Auroras study update

P. Bobik (bobik@saske.sk), K. Kudela, S. Pastircak, M. Putis

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Aurora effect on JEM-EUSO operational efficiency

To estimate auroras effect we evaluate for every position of ISS additional parameters

- **Kp index** to describe geomagnetic activity
- geomagnetic latitude and longitude of ISS

The K-index quantifies disturbances in the horizontal component of earth's magnetic field with an integer in the range 0-9 with 1 being calm and 5 or more indicating a geomagnetic storm. The official planetary Kp index is derived by calculating a weighted average of K-indices from a network of geomagnetic observatories.

Following a Table from NOAA

- http://www.swpc.noaa.gov/Aurora/index.html

we exclude from duty cycle (observation efficiency) moments when Kp index for ISS geomagnetic latitude was equal or higher than auroral boundary

Comparison of Auroral Boundaries from Kp and Auroral Activity Level at Local Midnight

Magnetic Latitude	Kp	Magnetic Latitude	NOAA POES Auroral Activity Level
66.5	0	67.5	1
64.5	1	66.5	2
62.4	2	65.6	3
60.4	3	63.9	4
58.3	4	62.5	5
56.3	5	60.7	6
54.2	6	58.6	7
52.2	7	56.7	8
50.1	8	54.6	9
48.1	9	51.0	10
		48.5	10+
		45.0	10++

Aurora effect on JEM-EUSO operational efficiency

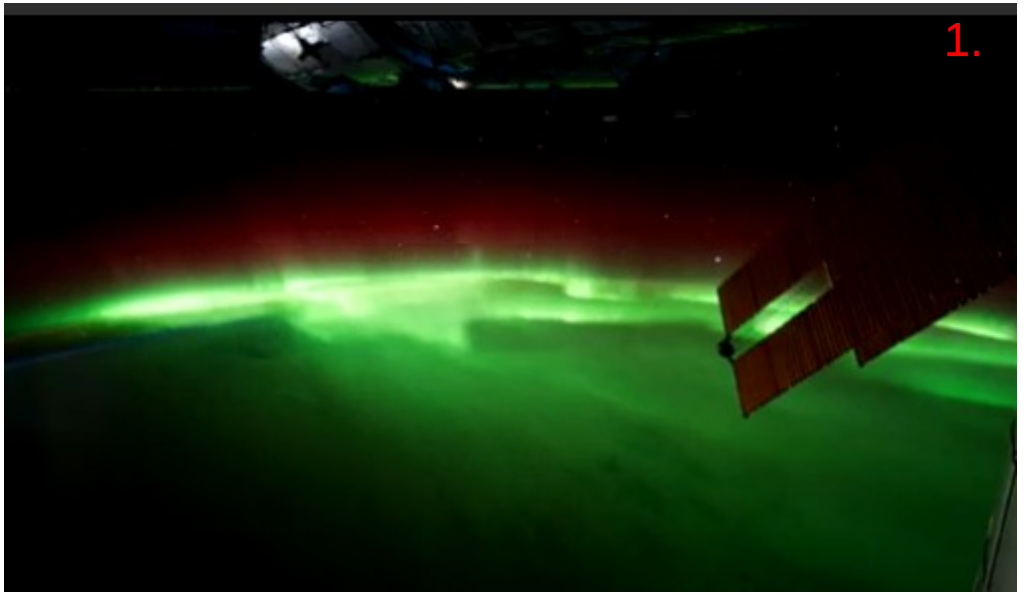
Simple verification of method

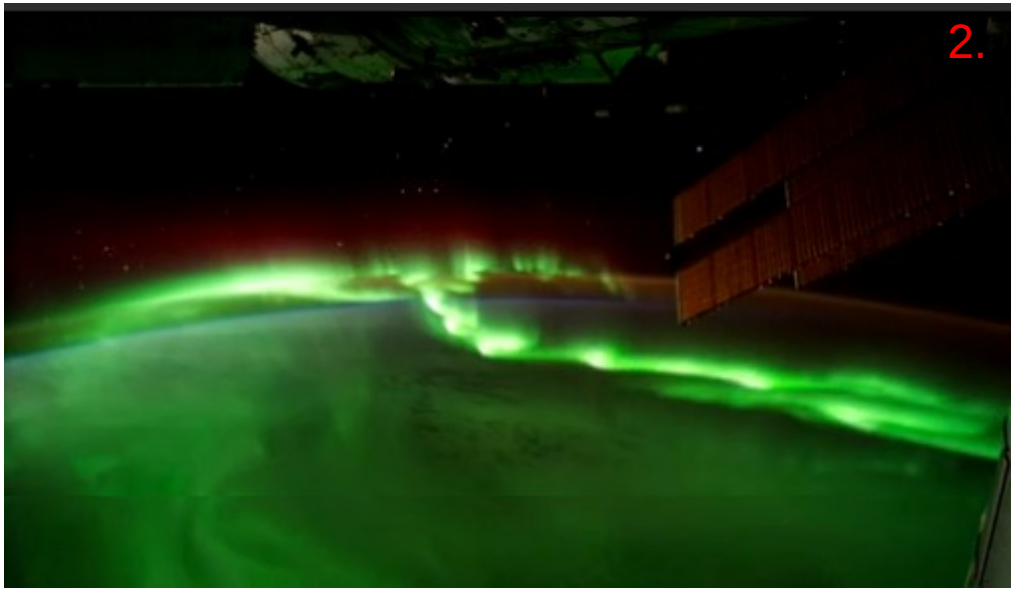
From few videos taken from ISS with auroras available at [1] we were able select one [2] in period 2000-2011 with clear aurora visible in nadir mode (directly under ISS).

Video was taken when ISS flew from Madagascar to Australia between 17:22 and 17:45 GMT on 17. september 2011. Part of video shows ISS flight over aurora australis.

For same time, our method identifies appearance of aurora. During the year 2011 method identifies 433 minutes (50 minutes in september 2011) with aurora appearance.

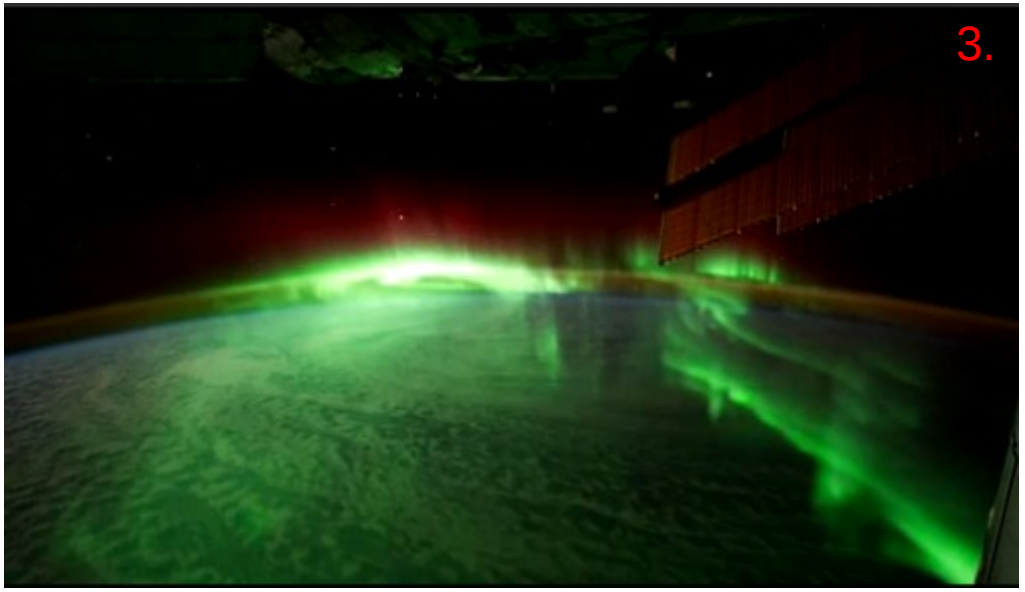
Coincidence between movie appearance of aurora and method identification of aurora in same time is a supporting argument to method validity.





