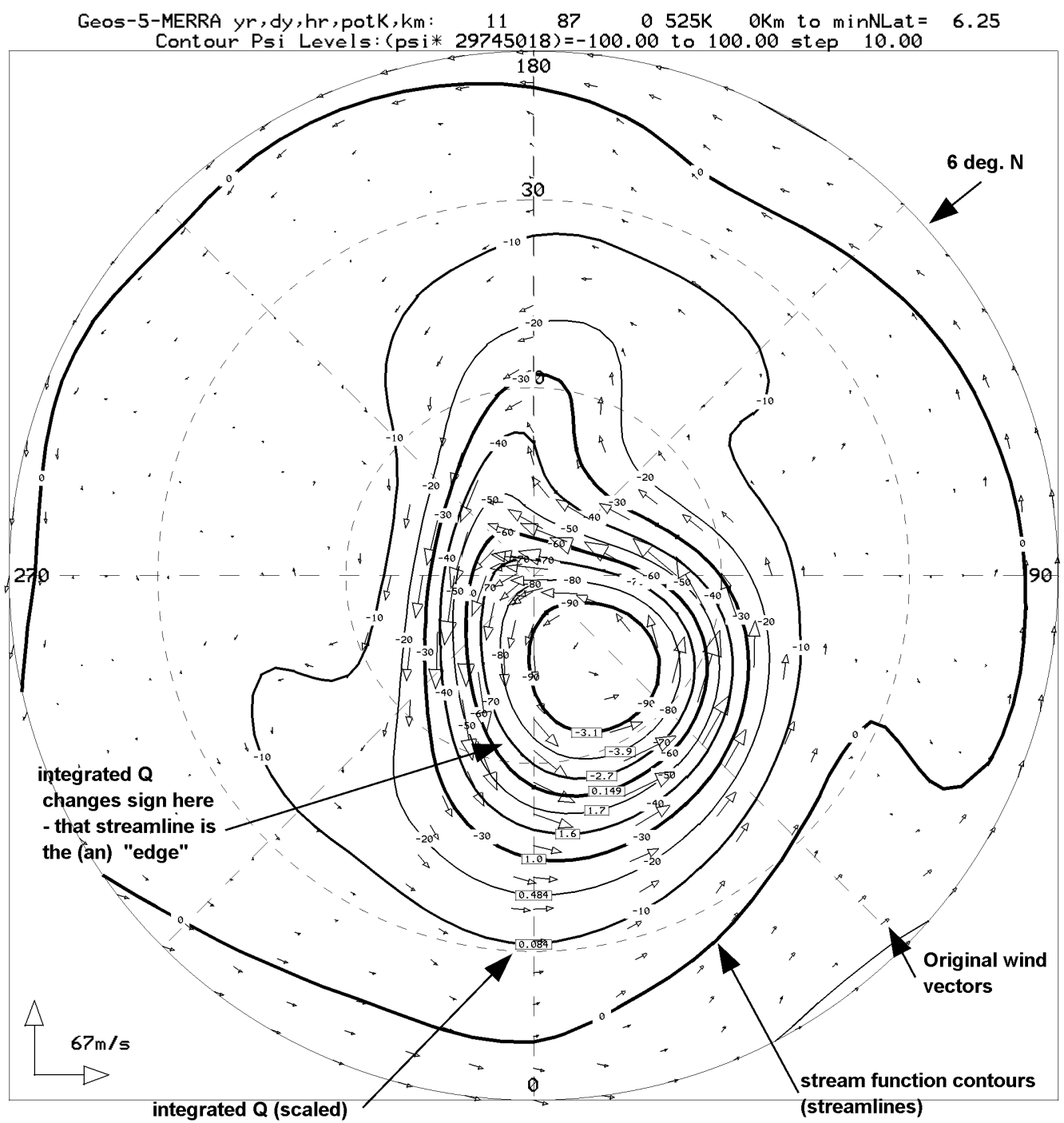
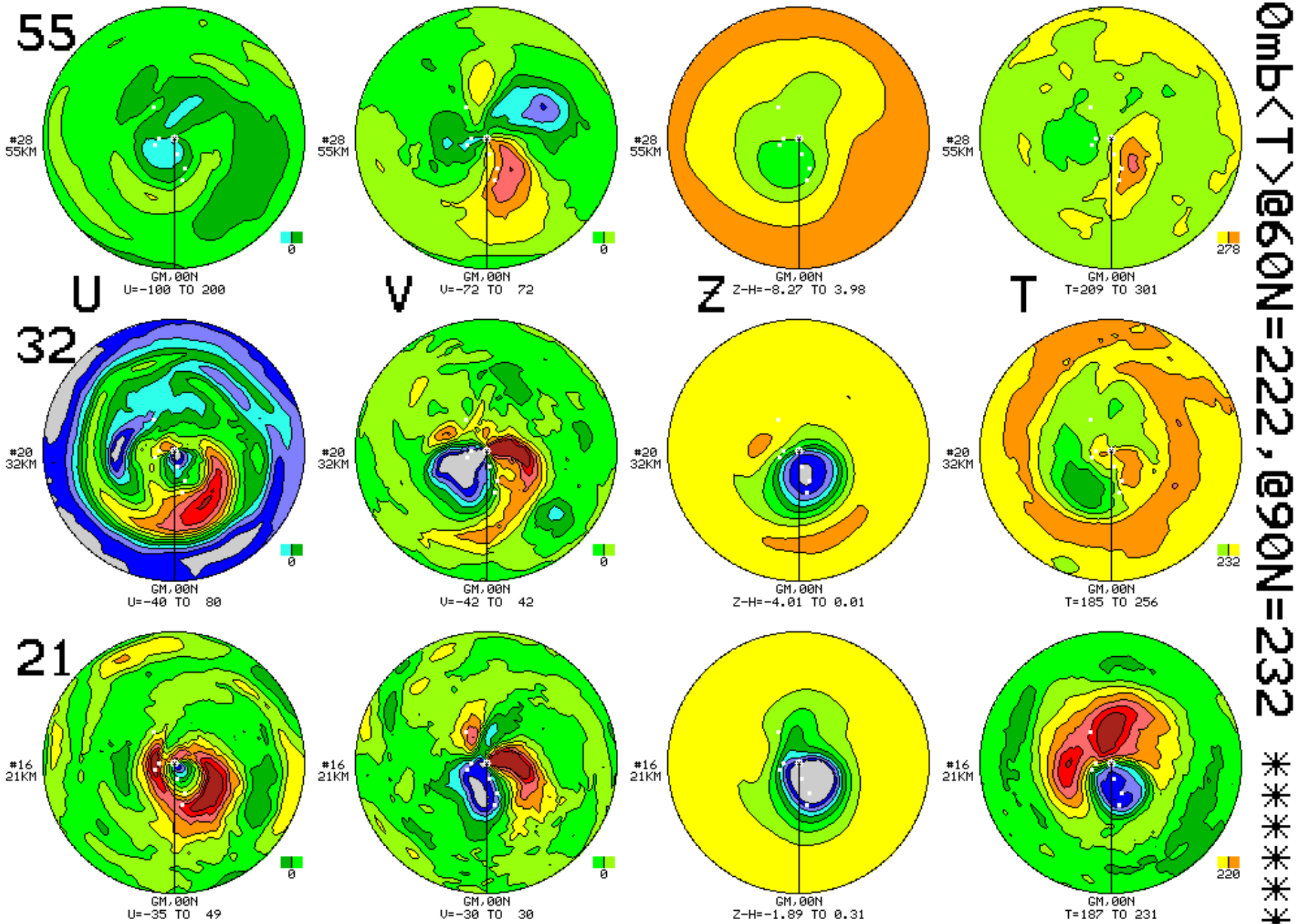
Abstract:

The UKMO/MetO (UK Met Office stratospheric assimilated) data, provided by the British Atmospheric Data Centre, BADC, covers winters from 1991/92 to 2014/15 (24 years). Vortex edge analysis based on V. Lynn Harvey, R. Bradley Pierce, and Duncan Fairlie (A climatology of stratospheric polar vorticies and anticyclones, JGR 107 No. D20, 4432, doi:1029/2001jd001471,2002) defines an "edge" as a streamline(s) where the integrated value of "Q" around the streamline (definition in later slide) changes sign.

A set of geographical points is kept for each edge, but more importantly for this paper, a "header" line contains parameters such as the mean speed around the edge, the area covered, the perimeter, and “centre”. This paper looks at some statistics of these data in Northern Hemisphere winters from 330K (~10Km) to 2000K (~50Km). Extended CMAM ("CMAM30") is also used to view/define parameters at the top of the vortex (~70Km), which until recently (Nov. 2009) was beyond the UKMO 24 year data set.


Geos-5-MERRA yr,dy,hr,potK,km: 11 87 0 525K 0Km to minNLat= 6.25
Contour Psi Levels:(psi* 29745018)=-100.00 to 100.00 step 10.00
180
30
270
90
0
6 deg. N
integrated Q changes sign here - that streamline is the (an) "edge"
67m/s
integrated Q (scaled)
stream function contours (streamlines)
Original wind vectors
-3.1
-3.9
-2.7
0.149
1.7
1.6
1.0
0.484
0.084


UKMOpp UVZT contours:Day=11:087 Lat(0N->NPole, Fixed scales)
55
#28
55KM
0
GM,00N
U=-100 TO 200
U
GM,00N
V=-72 TO 72
V
GM,00N
Z-H=-8.27 TO 3.98
Z
278
GM,00N
T=209 TO 301
T
32
#20
32KM
GM,00N
U=-40 TO 80
GM,00N
V=-42 TO 42
GM,00N
Z-H=-4.01 TO 0.01
232
GM,00N
T=185 TO 256
21
#16
21KM
GM,00N
U=-35 TO 49
GM,00N
V=-30 TO 30
GM,00N
Z-H=-1.89 TO 0.31
220
GM,00N
T=187 TO 231
10mb<T>@60N=222,@90N=232
MetO/UKMO data are courtesy of British Atmospheric Data Centre BADC (CMeek,UofSask)

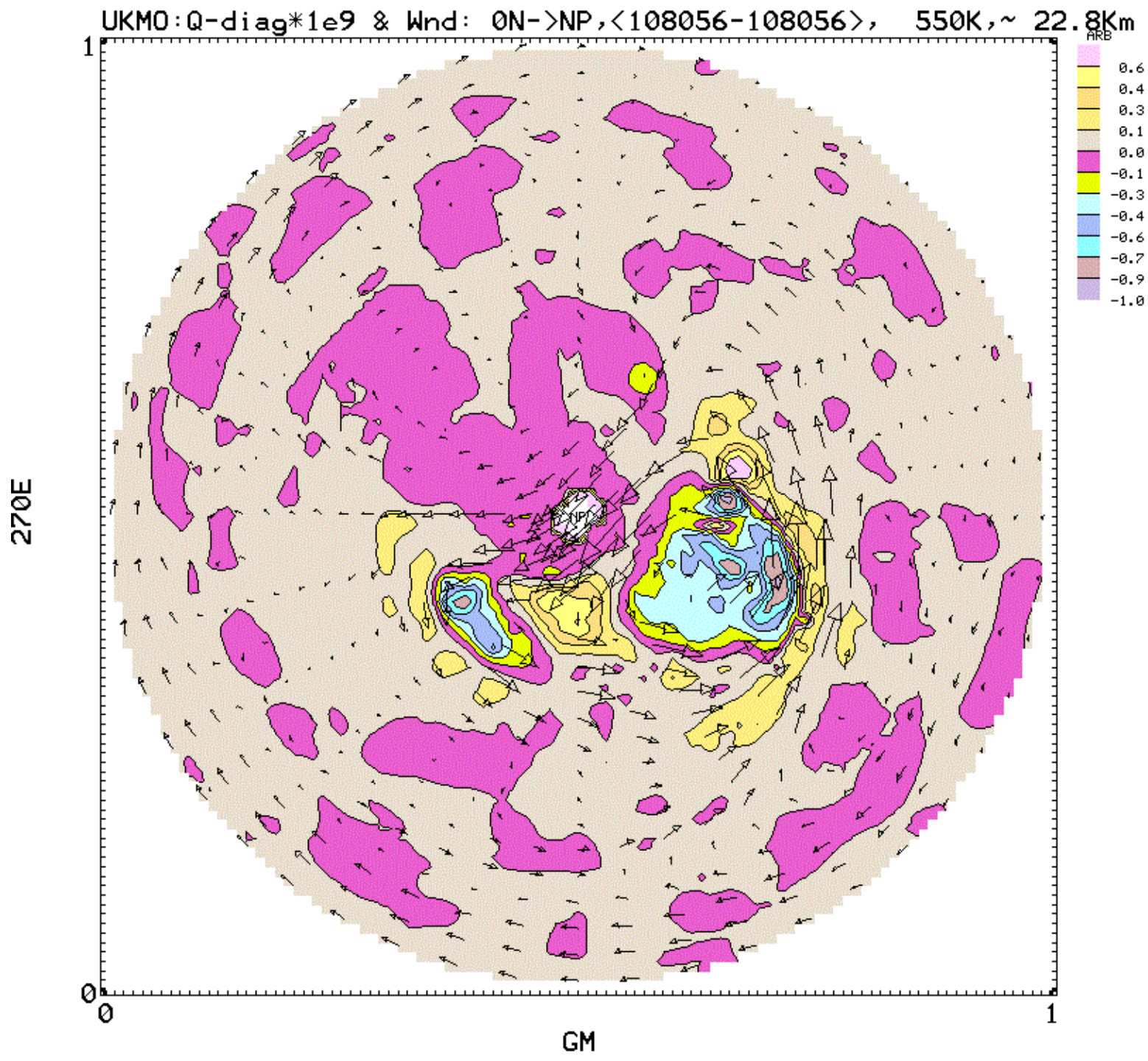
$$Q = \frac{1}{2}\left(\frac{1}{a\cos\phi}\frac{du}{d\lambda} - \frac{v}{a}\tan\phi\right)^2 + \frac{1}{2}\left(\frac{1}{a}\frac{dv}{d\phi}\right)^2$$

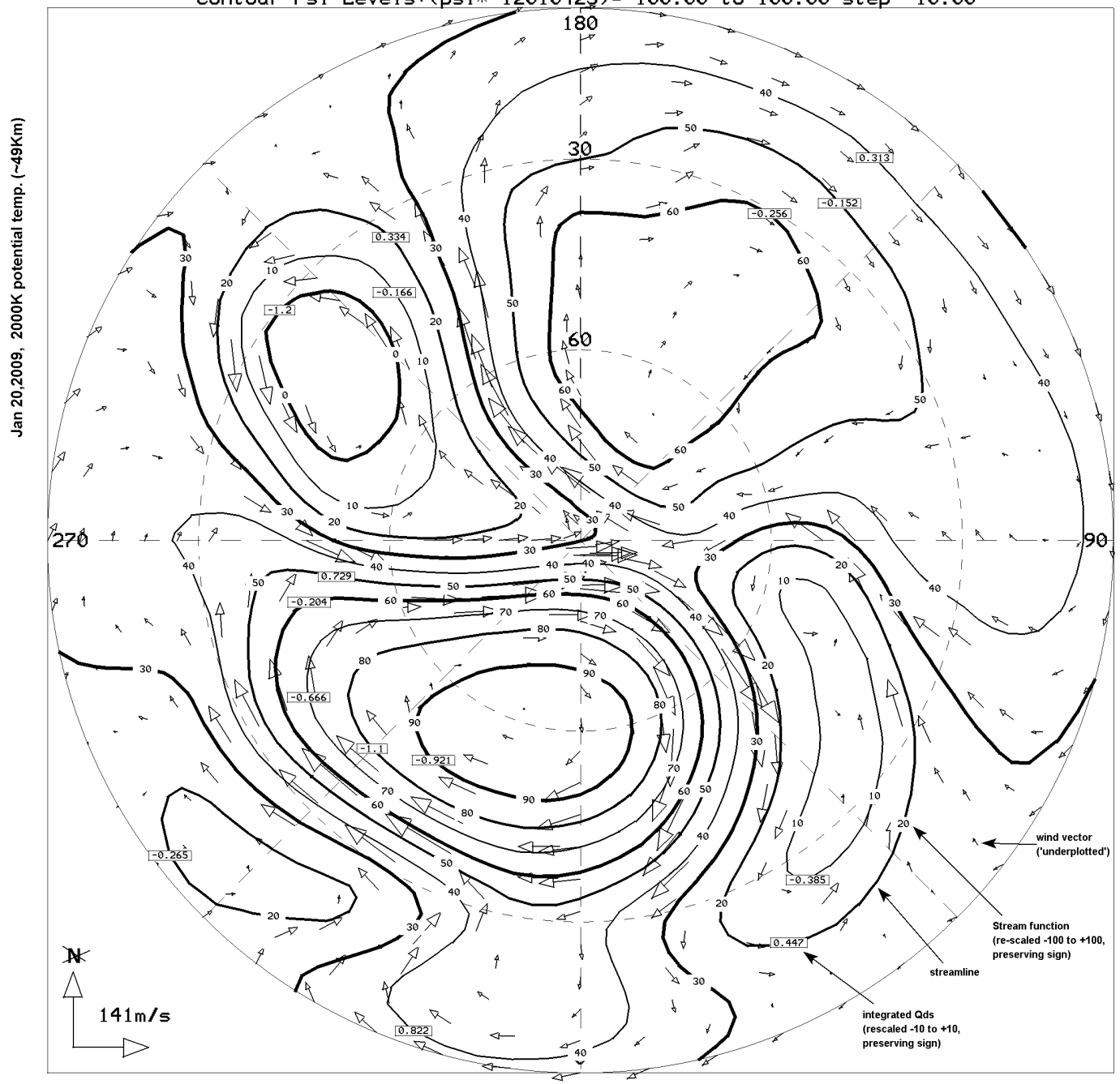
$$+ \left(\frac{1}{a^2\cos\phi}\frac{du}{d\phi}\frac{dv}{d\lambda} + \frac{u\tan\phi}{a^2}\frac{du}{d\phi}\right)$$

where ϕ = latitude; λ = longitude,
u = zonal wind, v = meridional wind,
and a = the radius of the Earth.

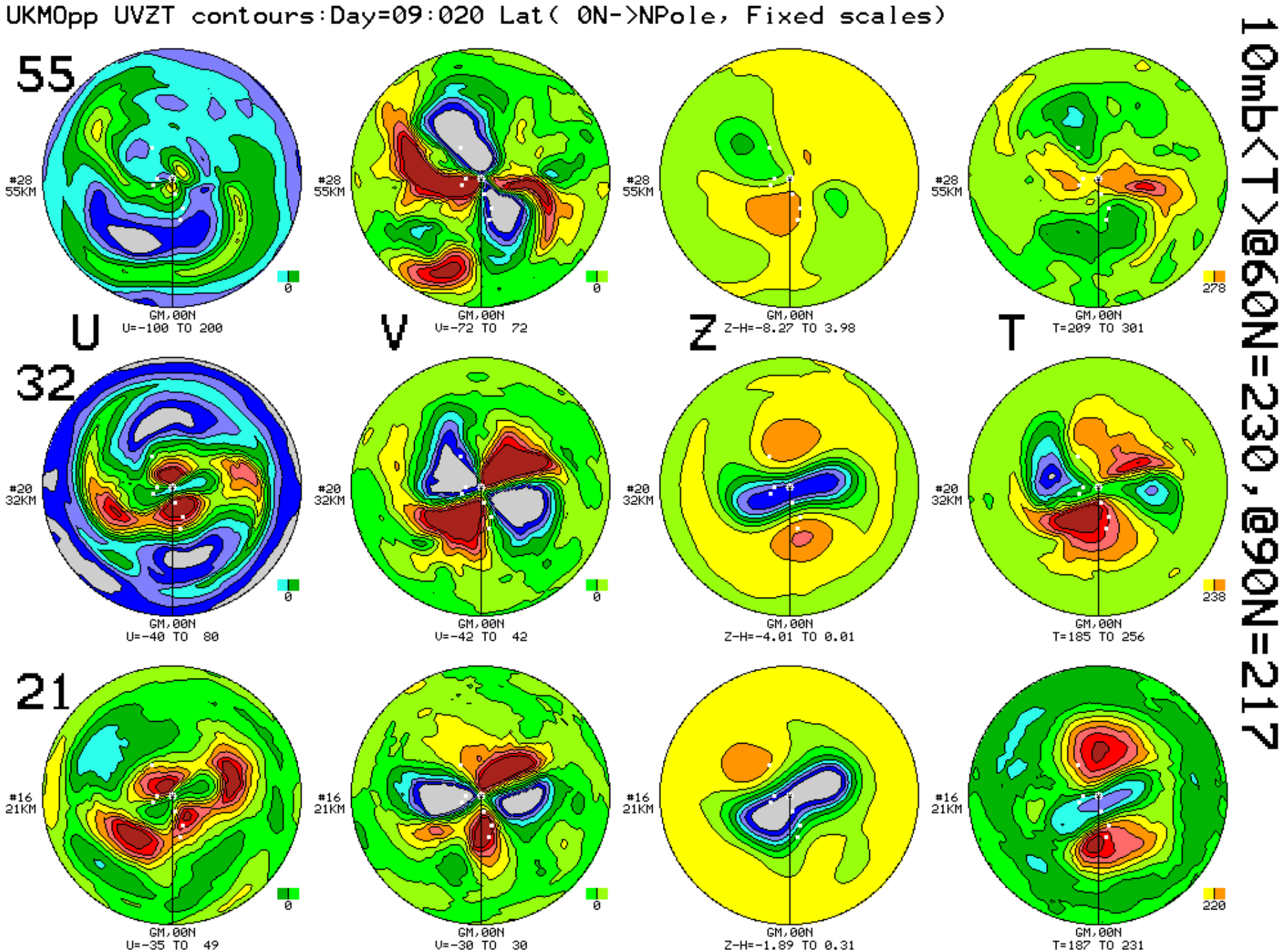
"Q is
positive (negative) where strain (rotation) dominates the flow. For example, shear zones on the edges of vortices and near jet streams have positive Q while negative Q is associated with stable rotational flow."