References:

1. http://www.nasa.gov/multimedia/videogallery/index.html
2. http://www.nasa.gov/multimedia/videogallery/index.html?media_id=112491731



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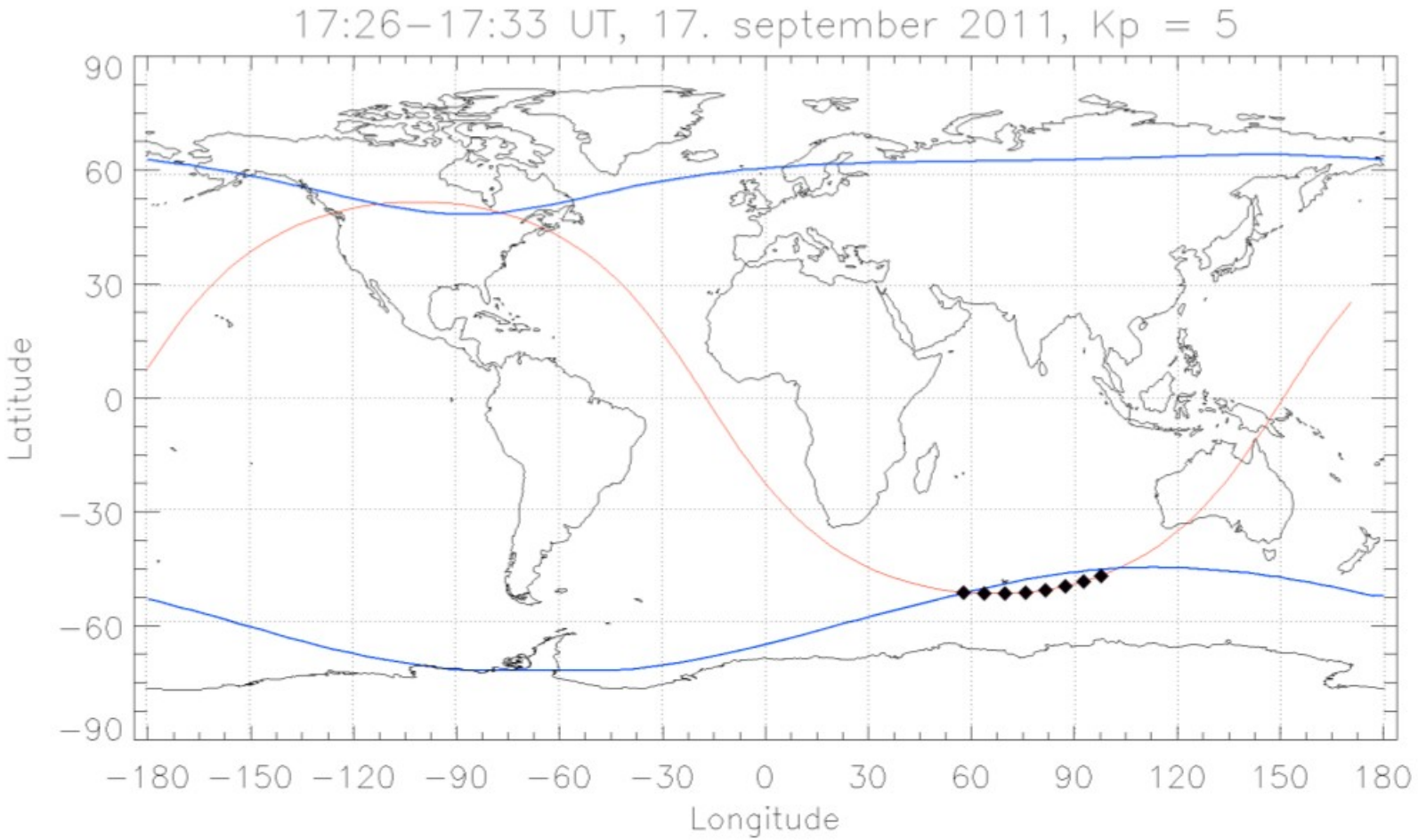
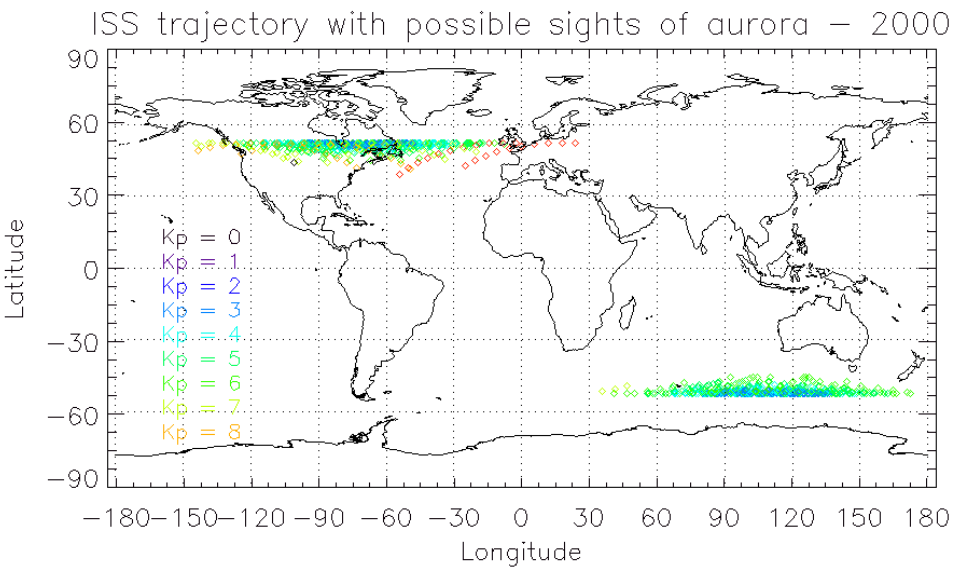