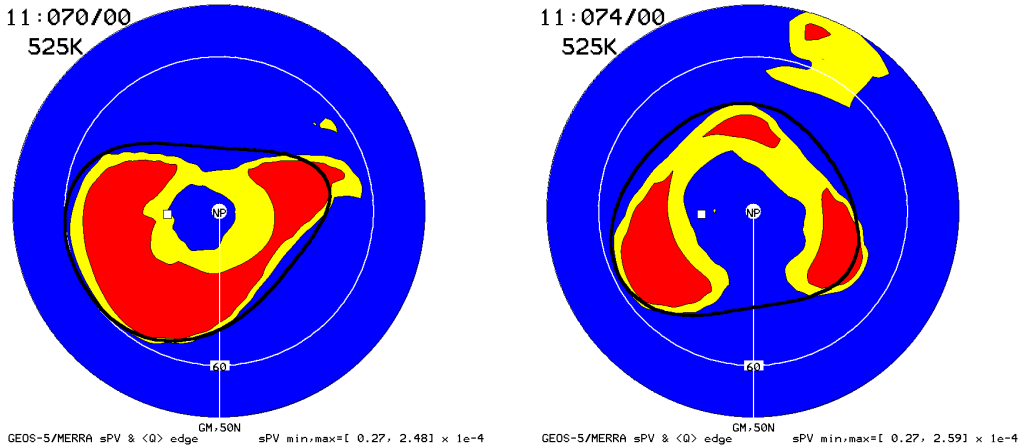
(Harvey et al., 2002)

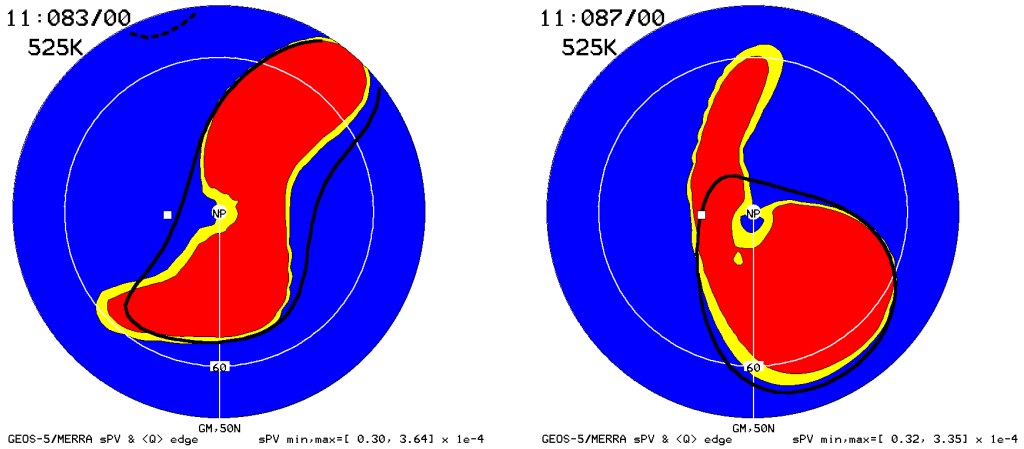

UKMO:Q-diag*1e9 & Wnd: 0N->NP,<108056-108056>, 550K,~ 22.8Km
ARB
0.6
0.4
0.3
0.1
0.0
-0.1
-0.3
-0.4
-0.6
-0.7
-0.9
-1.0
NP
1
0
0
1
270E
GM

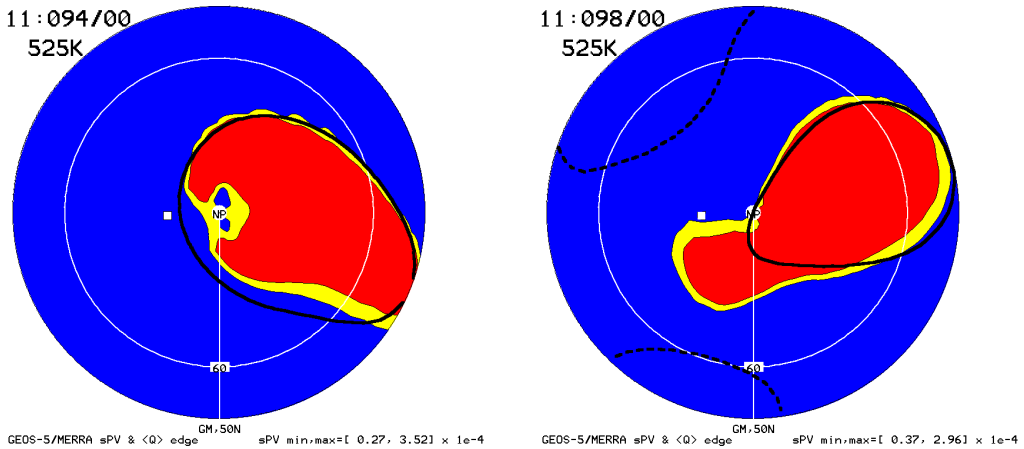


cem 7-OCT-2010 7:56:41

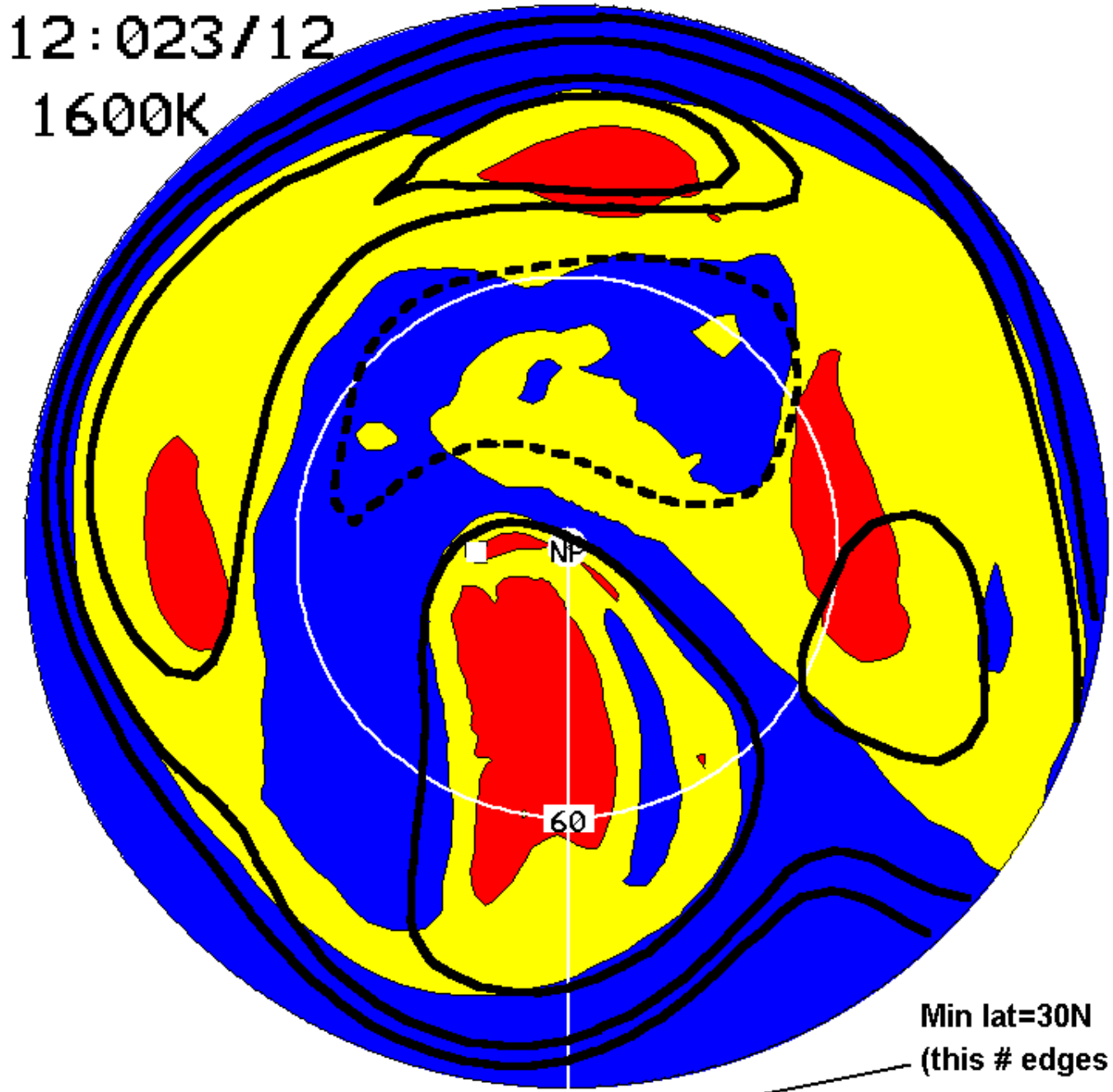

UKMOpp UVZT contours:Day=09:020 Lat(0N->NPole, Fixed scales)
55
#28
55KM
GM,00N
U=-100 TO 200
U
GM,00N
V=-72 TO 72
V
GM,00N
Z-H=-8.27 TO 3.98
Z
GM,00N
T=209 TO 301
T
32
#20
32KM
GM,00N
U=-40 TO 80
GM,00N
V=-42 TO 42
GM,00N
Z-H=-4.01 TO 0.01
GM,00N
T=185 TO 256
21
#16
21KM
GM,00N
U=-35 TO 49
GM,00N
V=-30 TO 30
GM,00N
Z-H=-1.89 TO 0.31
GM,00N
T=187 TO 231
10mb<T>@60N=230,@90N=217
MetO/UKMO data are courtesy of British Atmospheric Data Centre BADC (CMeek,UofSask)

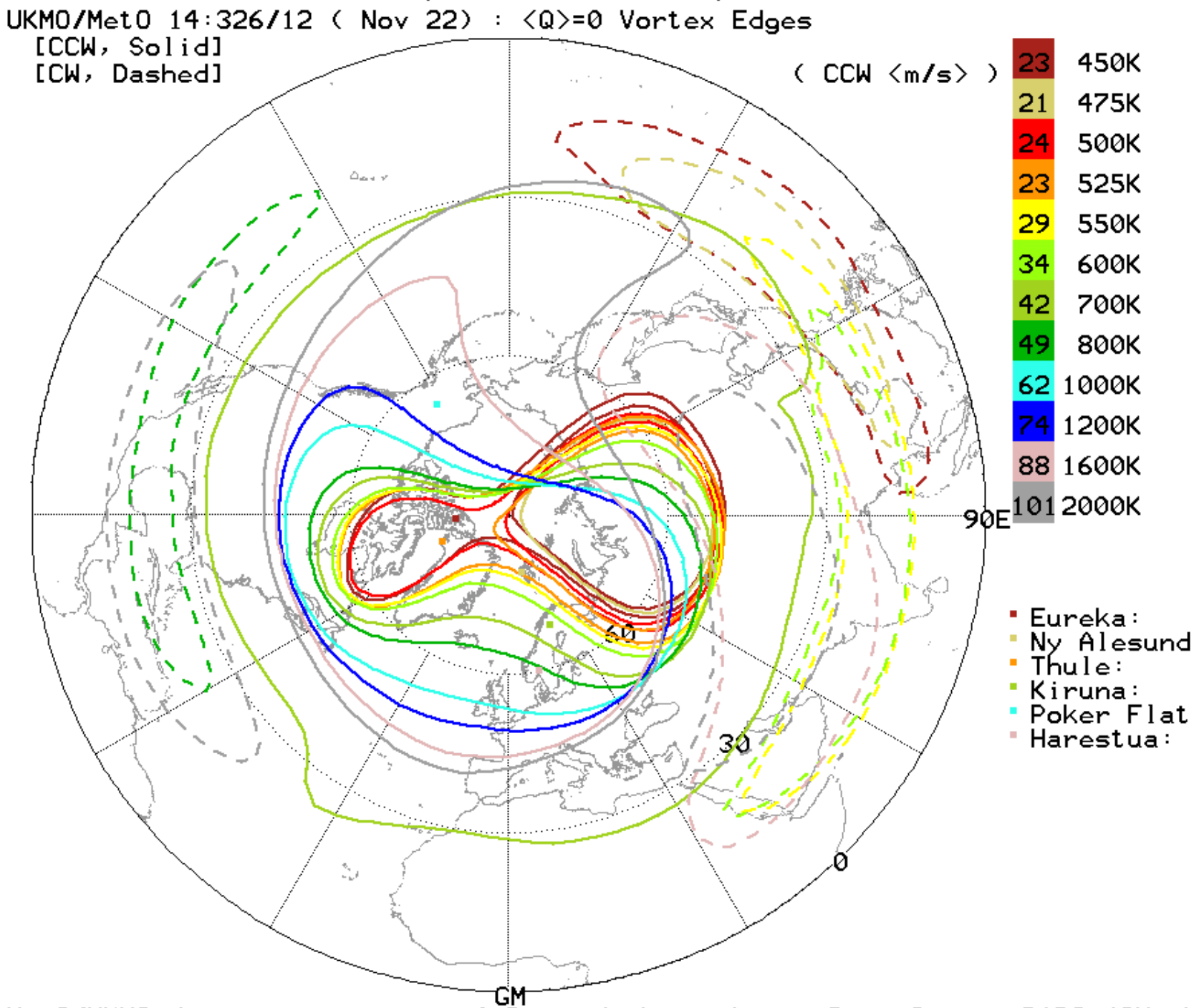




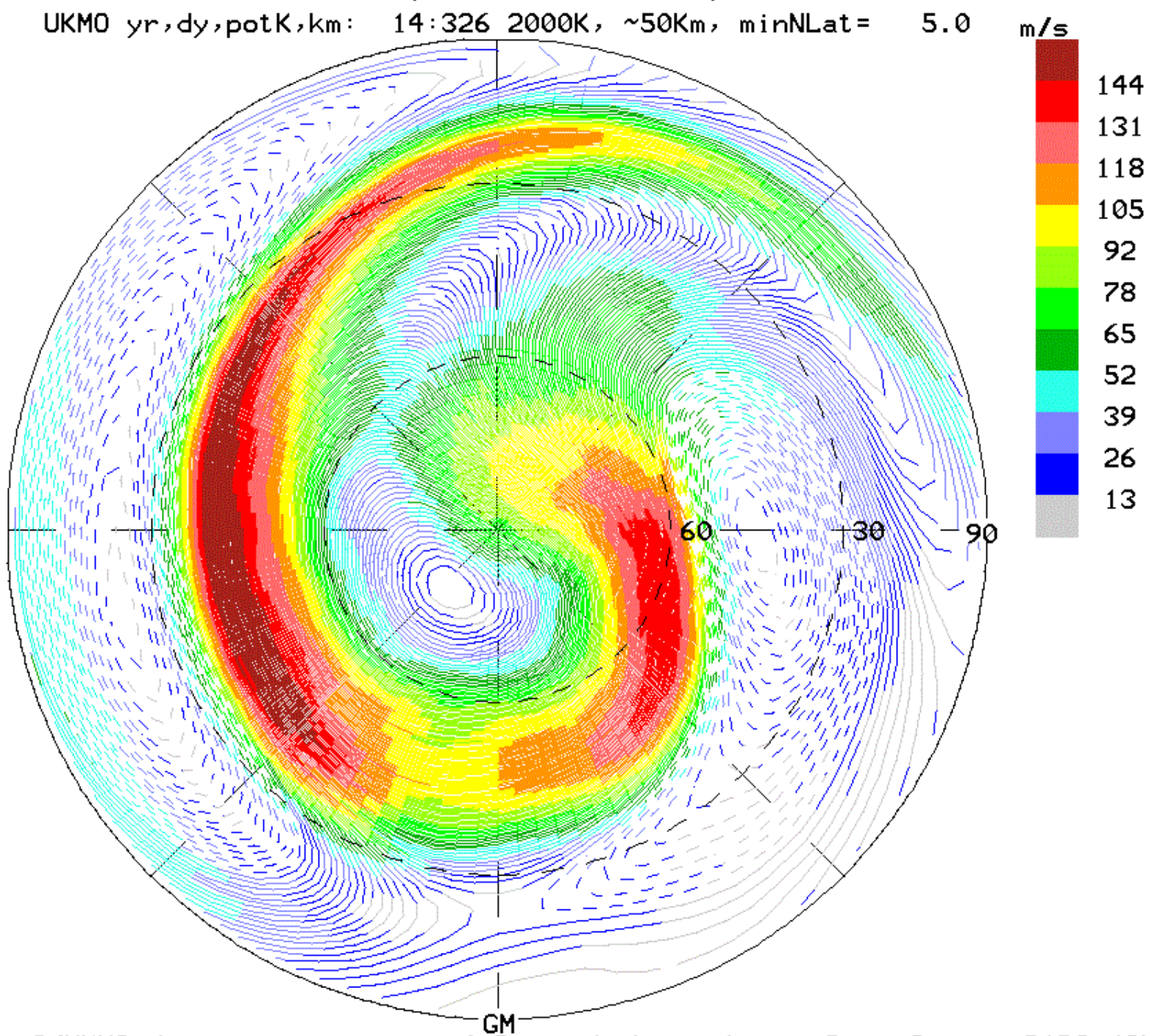


geosstr2.for +geos_5_merra_yyddd-a.pp + geosvz5a-a.for => unp70-98a.gif; yellow = between inner and outer "vortex edges"
(used pp-packed Geos-stored epv - converted to sPV with GM's function and inner-outer edge definition, ~~2.e-4 to 6e-4~~)
1.2e-4 to 1.6e-4