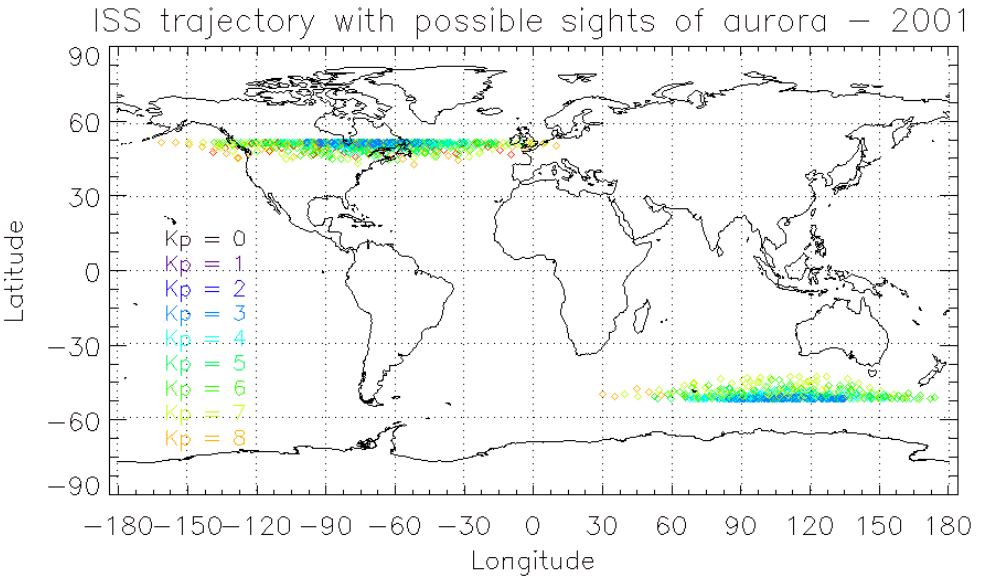
Figure A.17: Red line represent the trajectory of the ISS, blue lines are equator-ward boundaries of the auroral oval for magnetosphere disturbed at level Kp = 5. Diamonds on ISS trajectories are points on ISS trajectory with one minute step (from 17:26 till 17:33 GMT, 17 september 2011) excluded from EAS measurements visible on NASA video (NASA).

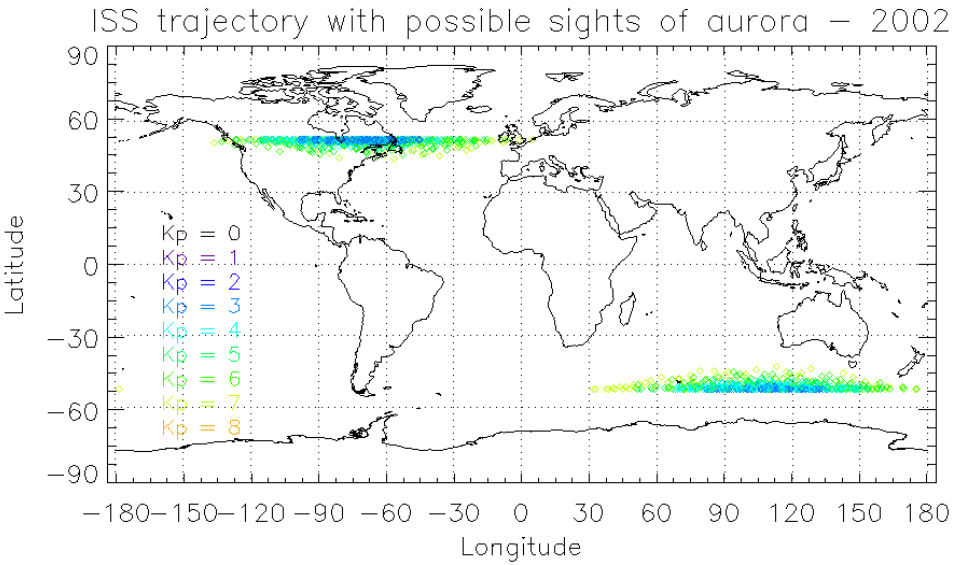
AdvSR article *Performances and air-shower reconstruction techniques for the JEM-EUSO mission*

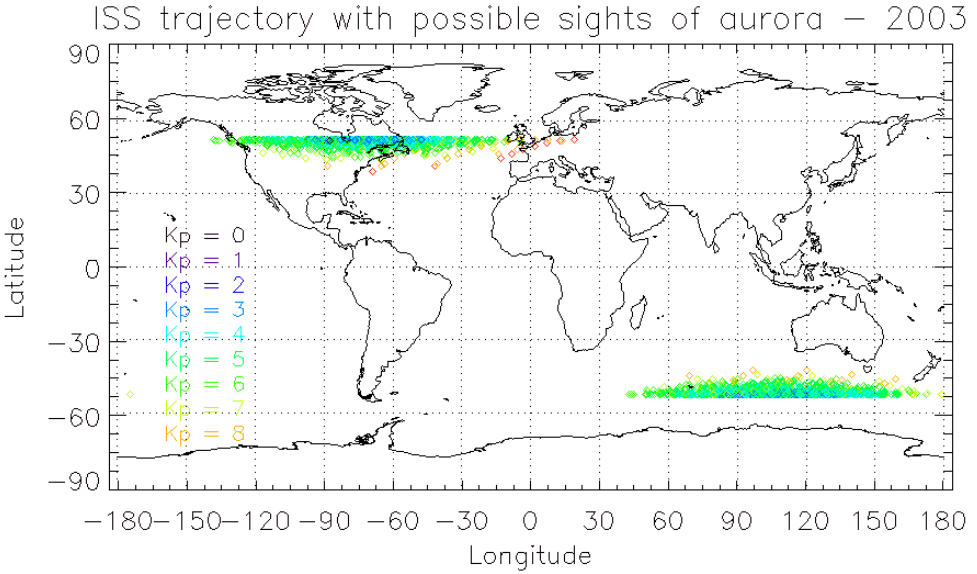
Aurora effect on JEM-EUSO operational efficiency