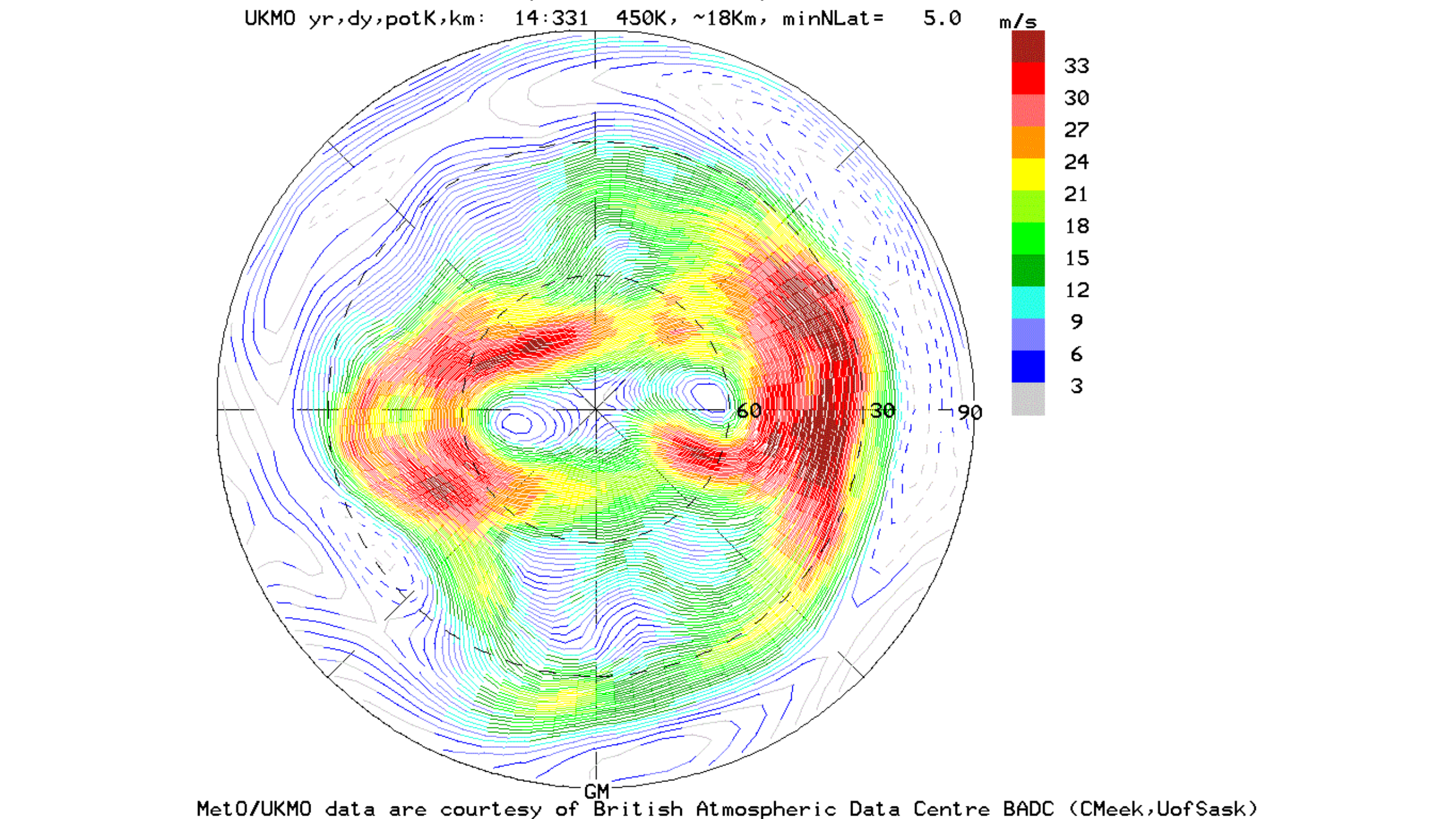

12:023/12
1600K
NP
60
c:\z\wortex\ukmovz5ab.for + sandlyyddd.bin => PV-Q16K1.gif
Min lat=30N
(this # edges unusual!)
CCW edge |V|: 41 11 17 GA,3ON 34
UKMO sPV & <Q> edge
sPV min,max=[0.39, 2.08] x 1e-4



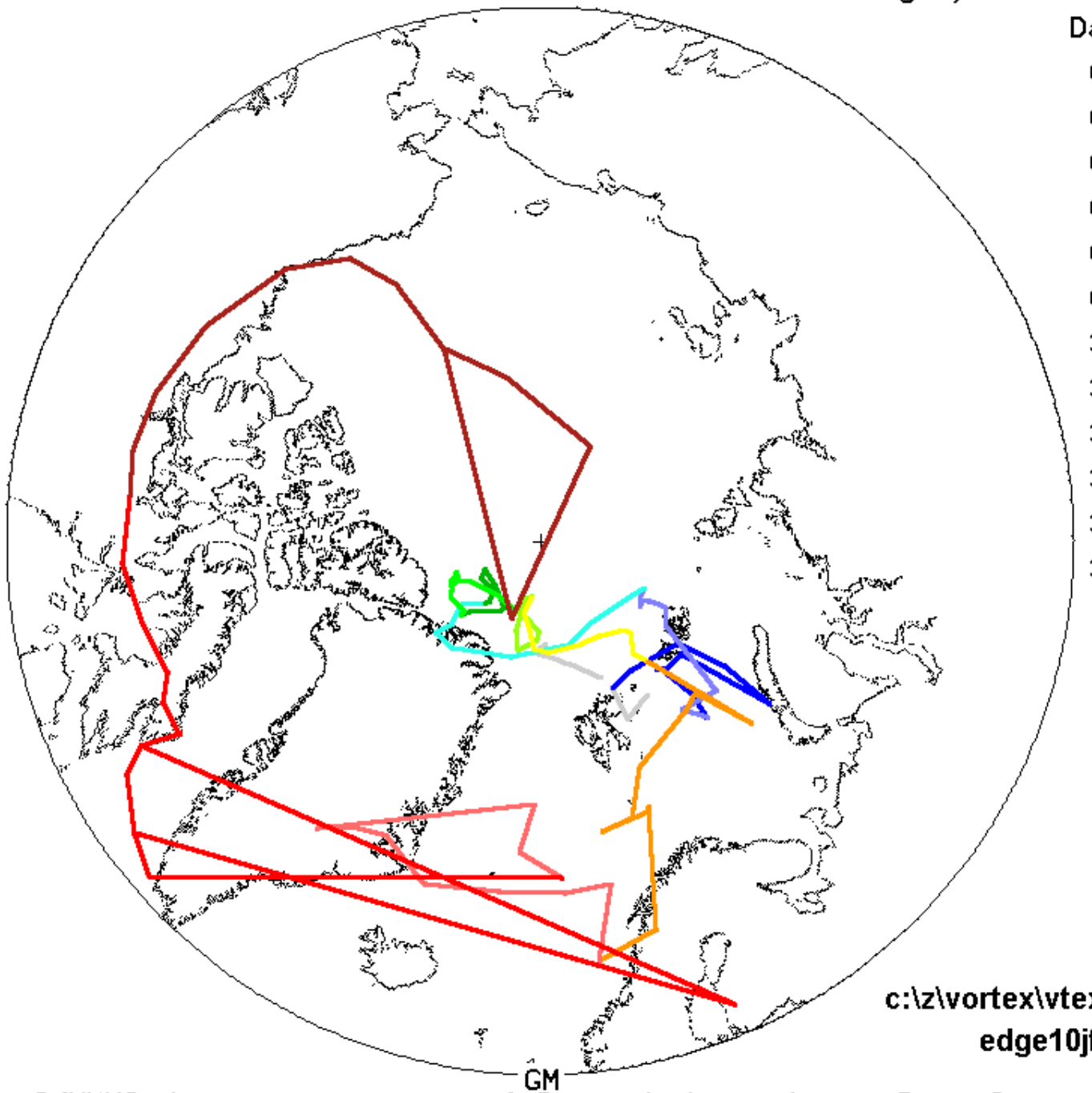
MetO/UKMO data are courtesy of British Atmospheric Data Centre BADC (CMeek,UofSask)



MetO/UKMO data are courtesy of British Atmospheric Data Centre BADC (CMeek,UofSask)


UKMO yr,dy,potK,km: 14:331 450K, ~18Km, minNLat= 5.0
m/s
33
30
27
24
21
18
15
12
9
6
3
60
30
90
GM
MetO/UKMO data are courtesy of British Atmospheric Data Centre BADC (CMeek,UofSask)

UKMO/MetO VtexCntr:09Nov-10Feb, LvL= 800K,10d/colr,grey-red,1degRes

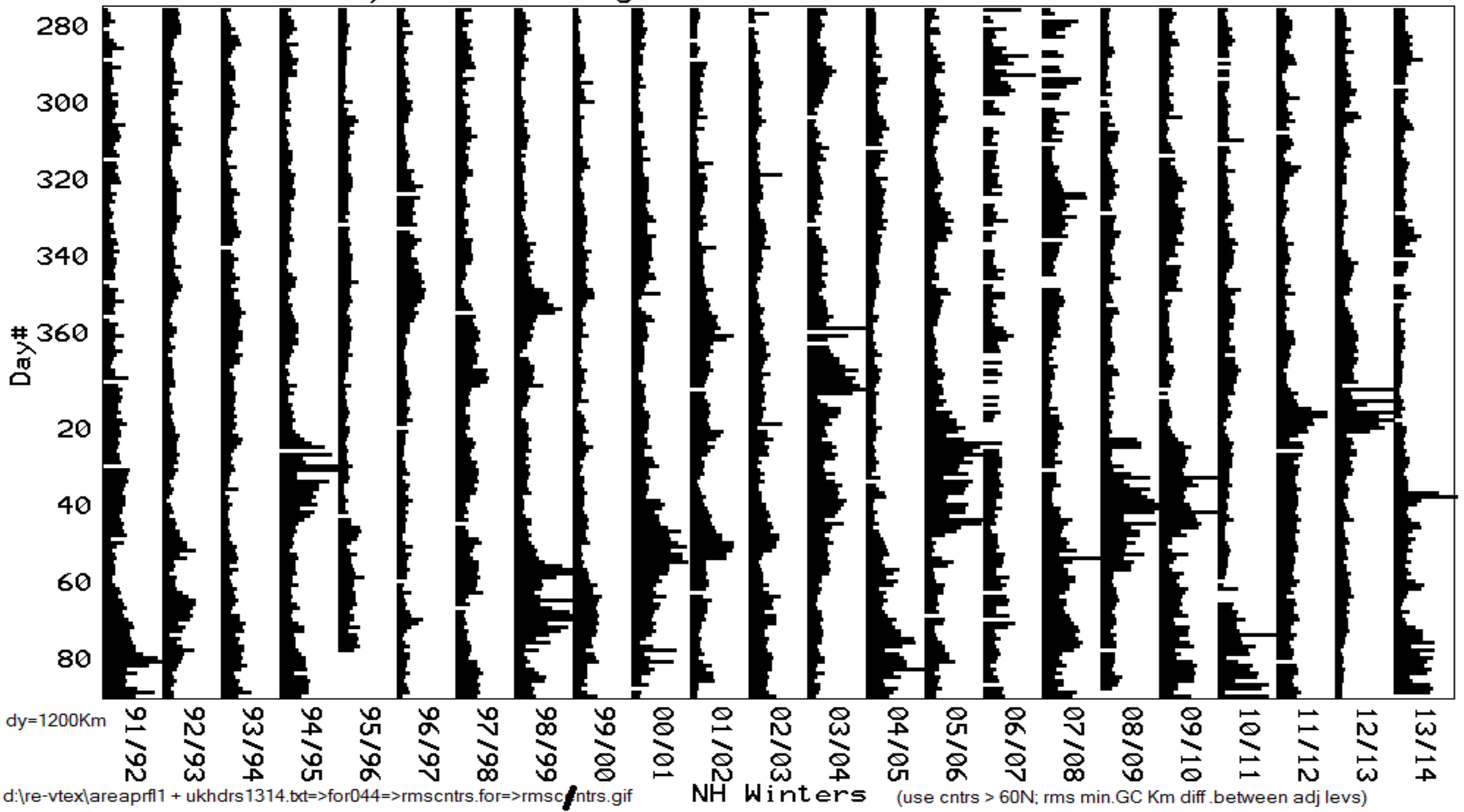


Day#Range

051	060
041	050
031	040
021	030
011	020
001	010
356	365
346	355
336	345
326	335
316	325
306	315

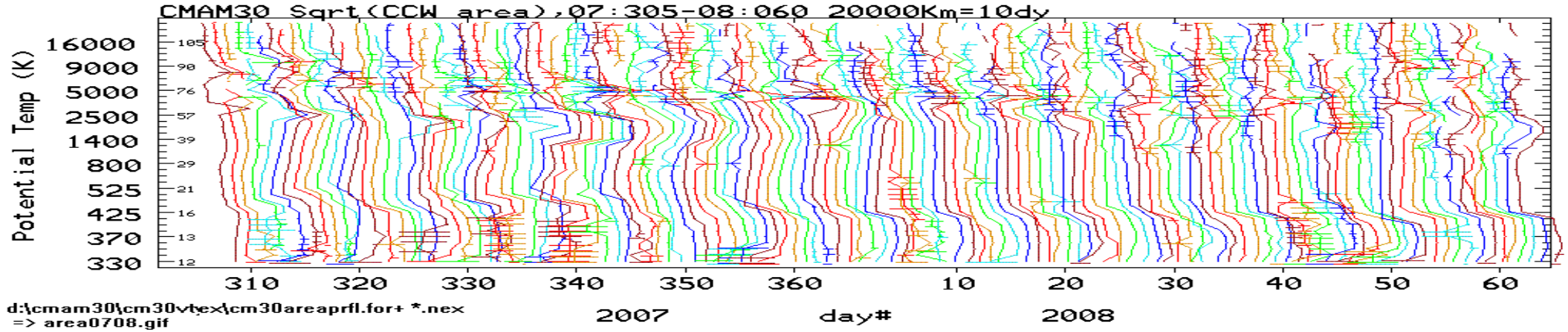
c:\z\vortex\vtexcntr2.for + edge9ond.nex
edge10jfm.nex = vtexc4.gif

MetO/UKMO data are courtesy of British Atmospheric Data Centre BADC (CMeek,UofSask)

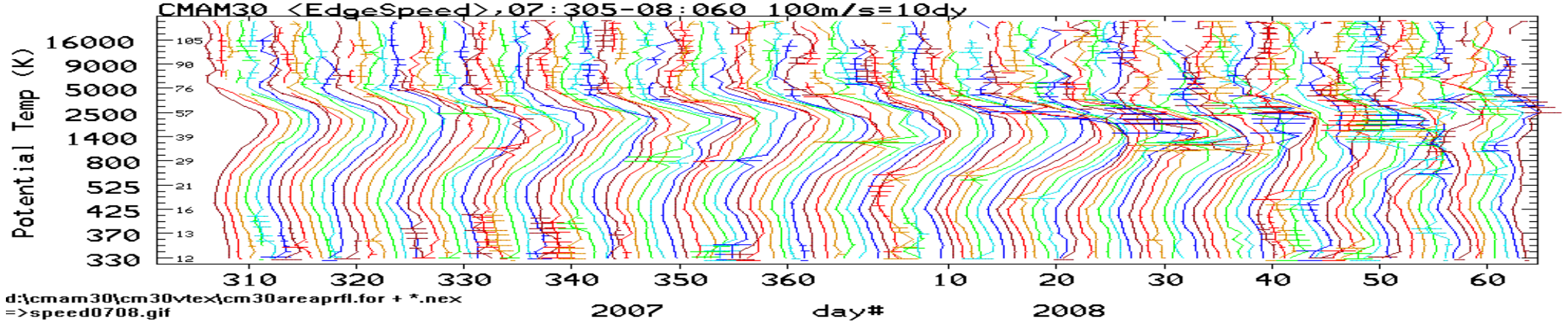

UKMO: RMS variability of vortex edge centres over all levs
Day#
280
300
320
340
360
20
40
60
80
dy=1200Km
91/92
92/93
93/94
94/95
95/96
96/97
97/98
98/99
99/00
00/01
01/02
02/03
03/04
04/05
05/06
06/07
07/08
08/09
09/10
10/11
11/12
12/13
13/14
NH Winters
d:\re-vtex\areaprfl1 + ukhdrs1314.txt=>for044=>rmscntrs.for=>rmscntrs.gif
(use cntrs > 60N; rms min.GC Km diff .between adj levs)