2000 - 2003









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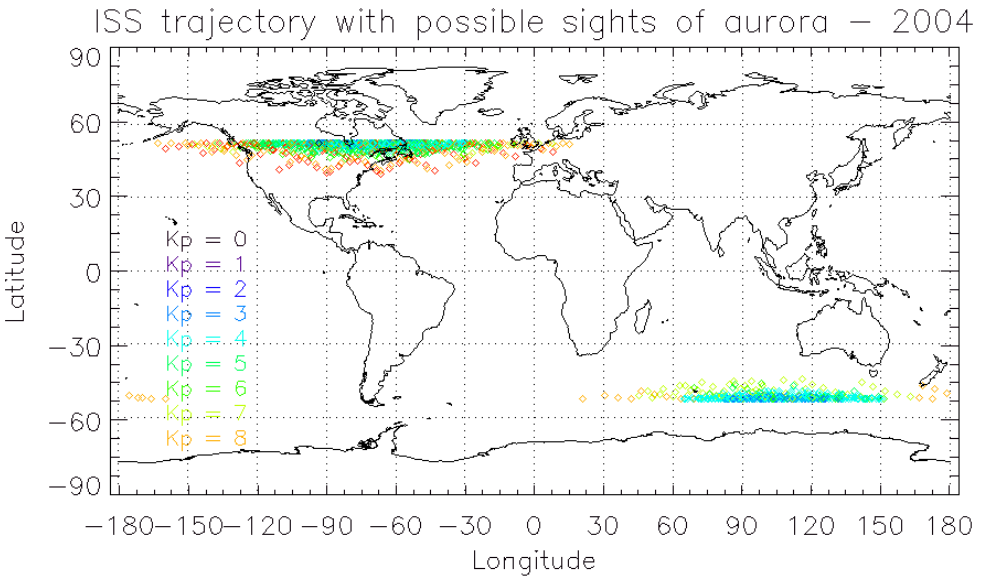
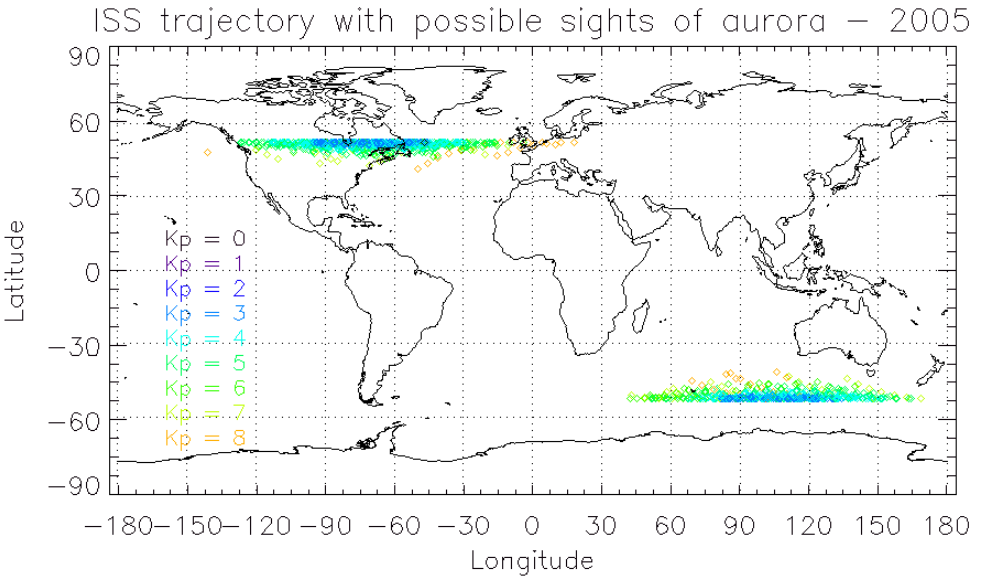
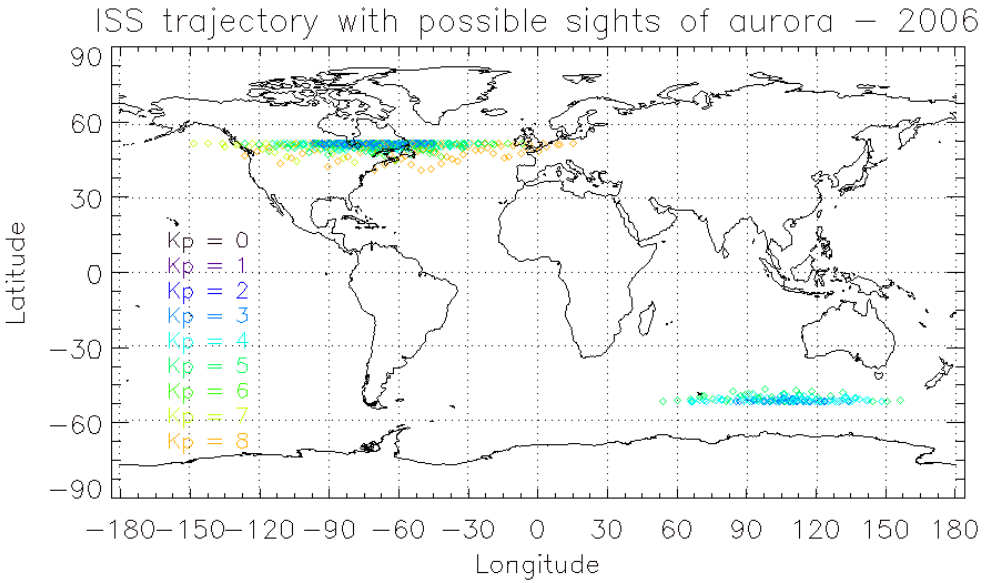
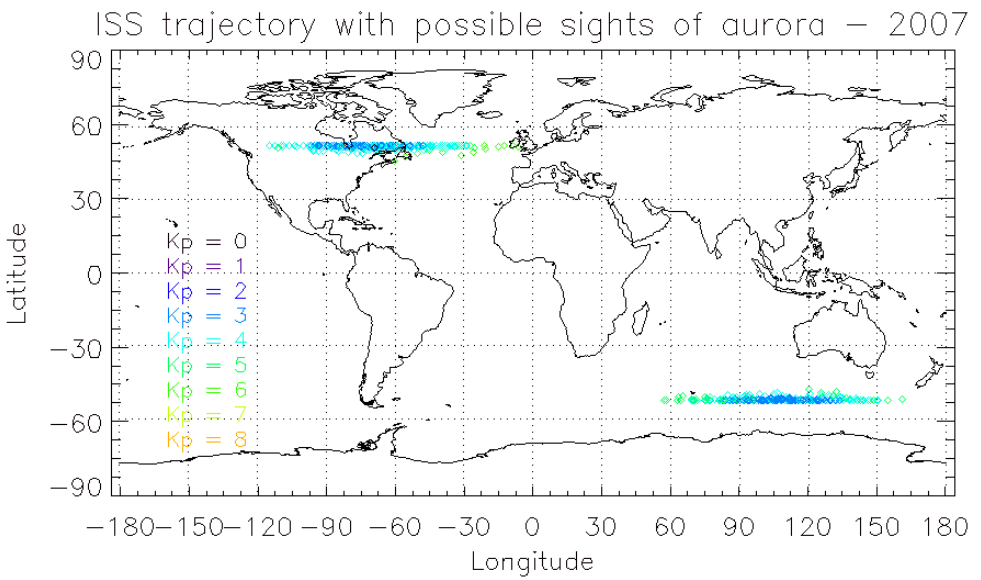
2004 - 2007