CMAM30

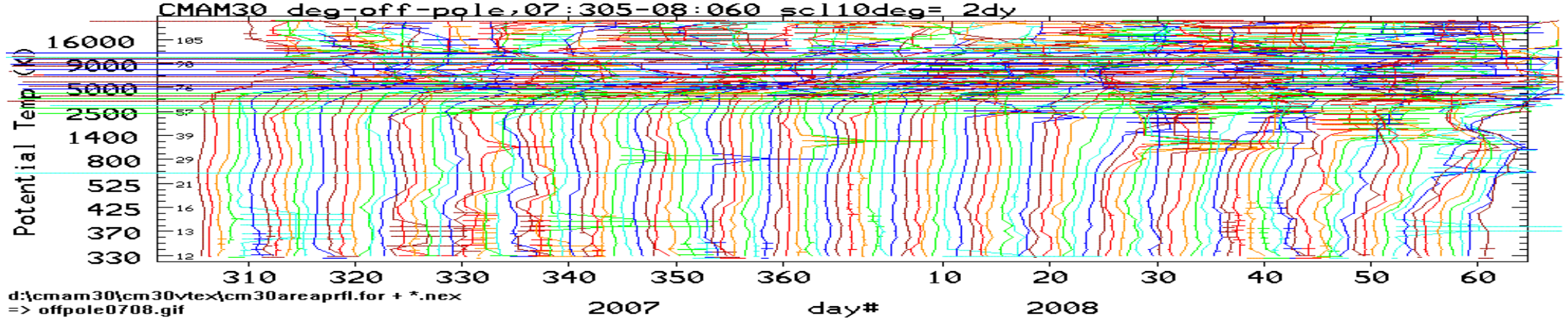
AREA



SPEED



OffPole Distance

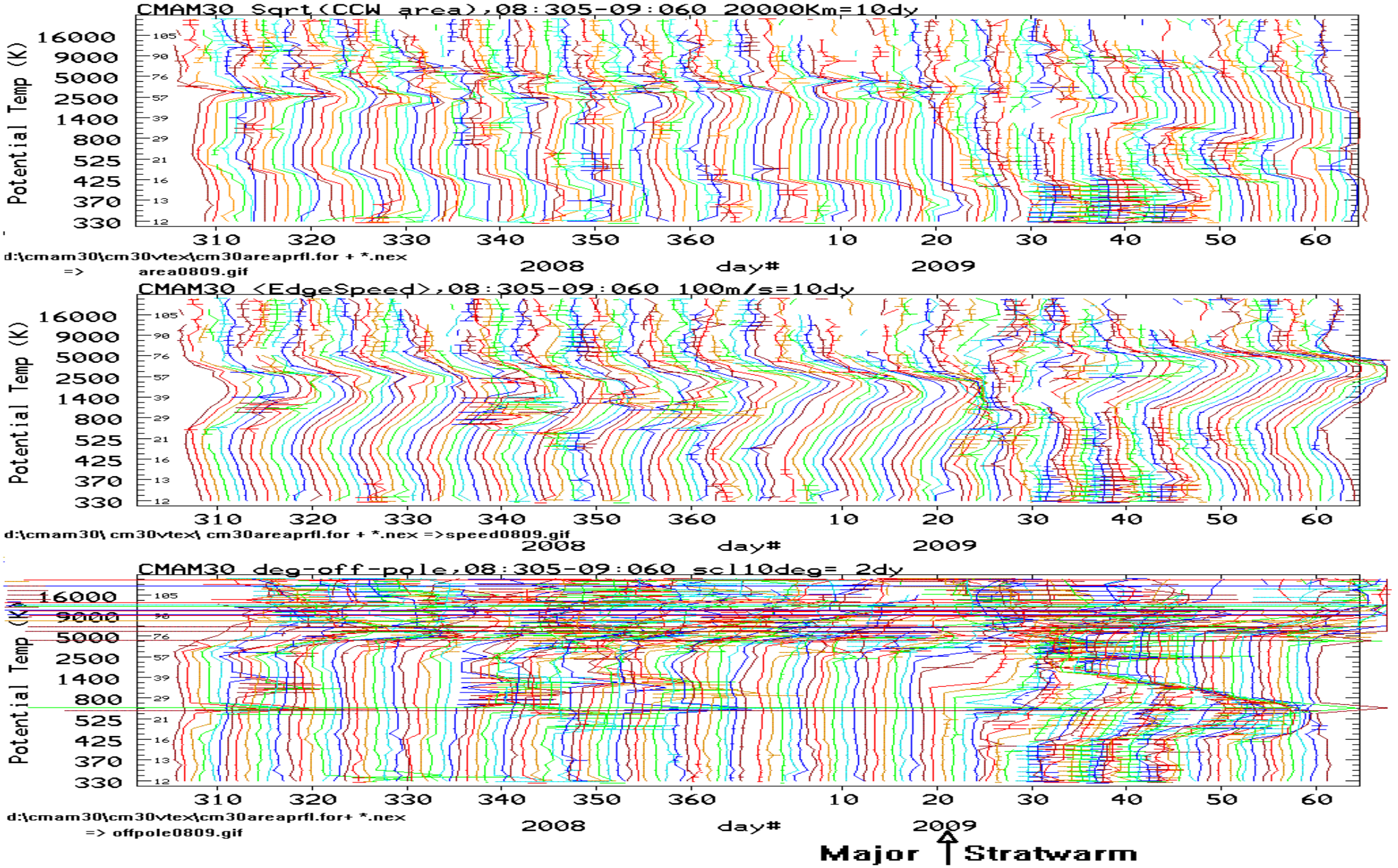


CMAM30

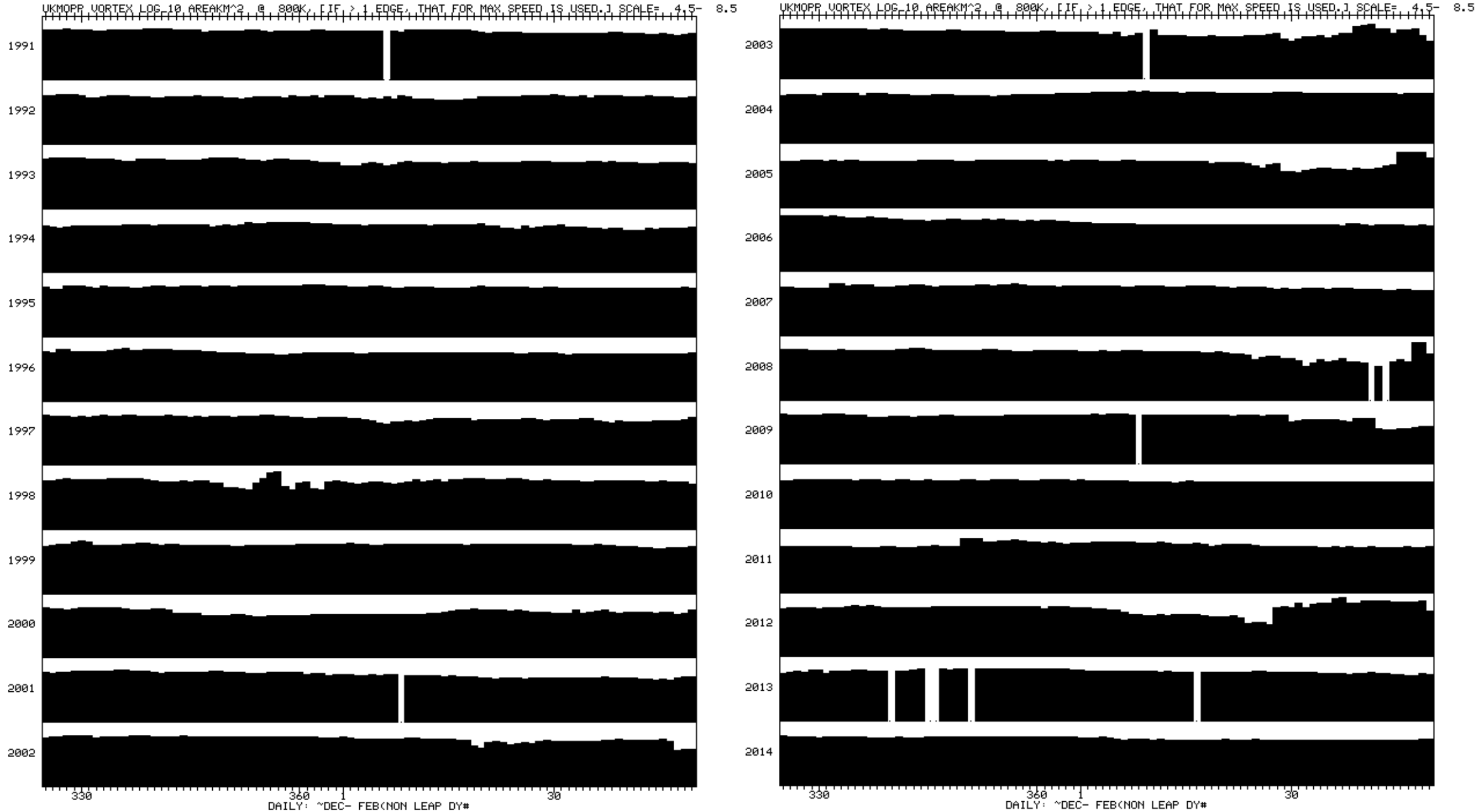
AREA

SPEED

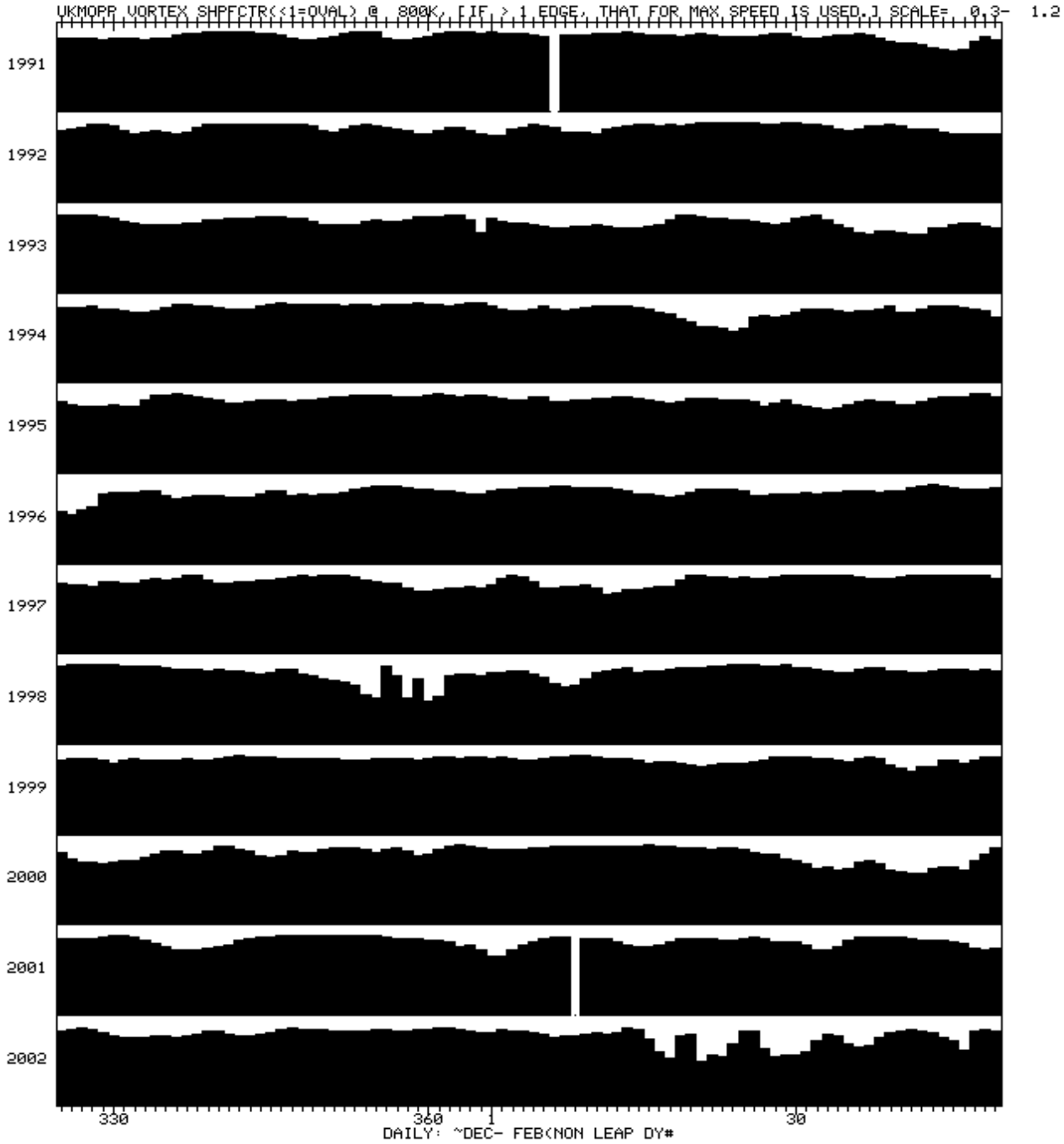
OffPole Dist.

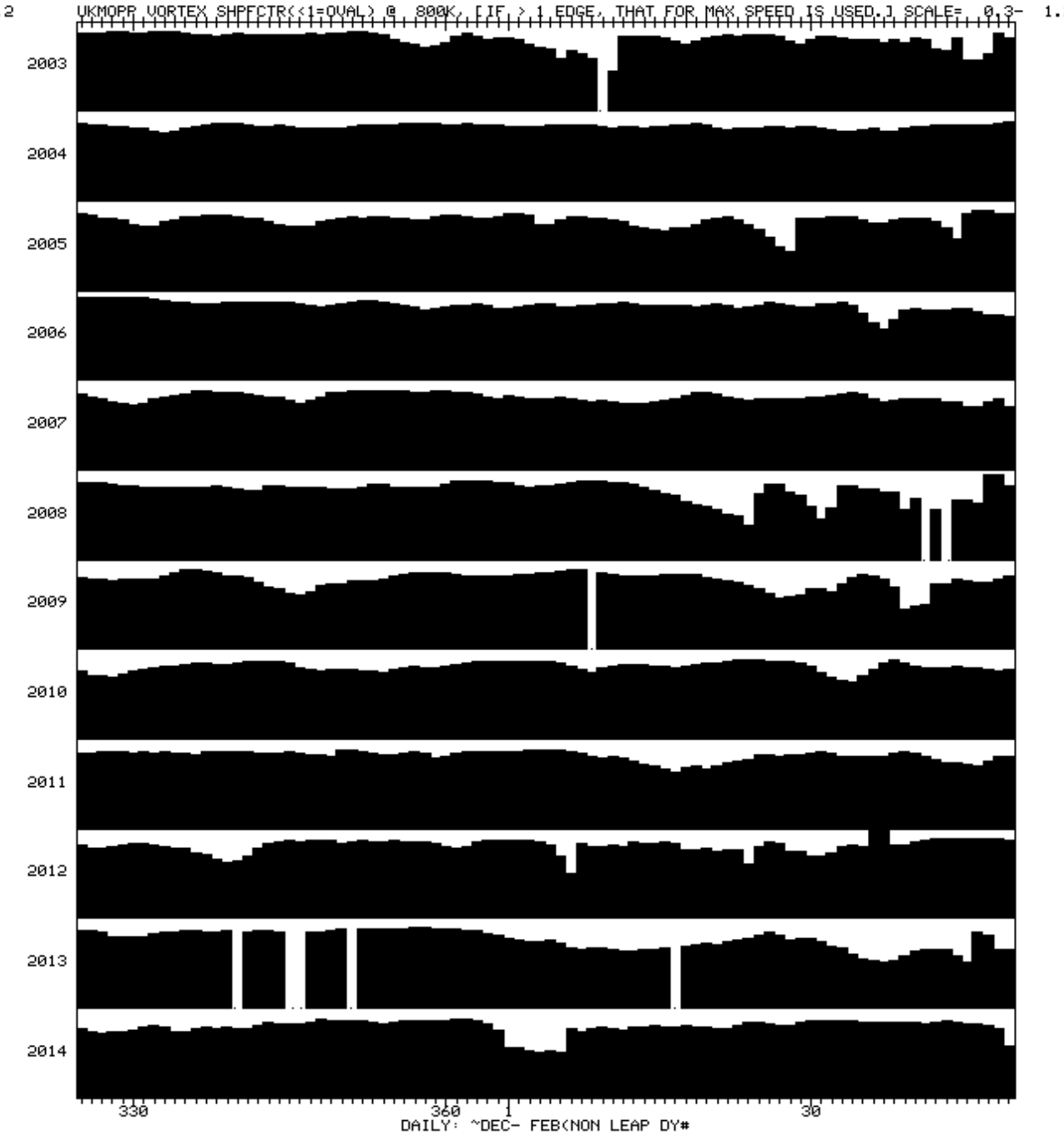


UKMO/MetO (BADC) Vortex log10 area(Km)^2 @ 800K, Winters (~Dec-Feb) 91/92 to 14/15

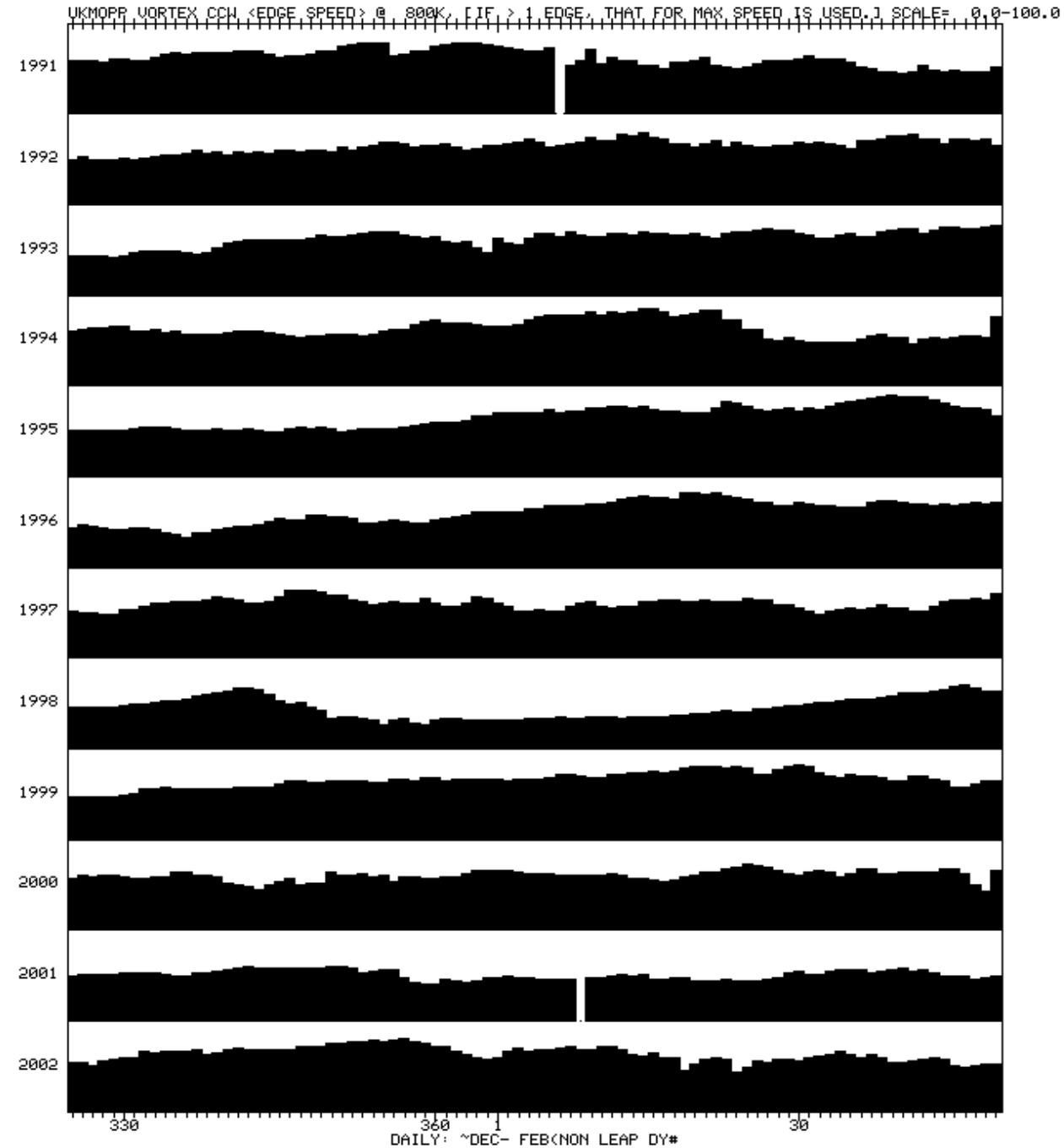


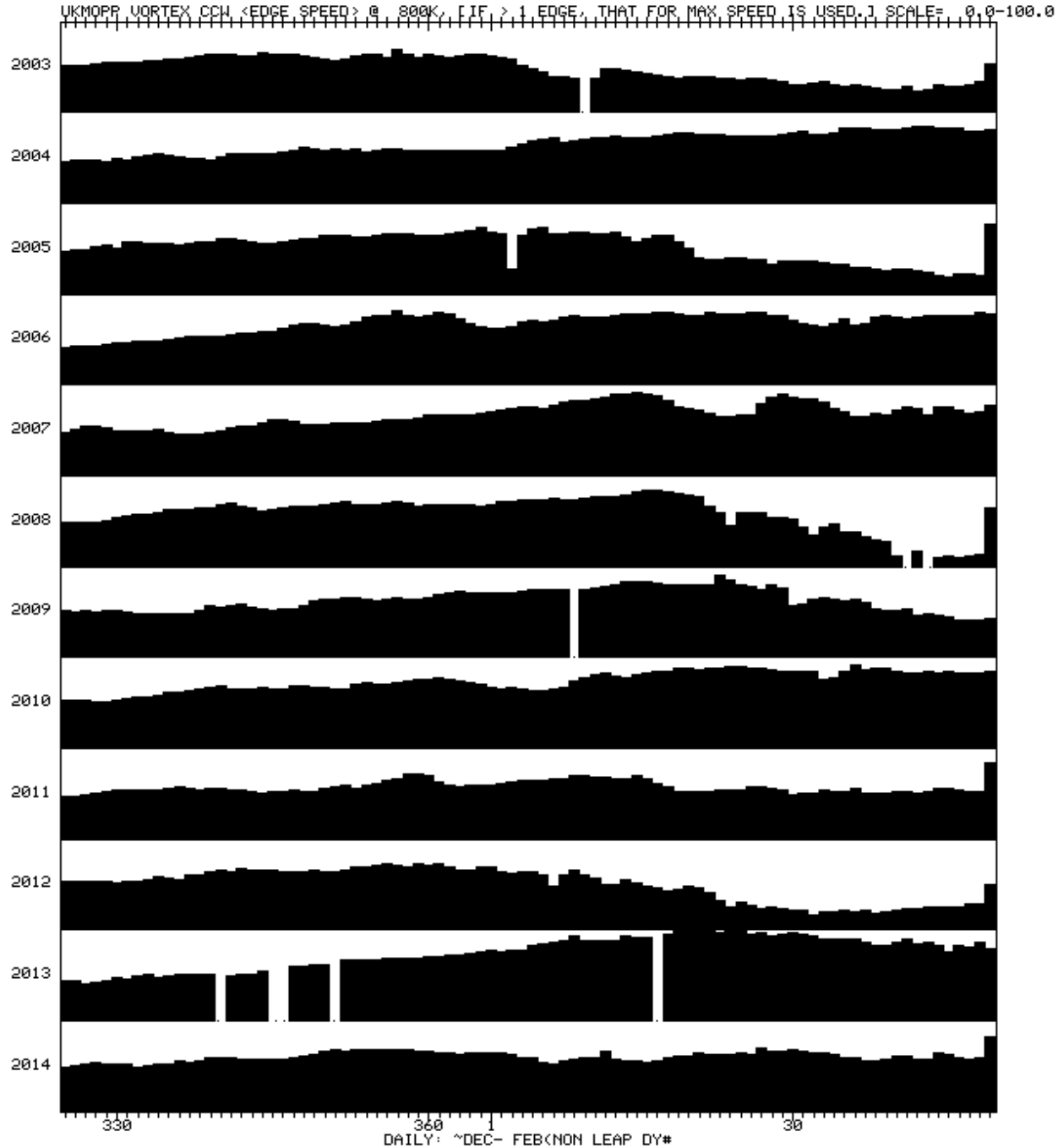
UKMO/MetO (BADC) Vortex Shape Factor=2 sqrt(pi area)/perim @800K, WInters (~Dec-Feb) 91/92 to 14/15





UKMO/MetO (BADC) Vortex edge speeds @ 800K, Winters (~Dec-Feb) 91/92 to 14/15

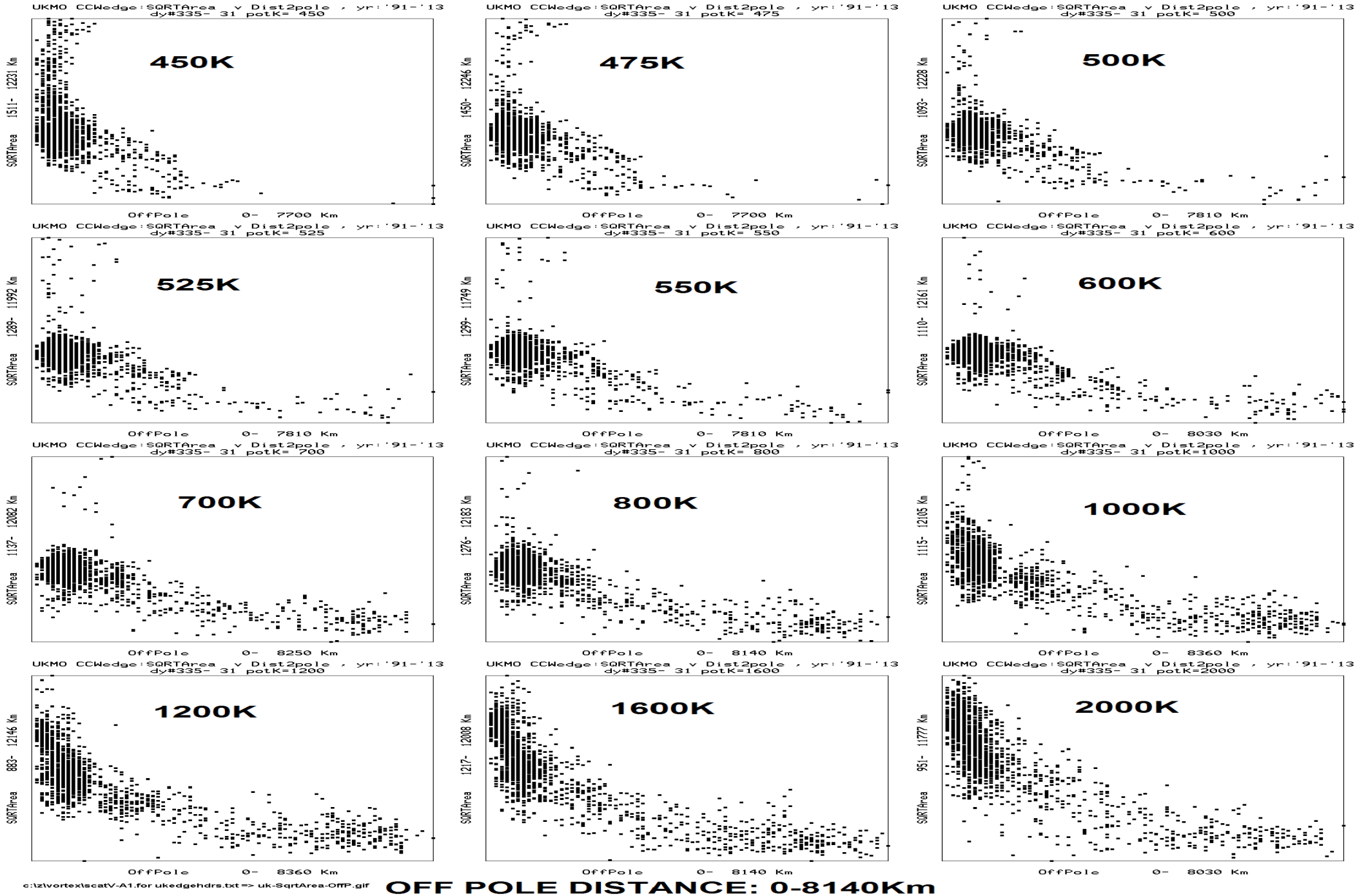




UKMO CCW Edge: sqrt(area) vs. OffPole distance:Dec&Jan 1991-2013

sqrt Area
vs
Off Pole

SQRT (AREA) : ~1200-12000Km

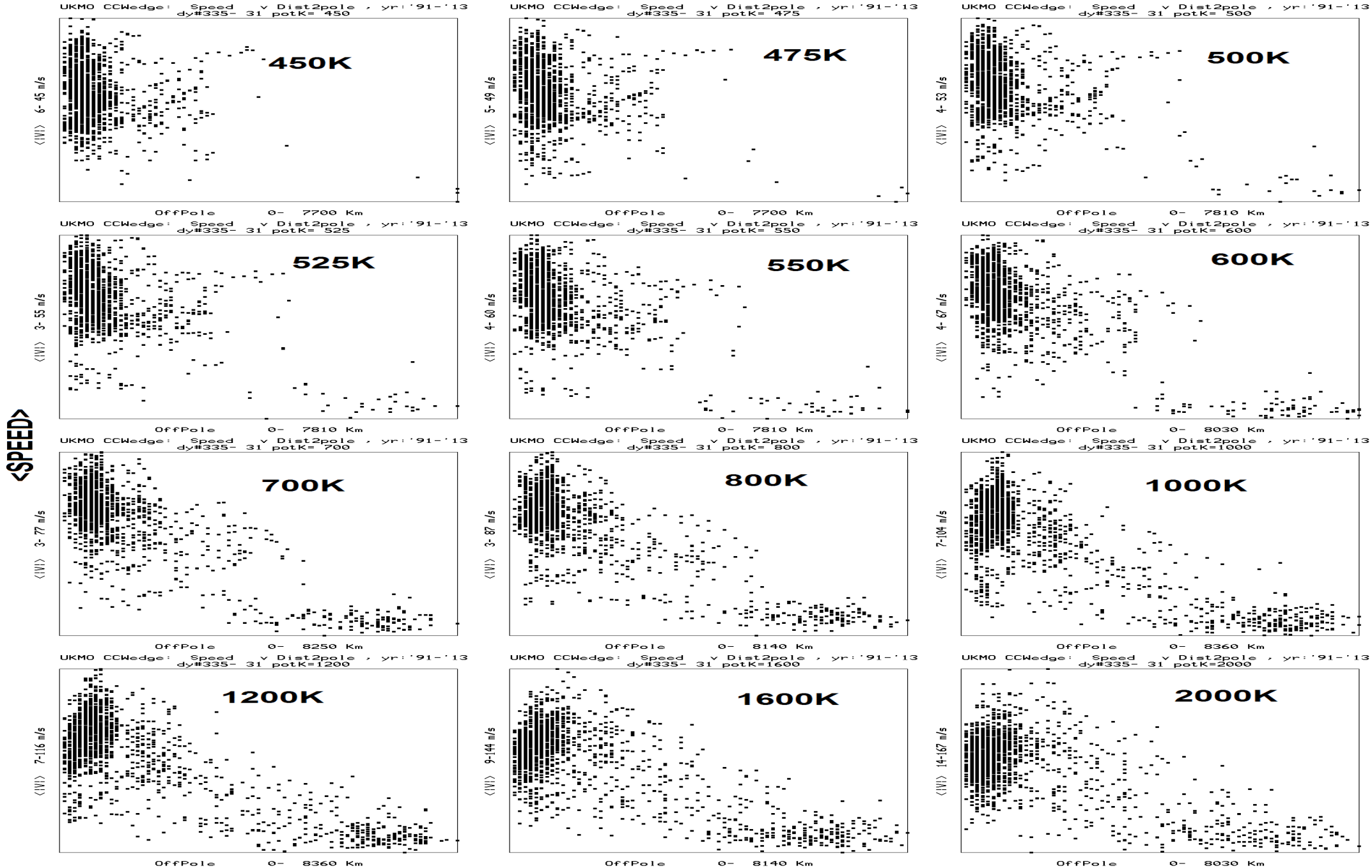


c:\lz\vortex\scatV-A1.for ukedgehdrs.txt => uk-SqrtArea-OffP.gif

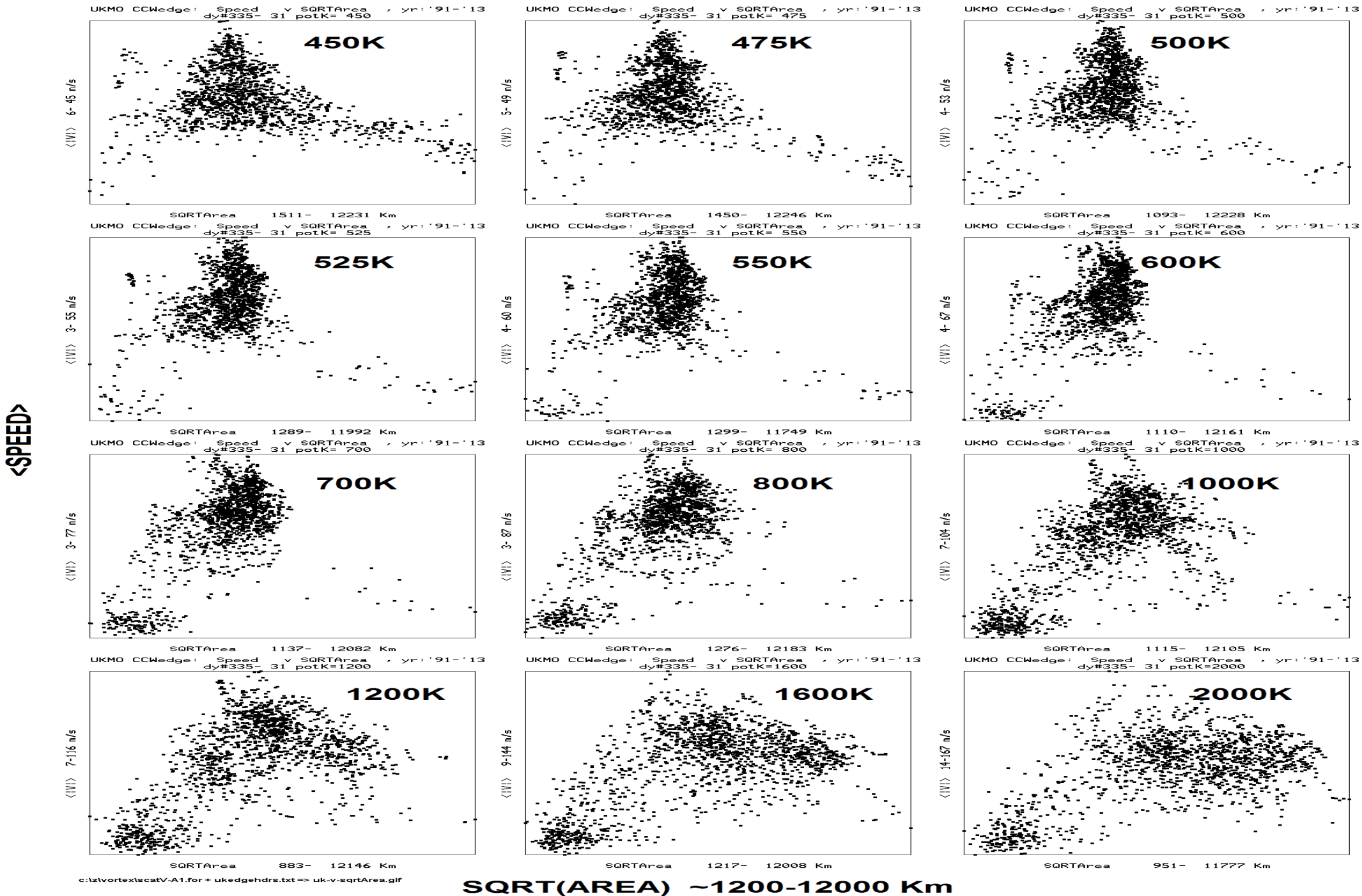
OFF POLE DISTANCE: 0-8140Km

UKMO CCW Edge: <Speed> vs. OffPole distance: Dec & Jan 1991-2013

Speed
vs
Off Pole



Speed
vs
Sqrt Area



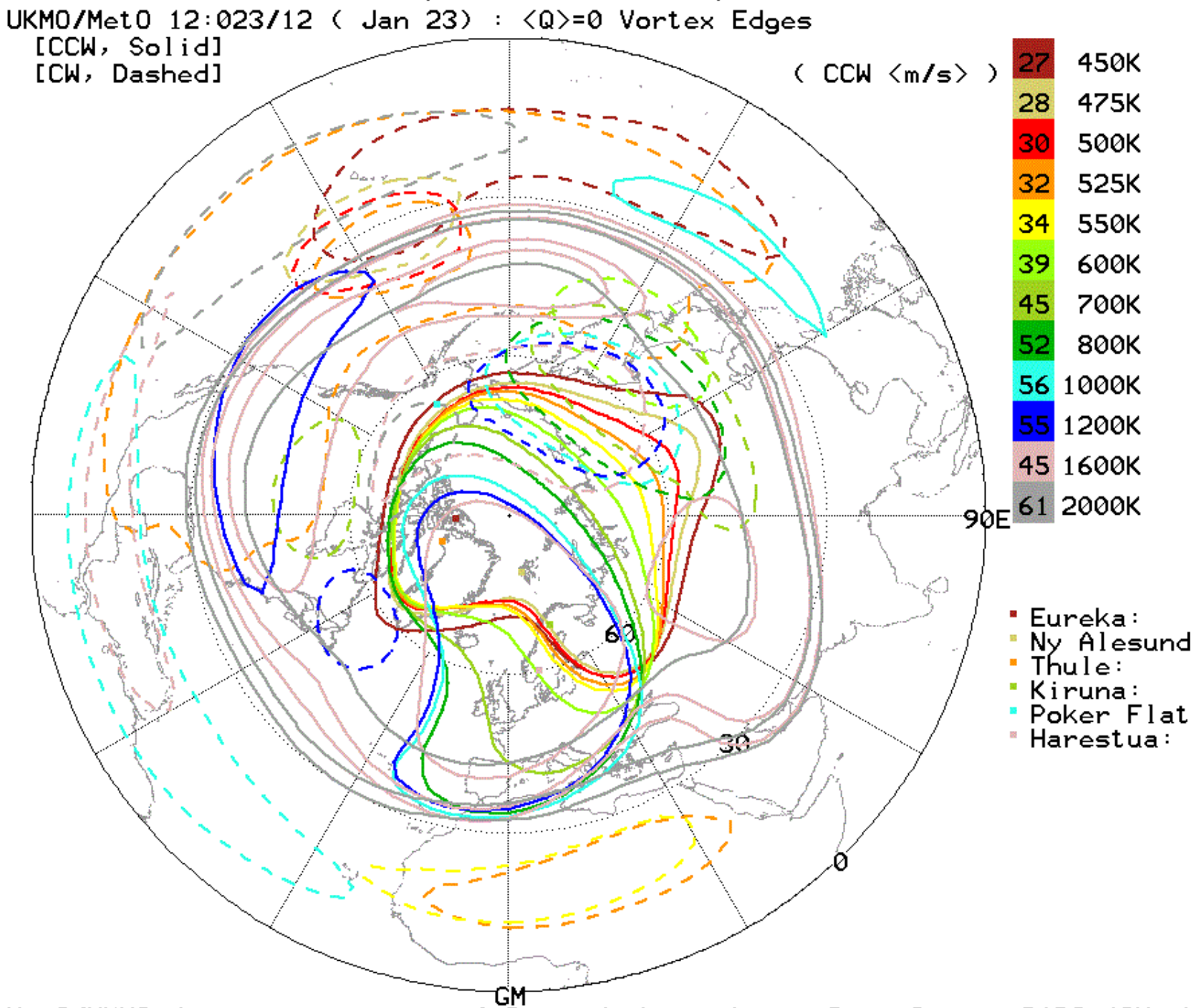
Conclusions

- 1. Caveat(s): the vortex-centre calculation used a simple-minded algorithm; this biases the centre to be closer to the pole.
- 2. In general the “scaled PV” (Gloria Manney) and “Q-diagnostic” edge determinations agree well. Differences may be due to the extra smoothing involved in defining the stream function. In any case there appears to be no clear definition of vortex edge, but at least the streamline method does emphasize that it is a barrier to transport. A recalculation of the stream function with higher spatial resolution might resolve the differences ... or not.
- 3. CMAM30 shows that the vortex defined by the Q-diagnostic extends to ~70Km. That limit may be just a precursor of the climatological zonal wind reversal around 80-90Km.
- 4. The 24 years of 800K (~25Km) vortex AREA plots clearly pick out the major stratwarms of 2009 and 2013.
- 5. At 800K,SHAPE FACTORS have variations not apparently related to stratwarms. That is, the vortex can be very stretched or otherwise irregular without actually breaking.
- 6. 800K EDGE SPEEDS are reduced by stratwarms; but there are other reductions maybe related to large off-pole position.
- 7. Scatter plots show : a reduction in AREA and average EDGE SPEED with OFF-POLE DISTANCE, and an increase in EDGE SPEED with AREA, at least above 700K for the latter.

Acknowledgements

Thanks to BADC for making UKMO/MetO stratospheric data available and to the University of Toronto for access to CMAM30. Geos-5-MERRA data have been provided by the Global Modeling and Assimilation Office (GMAO) at NASA Goddard Space Flight Center through the NASA GES DISC online archive.

… and to you for listening ….



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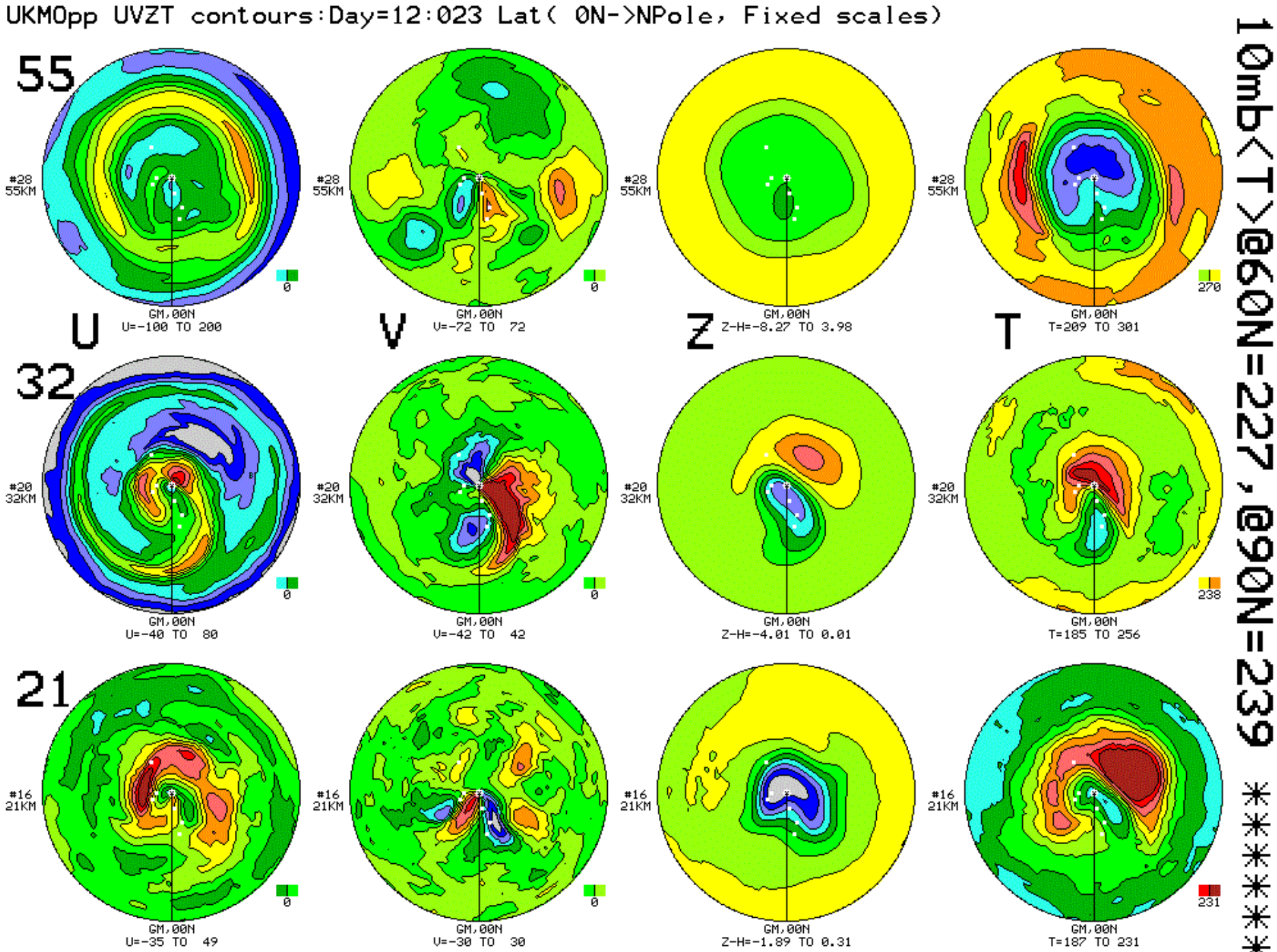
UKMOpp UVZT contours:Day=12:023 Lat(0N->NPole, Fixed scales)
55
32
21
#28
55KM
#20
32KM
#16
21KM
GM,00N
U=-100 TO 200
V=-72 TO 72
Z-H=-8.27 TO 3.98
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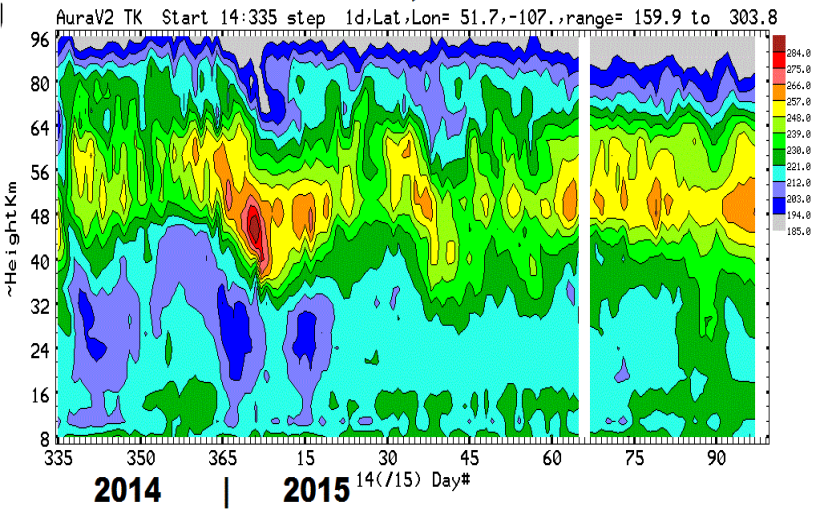
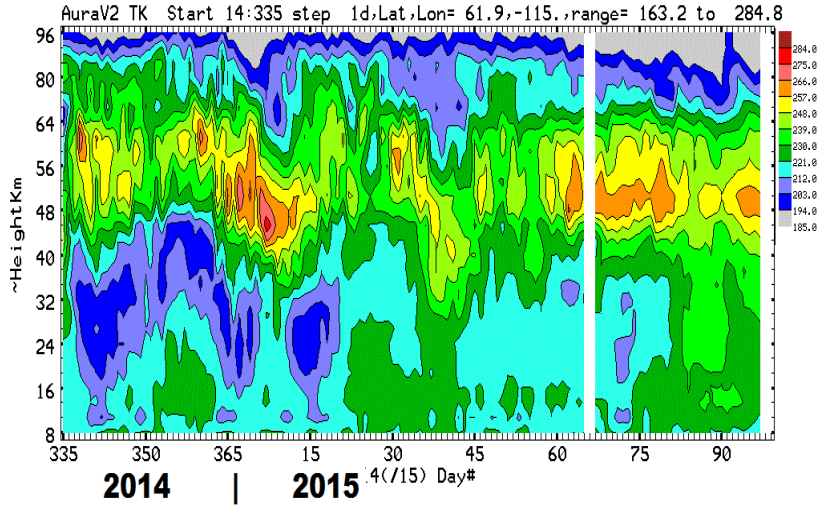
T=187 TO 231
U
V
Z
T
0
270
238
231
10mb<T>@60N=227,@90N=239
MetO/UKMO data are courtesy of British Atmospheric Data Centre BADC (CMeek,UofSask)