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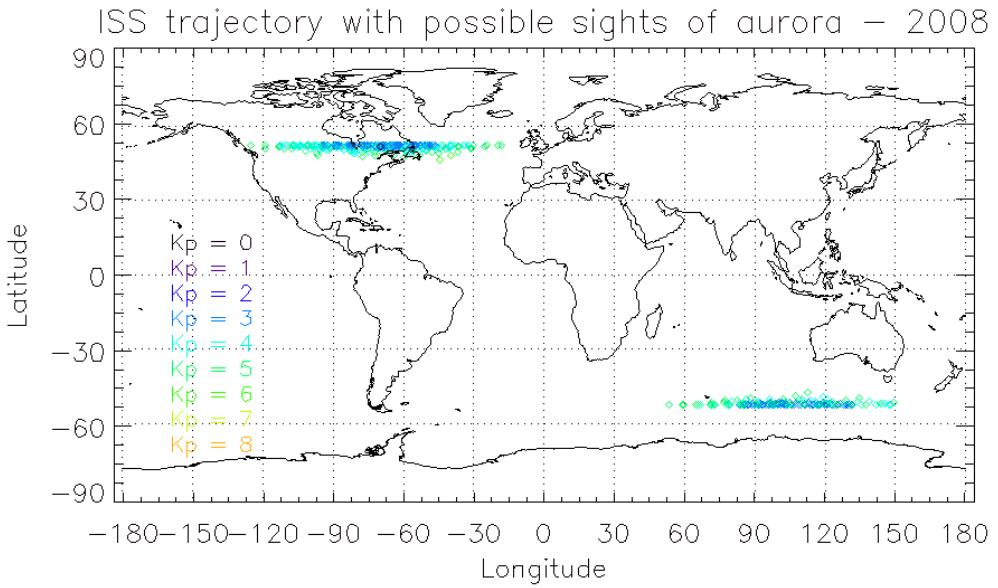
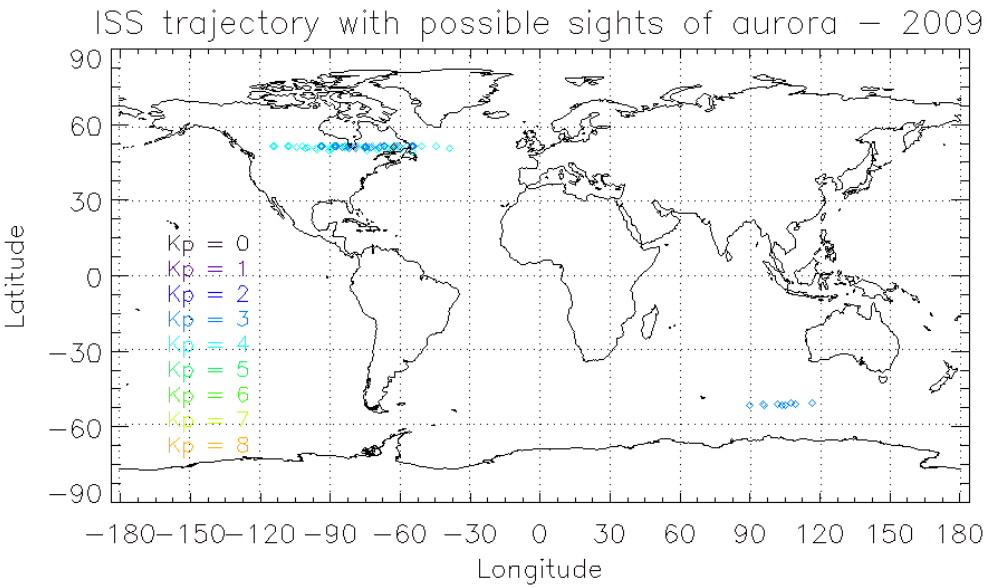
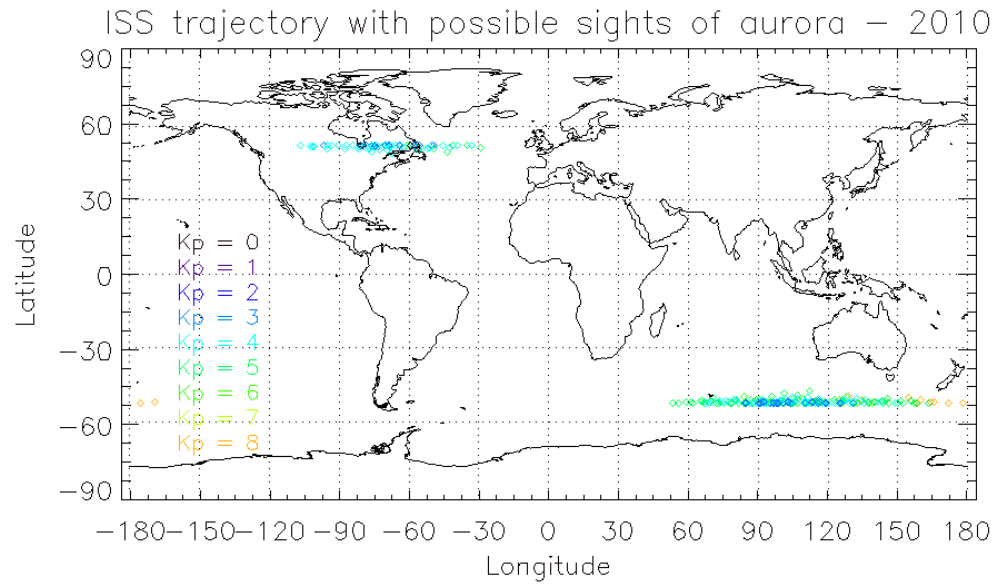
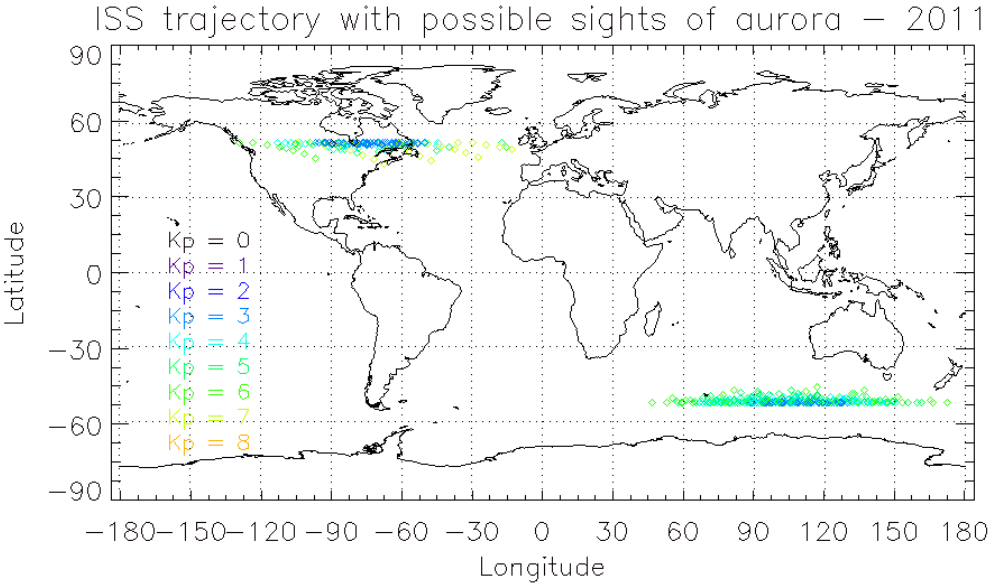
2008 - 2011