Daily Aura MLS V2 Temperatures, ~8-85 Km, Dec '14 to Mar '15

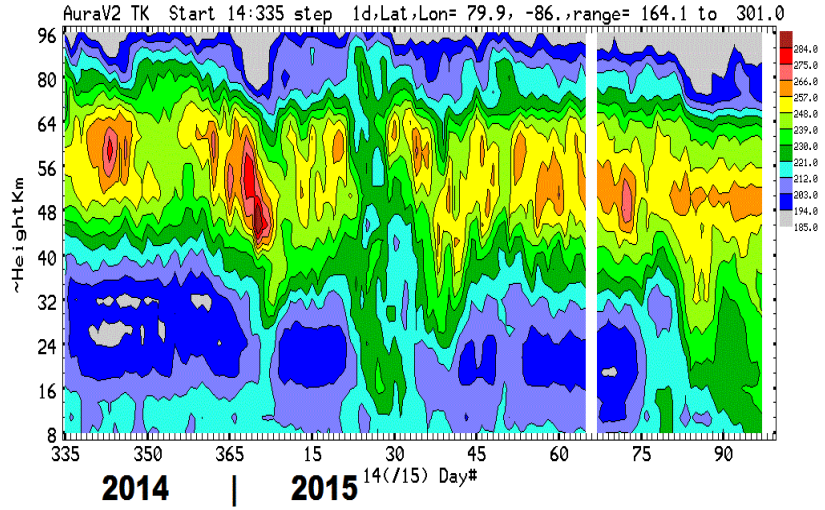
51.7N, -107E



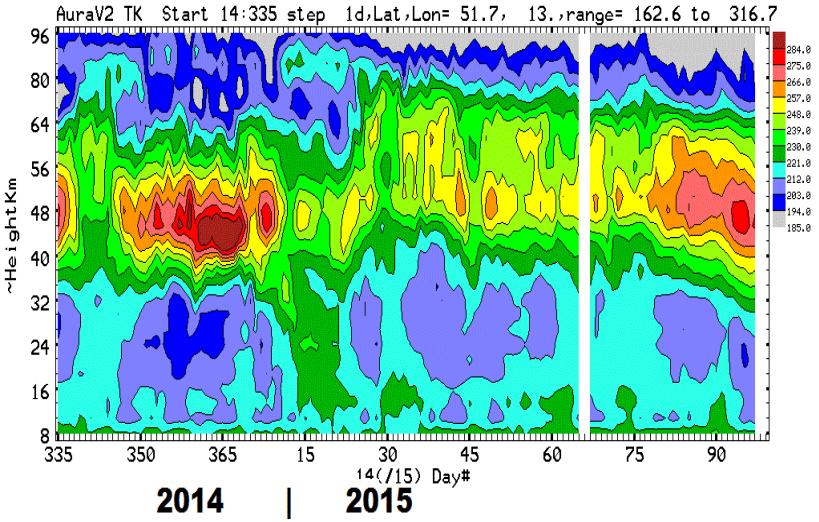
61.9N -115E



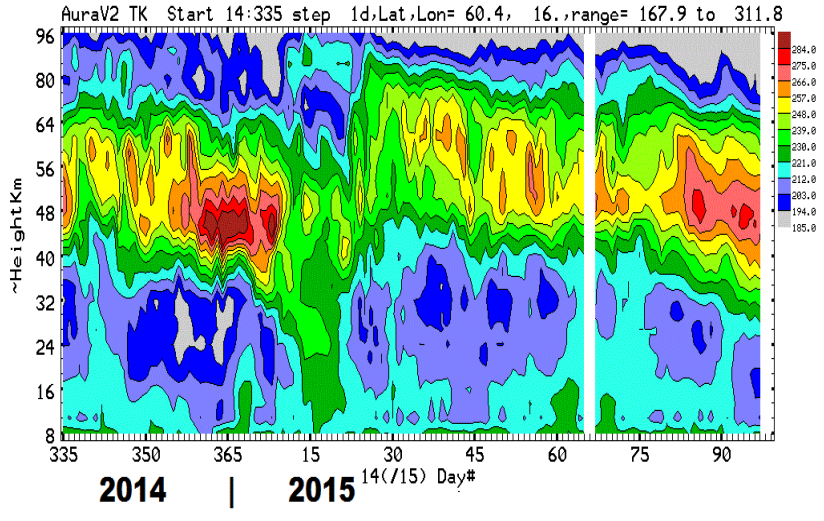
79.9N, -86E



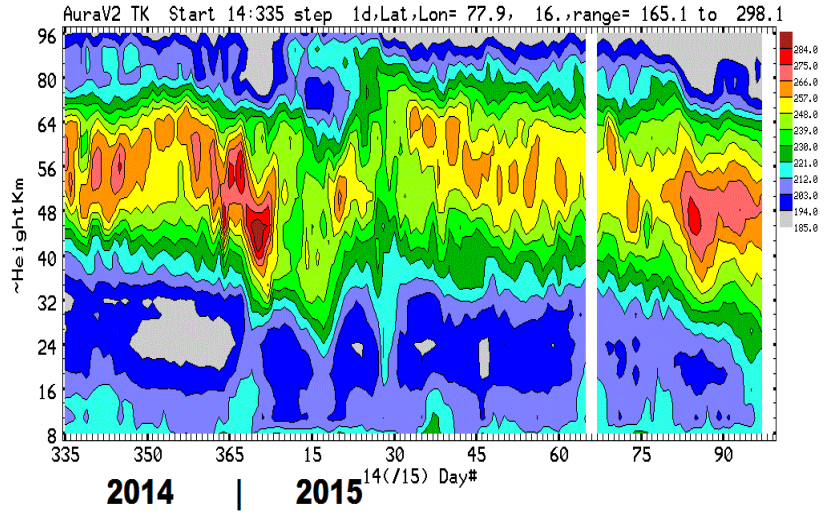
51.7N, 13E



60.4N, 16E

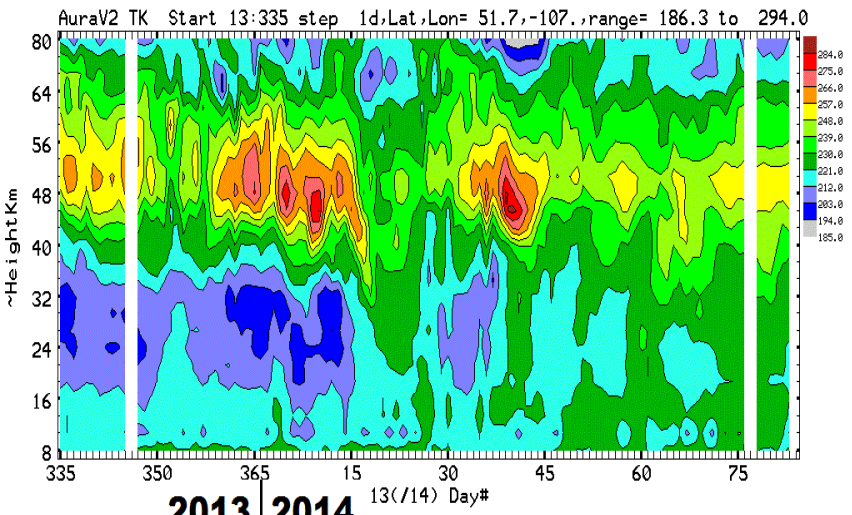


77.9N, 16E

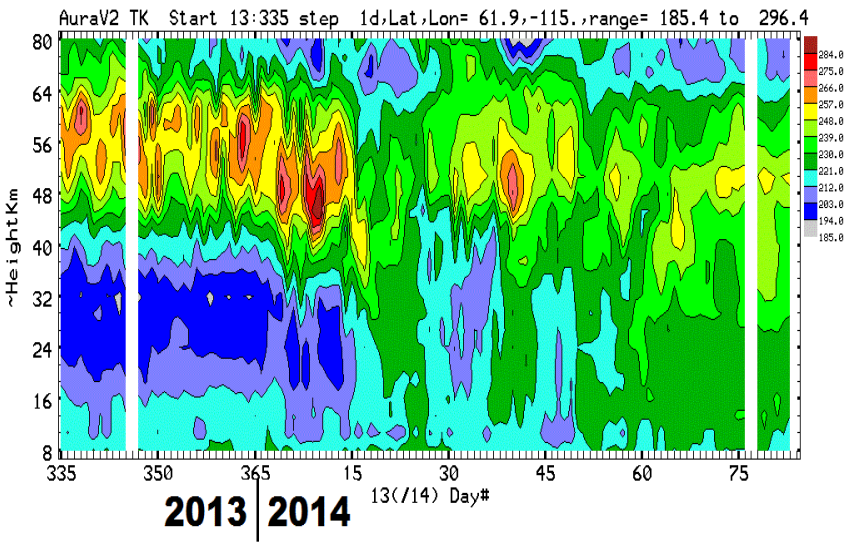


Daily Aura MLS V2 Temperatures, ~8-80 Km Dec '13 - Mar '14

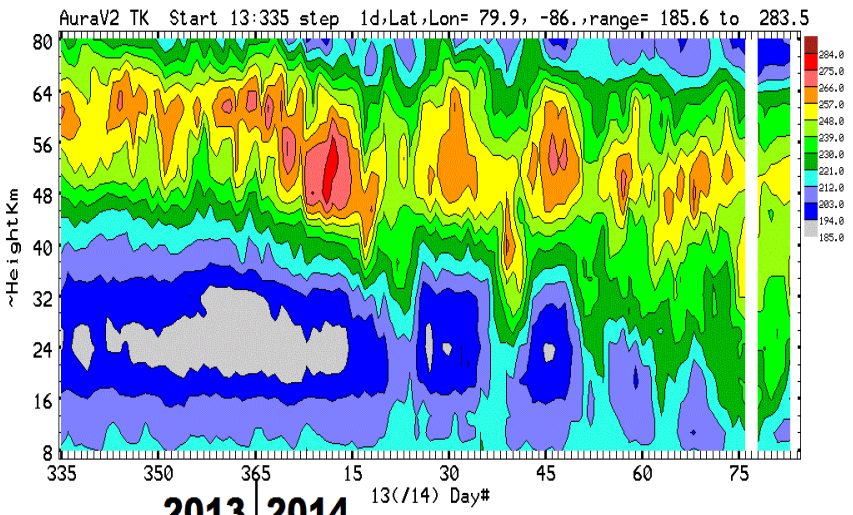
51.7N, -107E



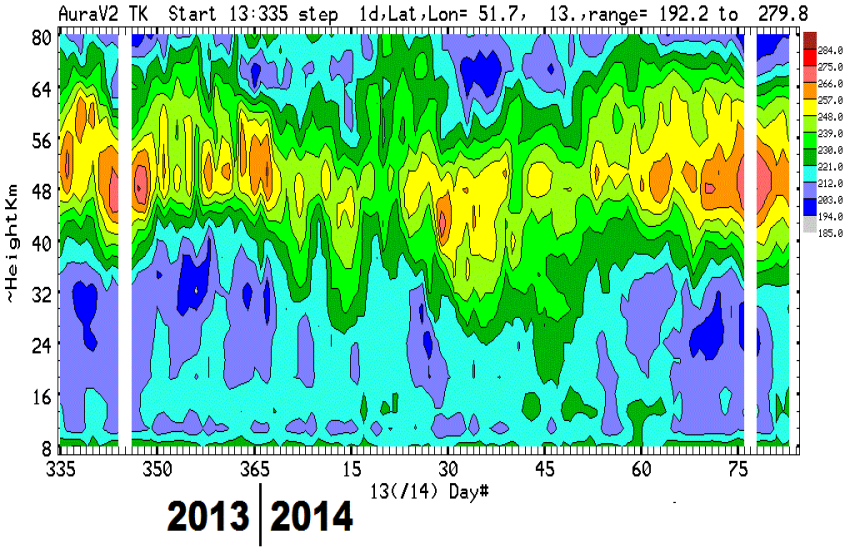
61.9N -115E



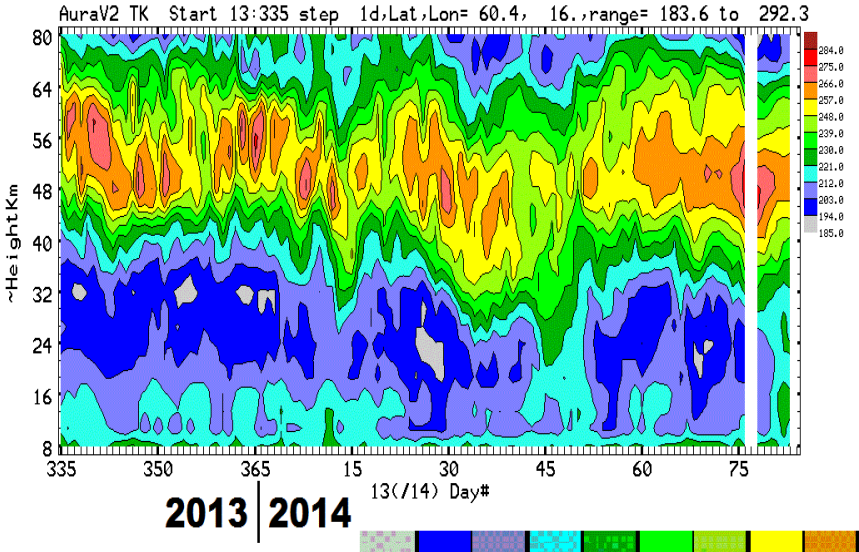
79.9N, -86E



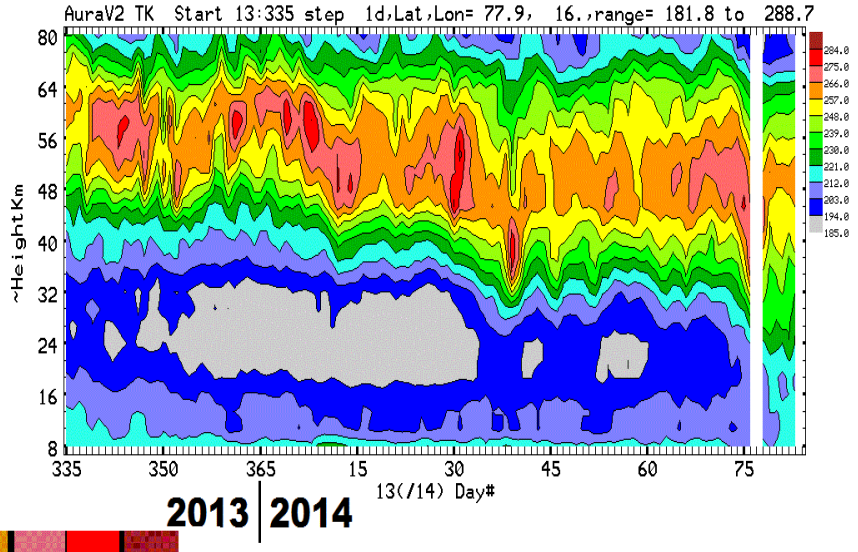
51.7N, 13E

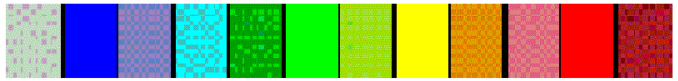


60.4N, 16E



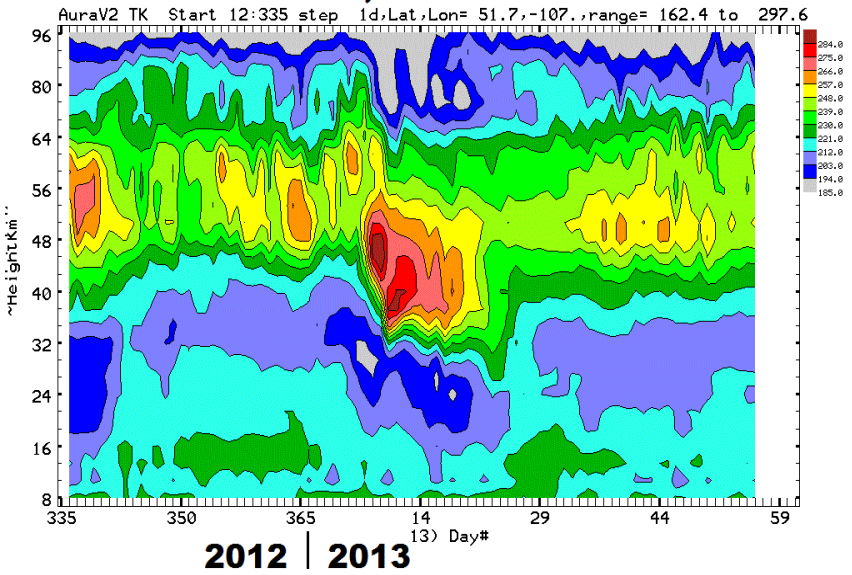
77.9N, 16E





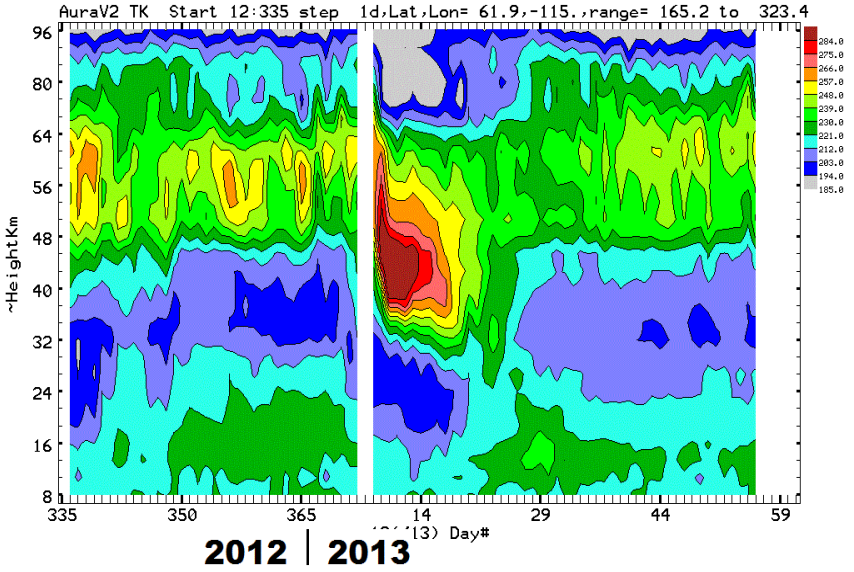
Daily Aura MLS V2 Temperatures, ~8-85 Km, Dec '12 to Feb '13