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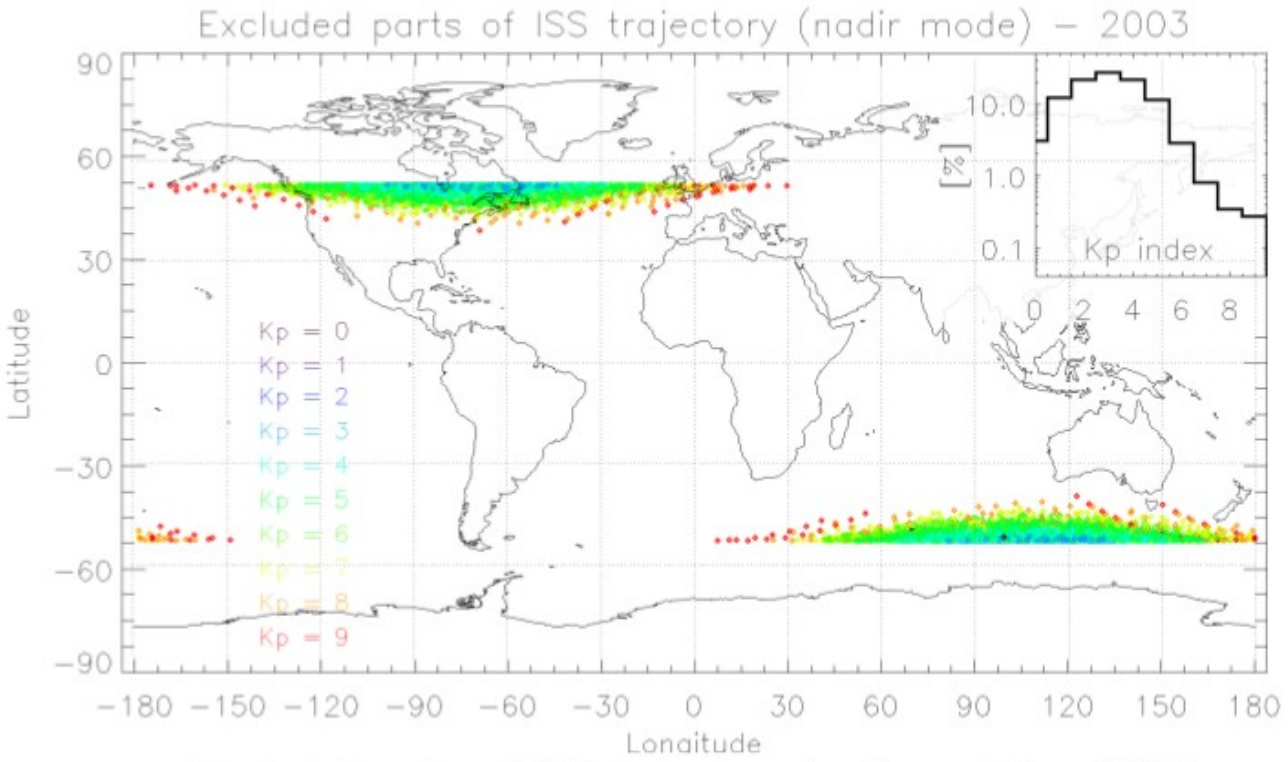
- Parts of the ISS trajectory excluded from duty cycle for year 2003 when the magnetopshere was most disturbed and for year 2009 when situation was most quiet during the searched period.

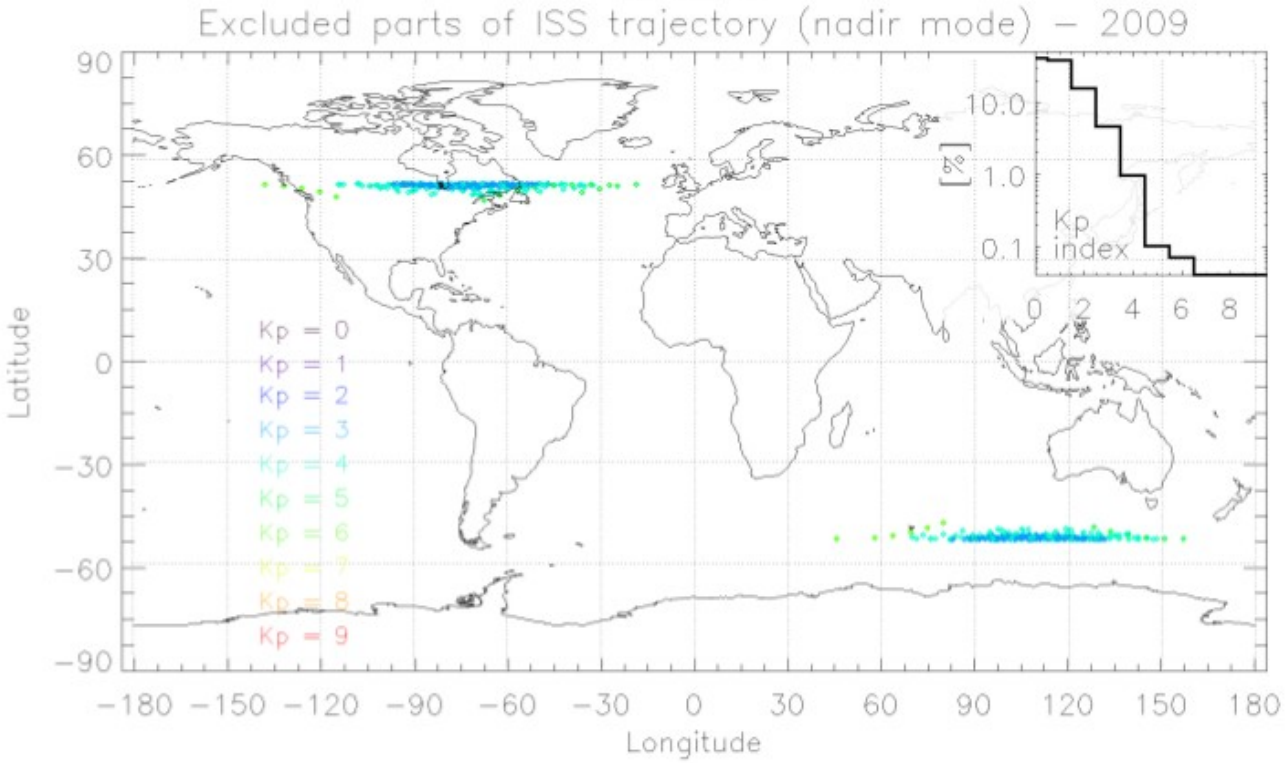
  - for year 2003 we exclude 12913 minutes

  - in 2009 only 608 minutes

- Different levels of Kp indexes are indicated by different colors on excluded ISS minute positions.