51.7N, -107E



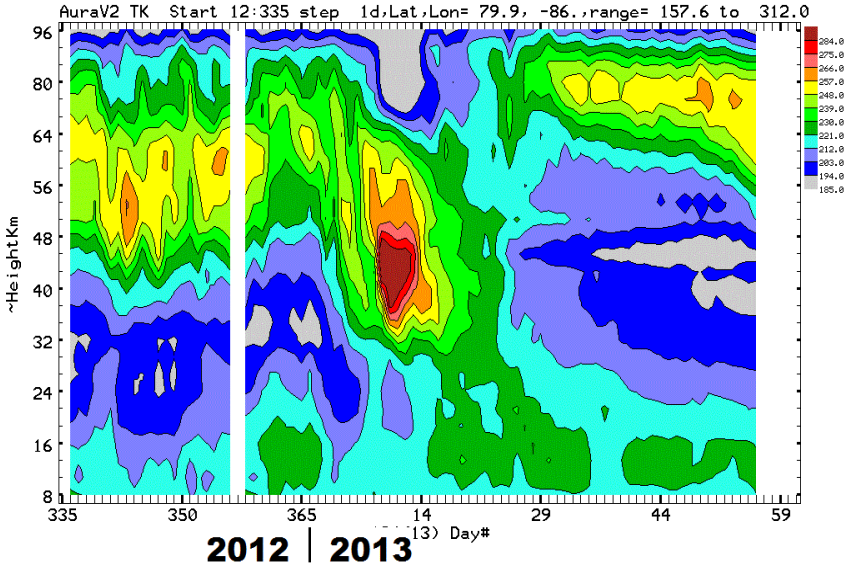
2012 | 2013

61.9N -115E



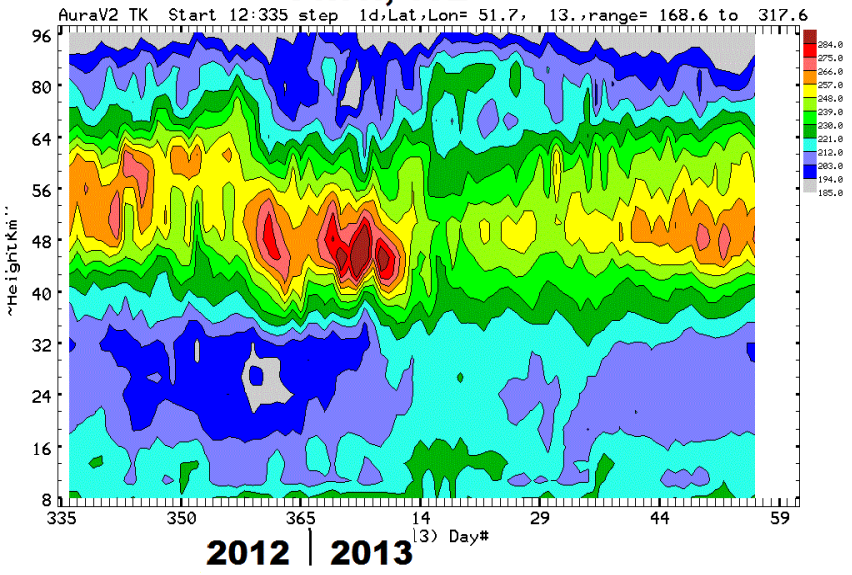
2012 | 2013

79.9N, -86E



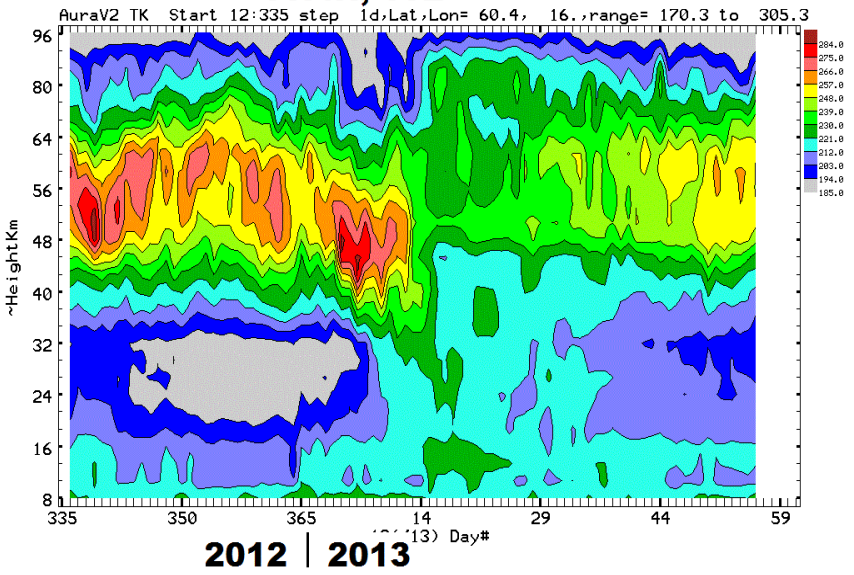
2012 | 2013

51.7N, 13E



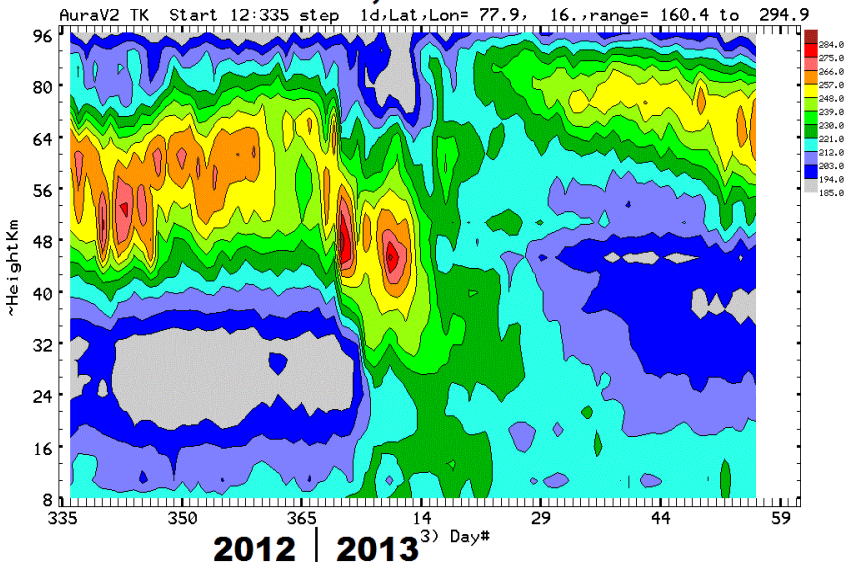
2012 | 2013

60.4N, 16E

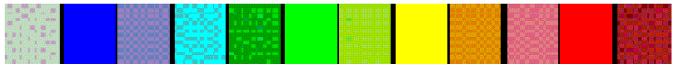


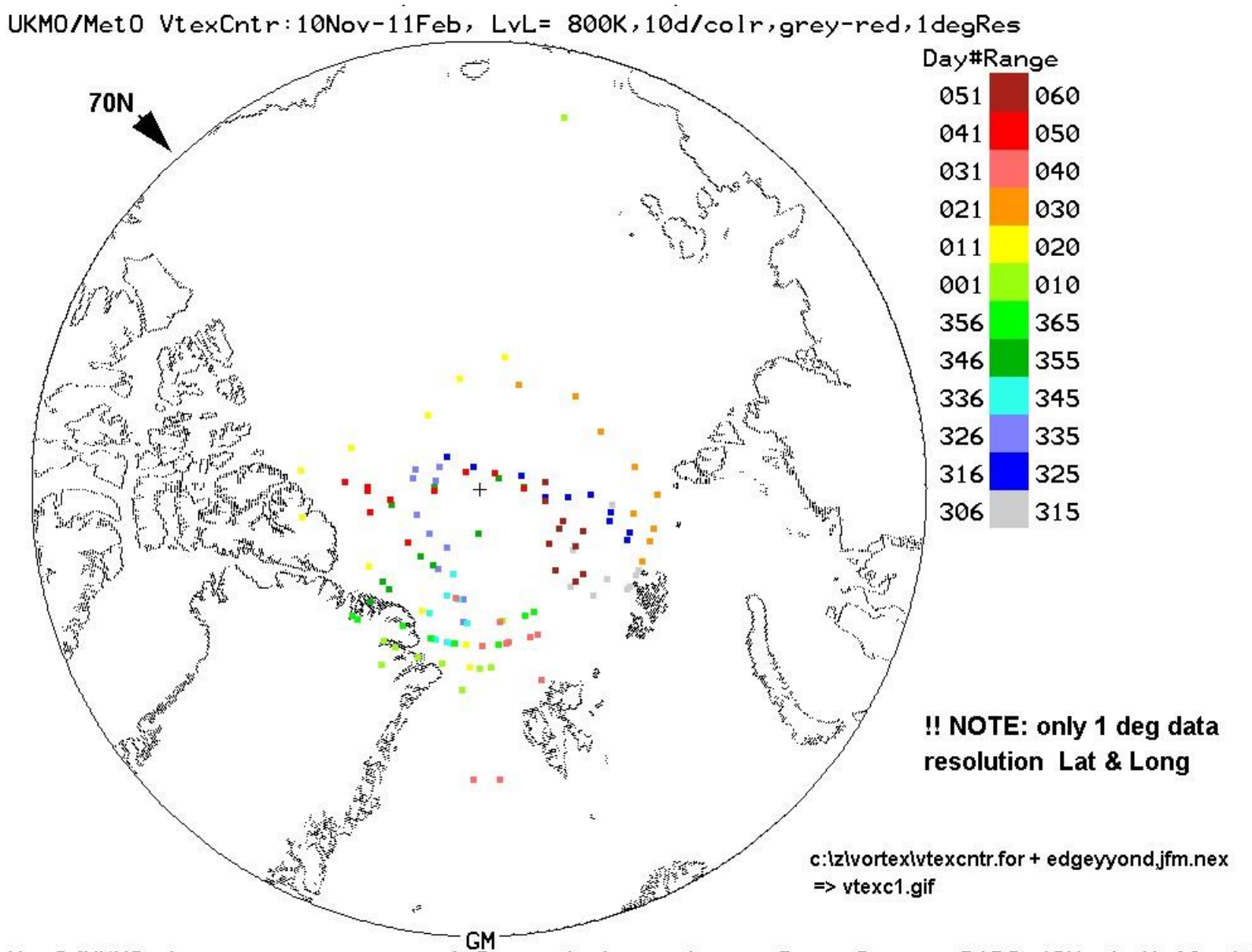
2012 | 2013

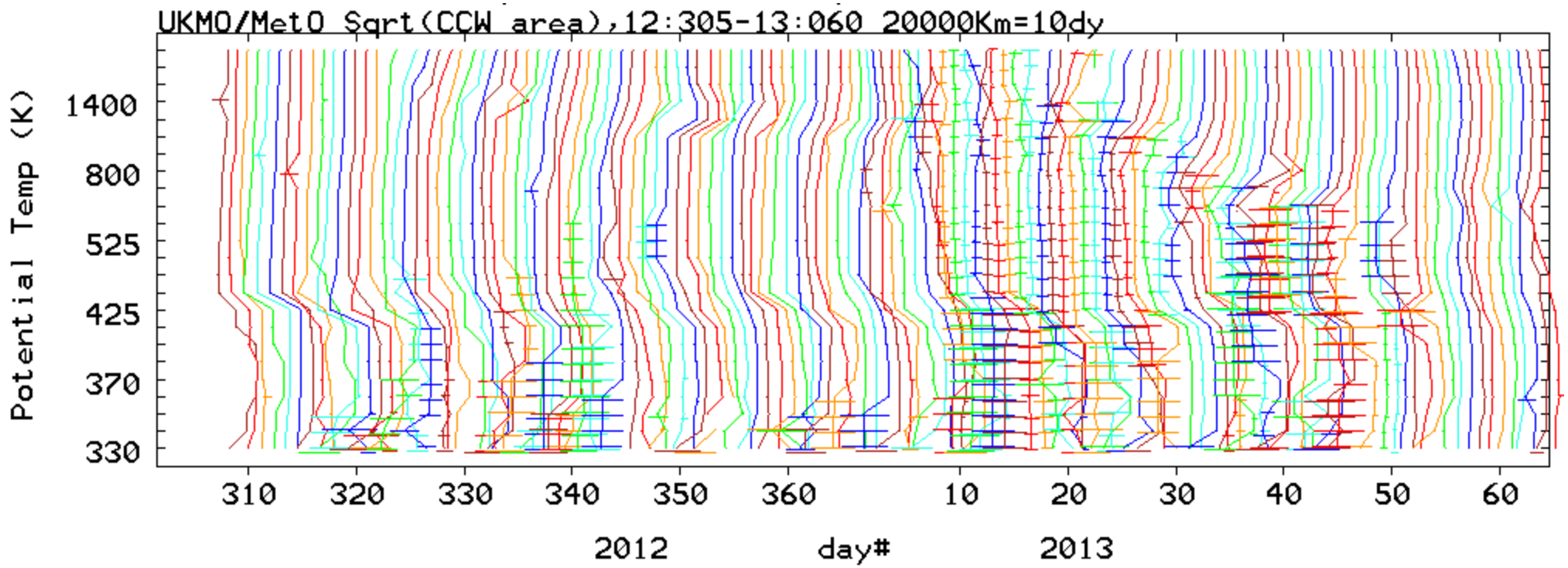
77.9N, 16E



2012 | 2013




UKMO/MetO VtexCntr:10Nov-11Feb, LvL= 800K,10d/colr,grey-red,1degRes
70N
Day#Range
051 060
041 050
031 040
021 030
011 020
001 010
356 365
346 355
336 345
326 335
316 325
306 315
!! NOTE: only 1 deg data resolution Lat & Long
c:\lz\vortex\vtexcntr.for + edgeyyond.jfm.nex
=> vtexc1.gif
GM
MetO/UKMO data are courtesy of British Atmospheric Data Centre BADC (CMeek,UofSask)



c:\z\vortex\areaprfl.for + edgeYY*.nex => areaprf1.gif

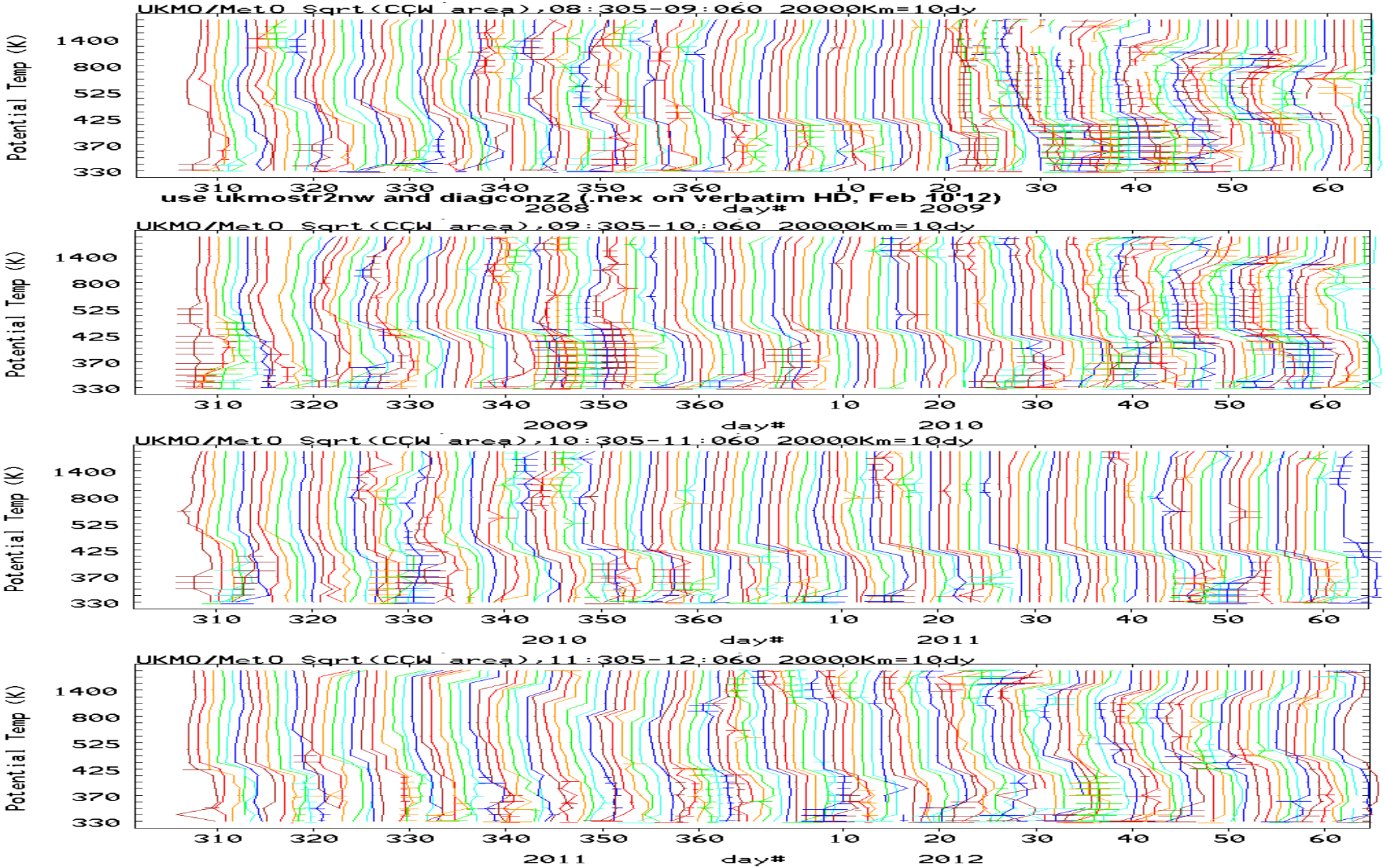
(bars show spread if more than one edge; dithered a bit in vertical)

MetO/UKMO data are courtesy of British Atmospheric Data Centre BADC (CMeek,UofSask)

NOTE: used new ukmostr2nw & diagconz2 on all

(i.e. redid sandl and .nex - now on Verbatim HD in \ukmo2008 etc

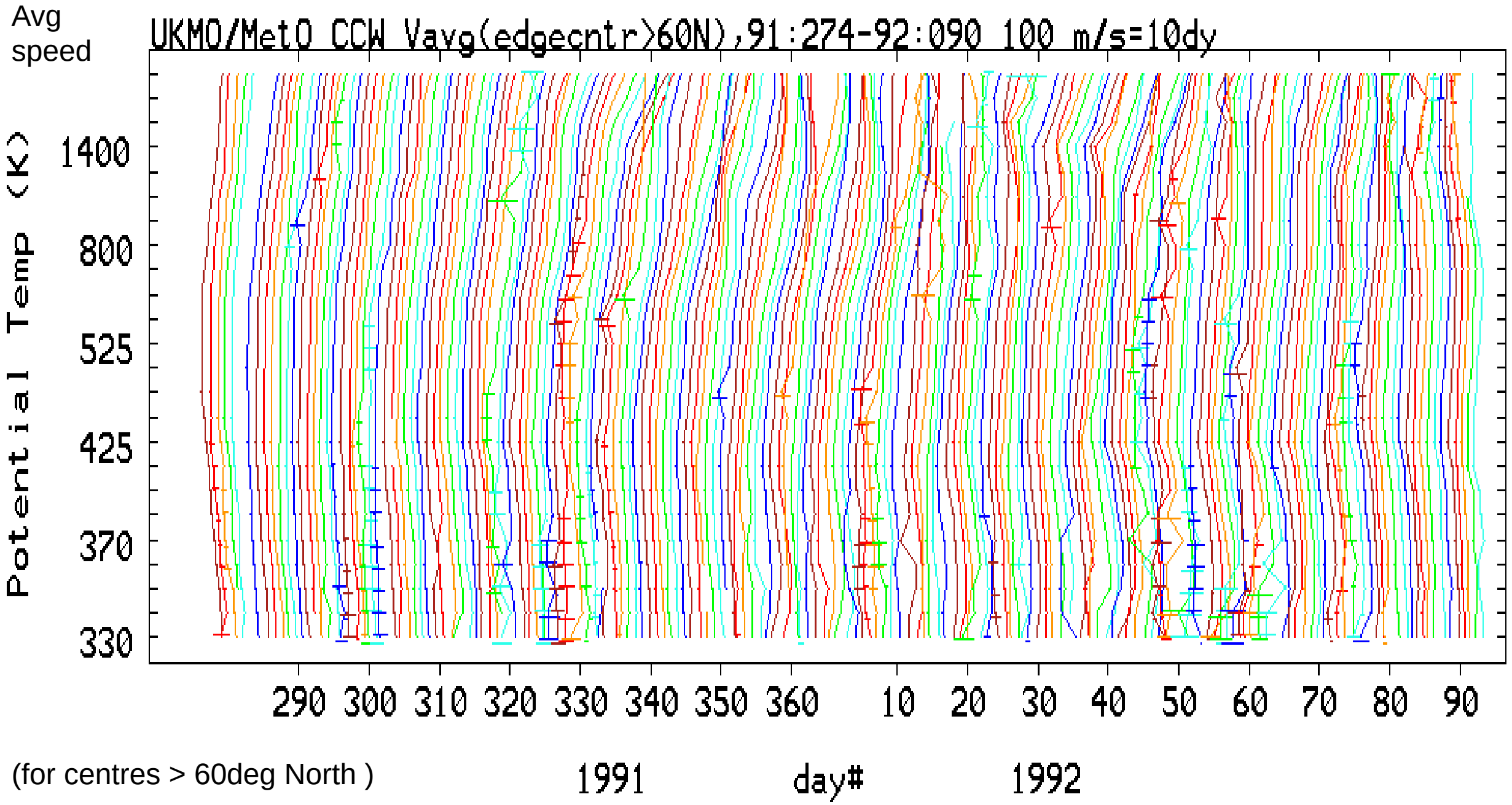
Sqrt (Area)



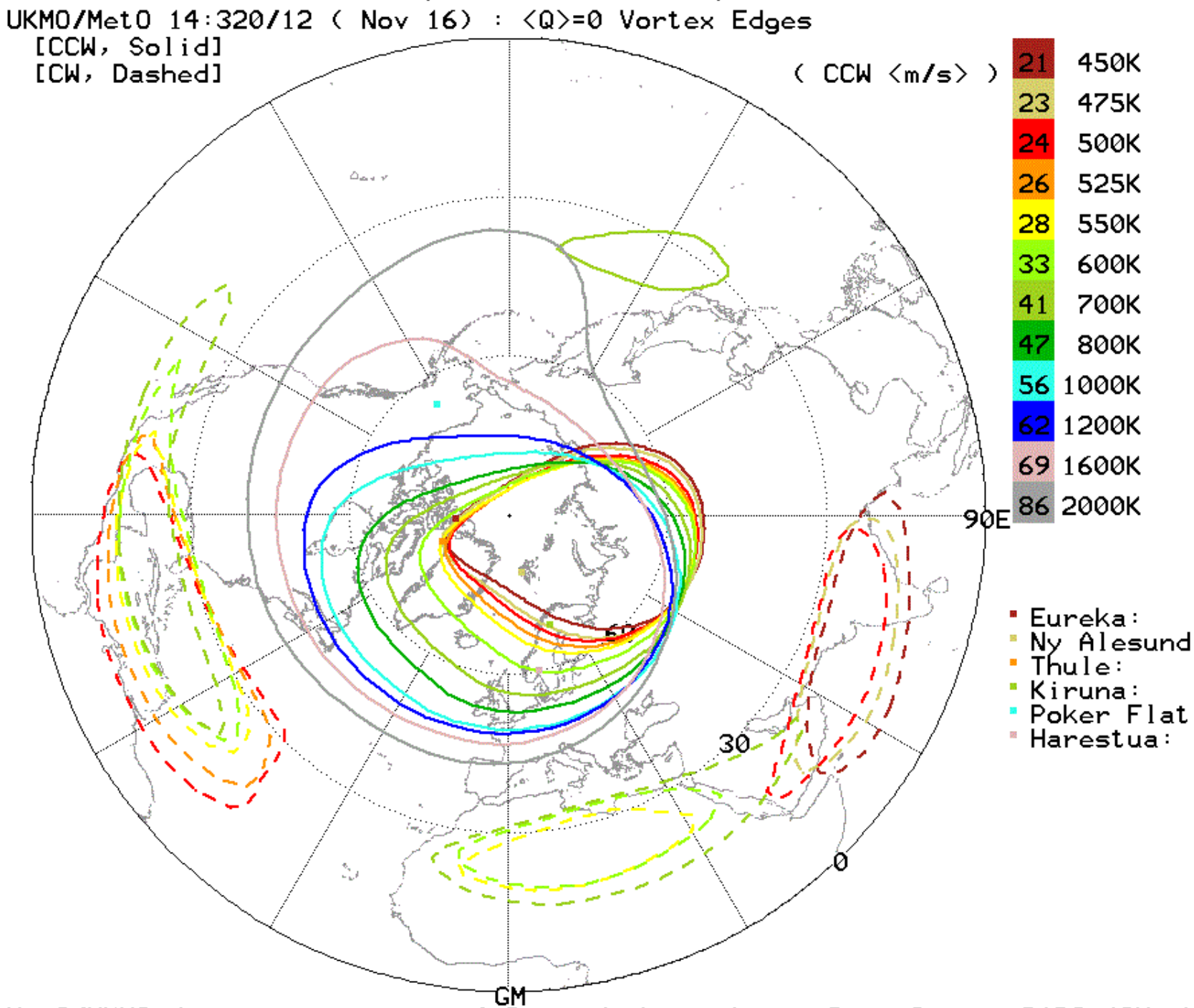
c:\z\vortex\areaprfl.for + edgeYY*.nex => areaprf1.gif

(bars show spread if more than one edge; dithered a bit in vertical)

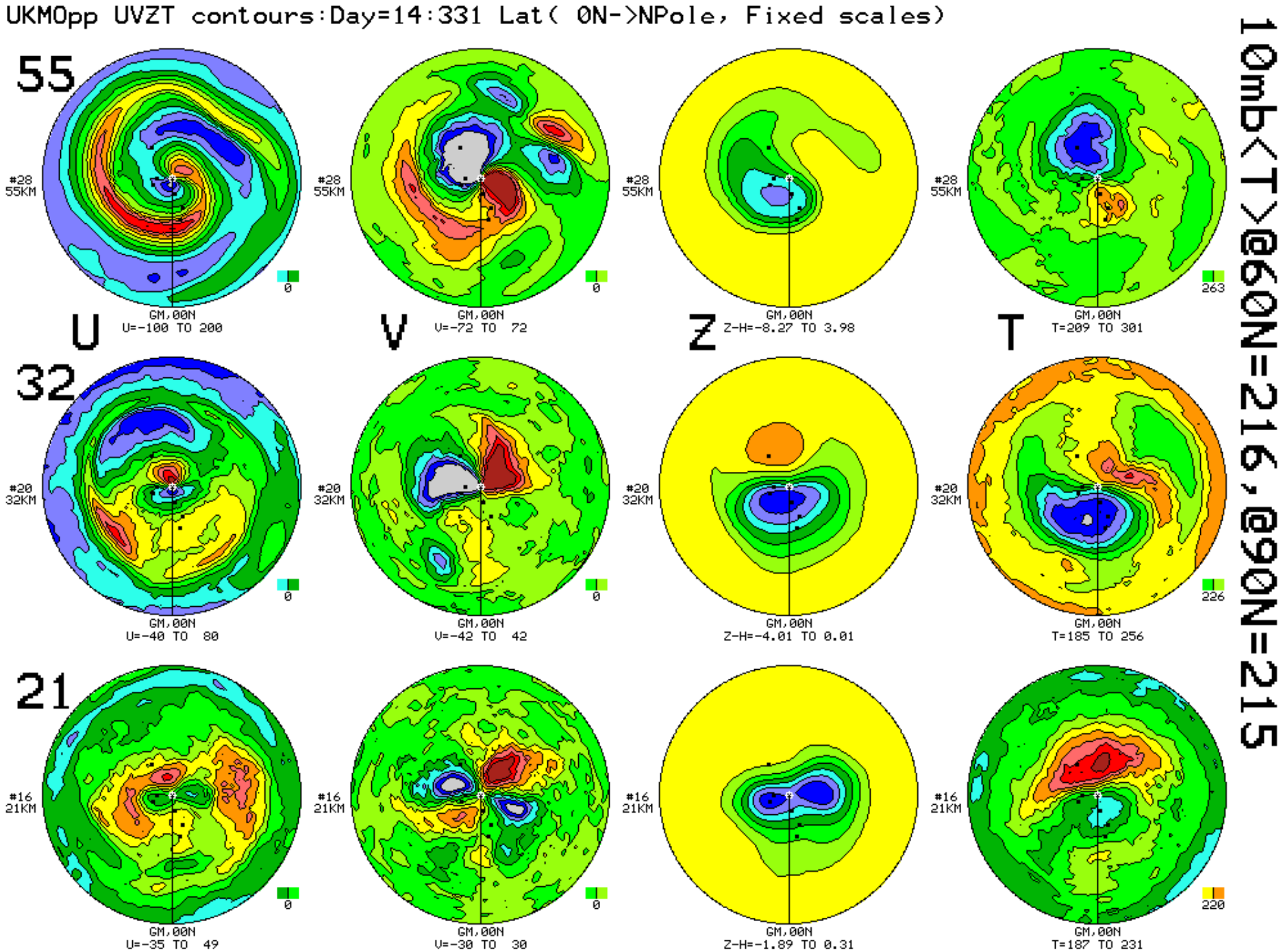
MetO/UKMO data are courtesy of British Atmospheric Data Centre BADC (CMeek,UofSask)

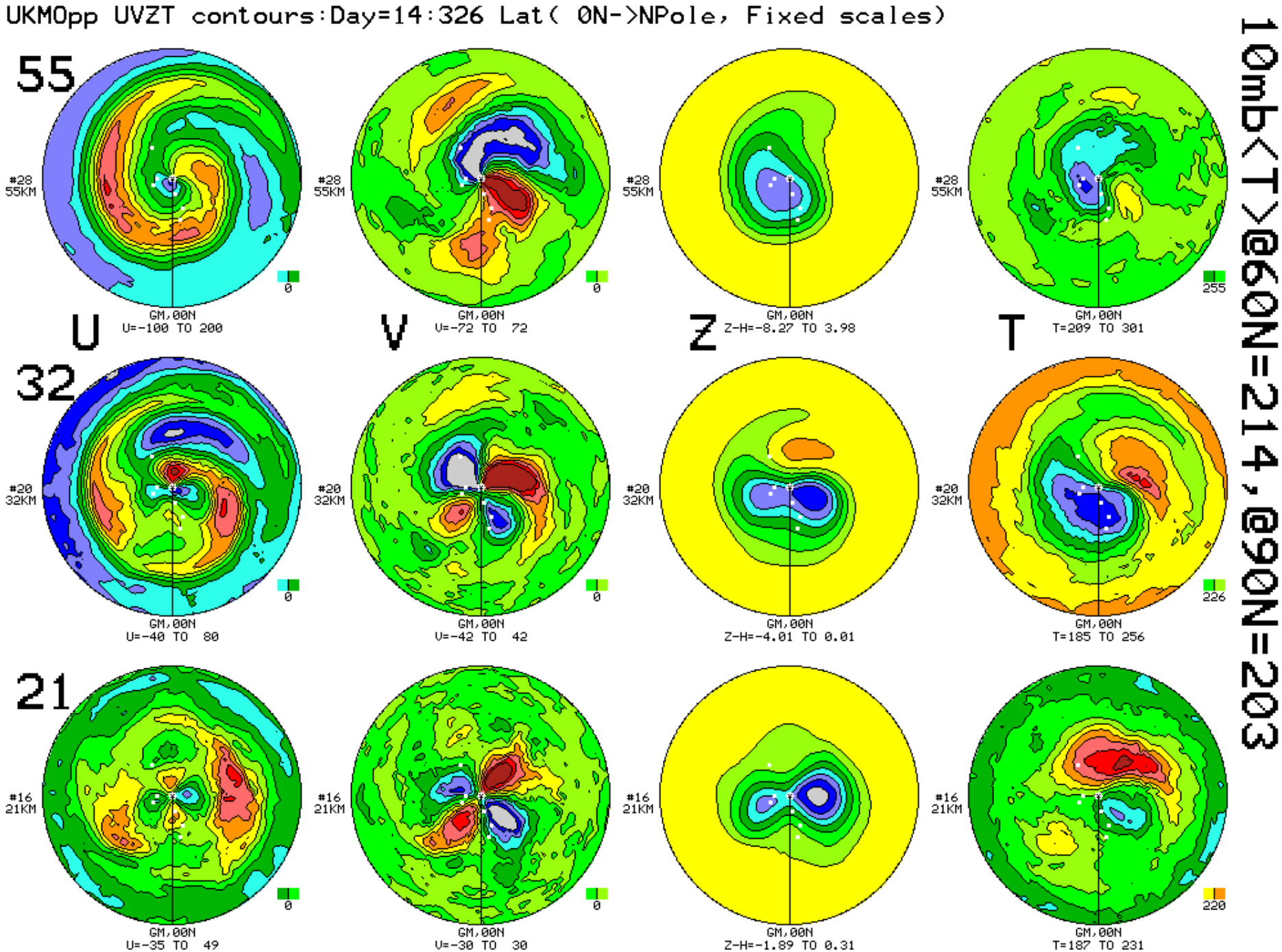


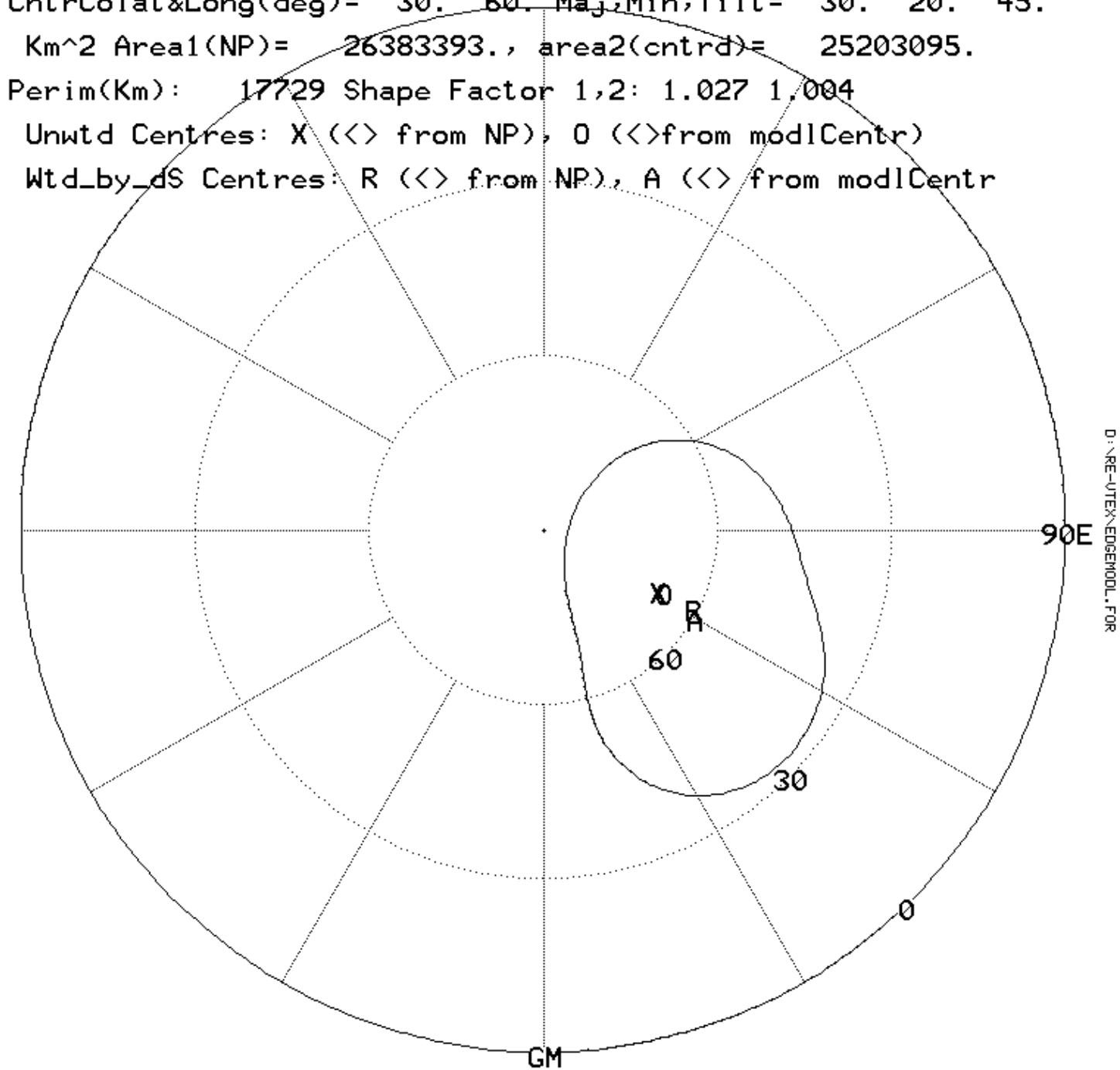
(for centres > 60deg North)



MetO/UKMO data are courtesy of British Atmospheric Data Centre BADC (CMeek,UofSask)


UKMOpp UVZT contours:Day=14:331 Lat(0N->NPole, Fixed scales)
55
#28
55KM
0
GM,00N
U=-100 TO 200
U
GM,00N
V=-72 TO 72
V
GM,00N
Z-H=-8.27 TO 3.98
Z
263
GM,00N
T=209 TO 301
T
32
#20
32KM
GM,00N
U=-40 TO 80
GM,00N
V=-42 TO 42
GM,00N
Z-H=-4.01 TO 0.01
226
GM,00N
T=185 TO 256
21
#16
21KM
GM,00N
U=-35 TO 49
GM,00N
V=-30 TO 30
GM,00N
Z-H=-1.89 TO 0.31
220
GM,00N
T=187 TO 231
10mb<T>@60N=216,@90N=215
MetO/UKMO data are courtesy of British Atmospheric Data Centre BADC (CMeek,UofSask)


UKMOpp UVZT contours:Day=14:326 Lat(0N->NPole, Fixed scales)
10mb<T>@60N=214,@90N=203
55
#28
55KM
0
GM,00N
U=-100 TO 200
U
GM,00N
V=-72 TO 72
V
GM,00N
Z-H=-8.27 TO 3.98
Z
255
GM,00N
T=209 TO 301
T
32
#20
32KM
GM,00N
U=-40 TO 80
GM,00N
V=-42 TO 42
GM,00N
Z-H=-4.01 TO 0.01
226
GM,00N
T=185 TO 256
21
#16
21KM
GM,00N
U=-35 TO 49
GM,00N
V=-30 TO 30
GM,00N
Z-H=-1.89 TO 0.31
220
GM,00N
T=187 TO 231
MetO/UKMO data are courtesy of British Atmospheric Data Centre BADC (CMeek,UofSask)


CntrColat&Long(deg)= 30. 60. Maj,Min,Tilt= 30. 20. 45.
Km^2 Area1(NP)= 26383393., area2(cntrd)= 25203095.
Perim(Km): 17729 Shape Factor 1,2: 1.027 1.004
Unwtd Centres: X (<> from NP), O (<>from modlCentr)
Wtd_by_dS Centres: R (<> from NP), A (<> from modlCentr
90E
X
O
R
A
60
30
0
GM
D:\RE-UTEX\EDGEMODL.FOR