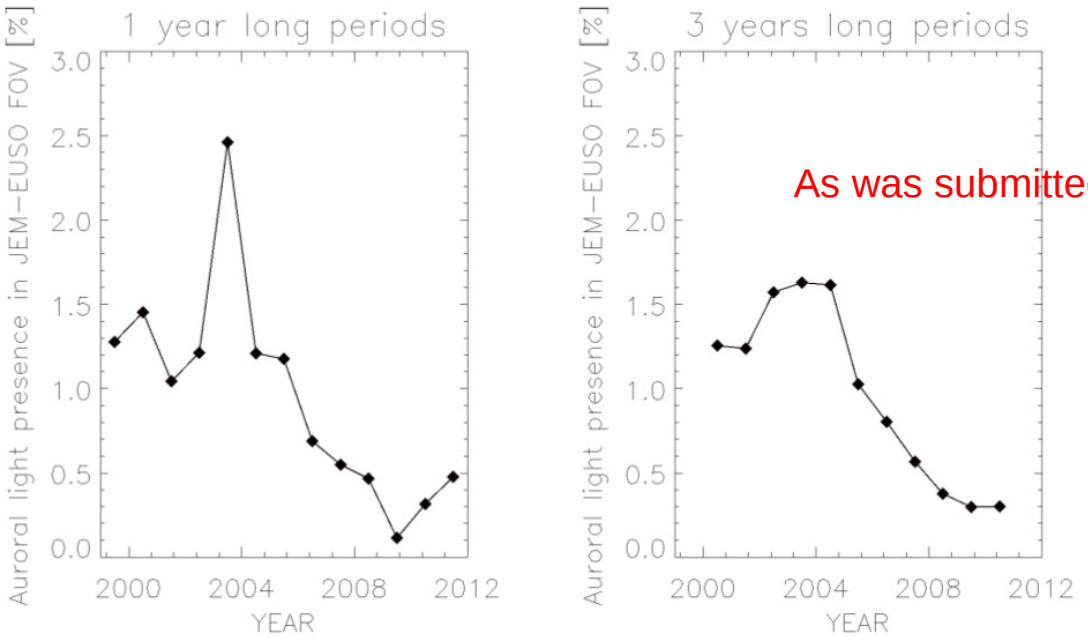
  - while for most disturbed year (2003) we have 36% of time on orbit with Kp at levels 0, 1 or 2, for most quiet year 2009 it is 94%





Aurora effect on JEM-EUSO operational efficiency

1 year and 3 years long periods

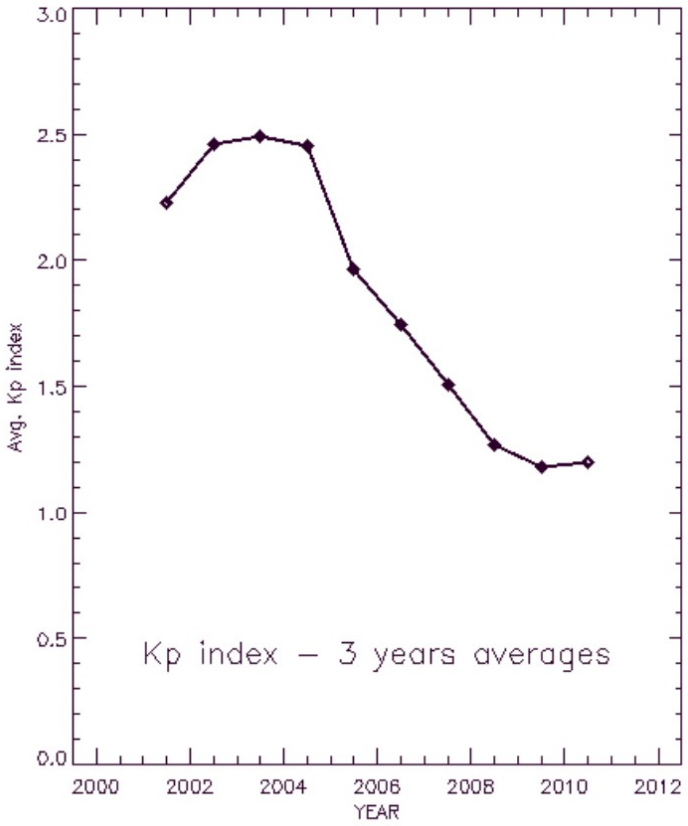


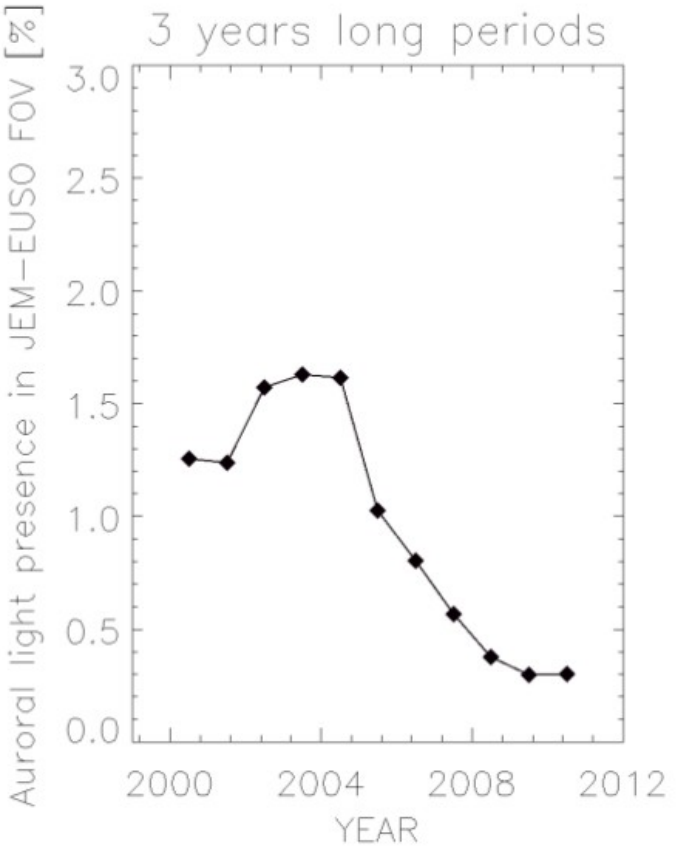
As was submitted in 1st revision to *AdvSR*

Figure 3: Left panel: Fraction of time in which auroral light restrain EAS measurements for one year long periods from 2000 to 2011 ($f_{A.L.}$). Right panel: Same as in the left panel, but integrating for 3 years periods.

- The fraction of time in which EAS measurements can not be performed due to the presence of auroral lights ($f_{A.L.}$) from 2000 to 2011 is presented in the left panel of Figure 3. $f_{A.L.}$ varies between 2.46% in year 2003 to 0.12% in year 2009.
- Since the effect clearly depends on time, specifically on solar cycle, the influence is estimated also in 3 years moving time windows, i.e. periods 2000–2002, 2001–2003, till 2009–2011. We selected 3 years long periods because we estimate similarly long measurements of JEM-EUSO on ISS in years 2017–2019. The effect of auroras presented in the right panel of Figure 3 is the highest for periods 2002–2004 and 2003–2005 when $f_{A.L.}$ ~1.6% and it is lowest in periods 2008–2010 and 2009–2011 when $f_{A.L.}$ ~0.3%.

Auroral efect vs. Kp index





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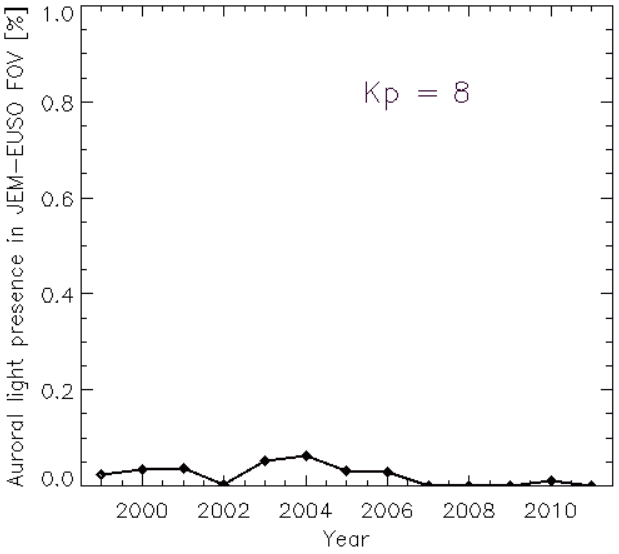
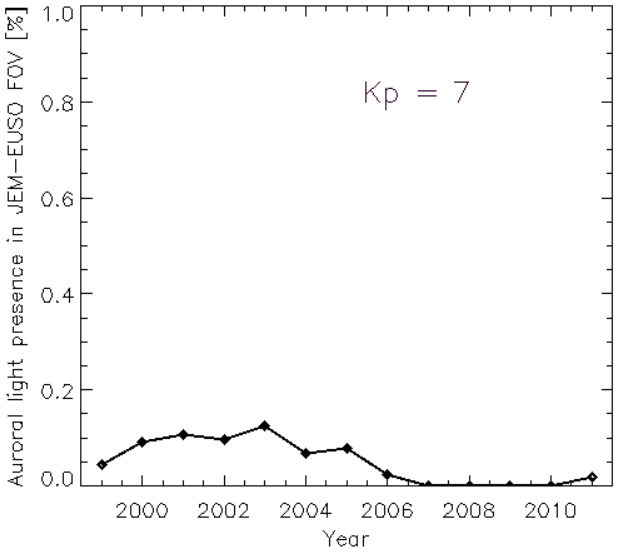
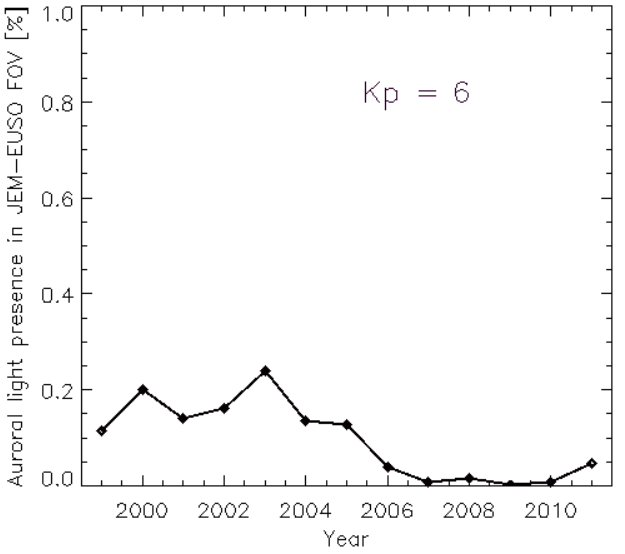
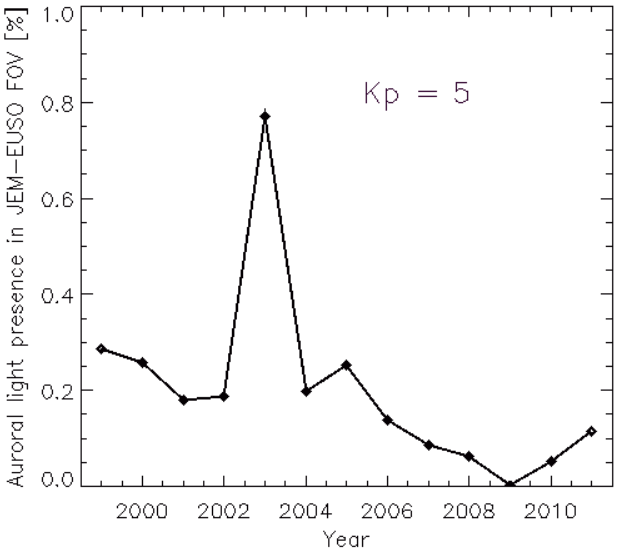
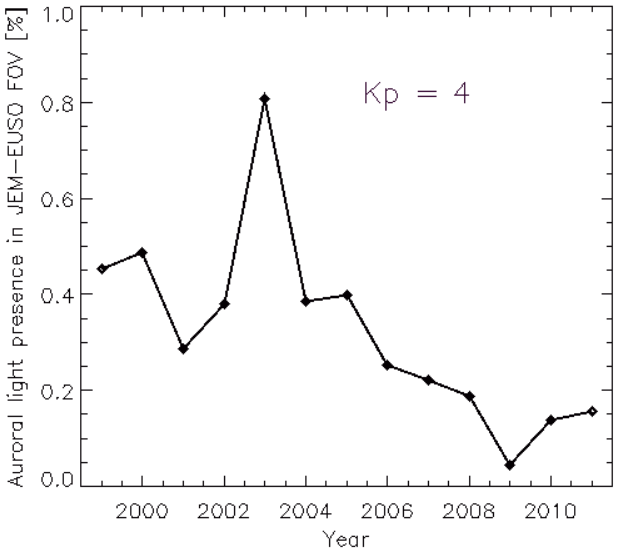
Auroral efect vs. Kp index

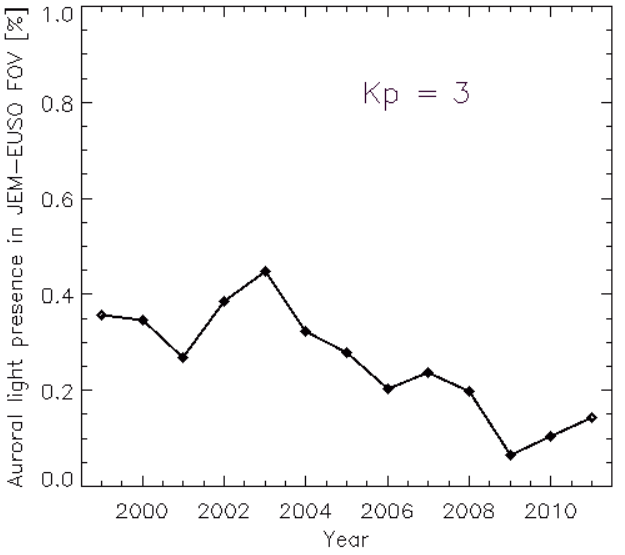


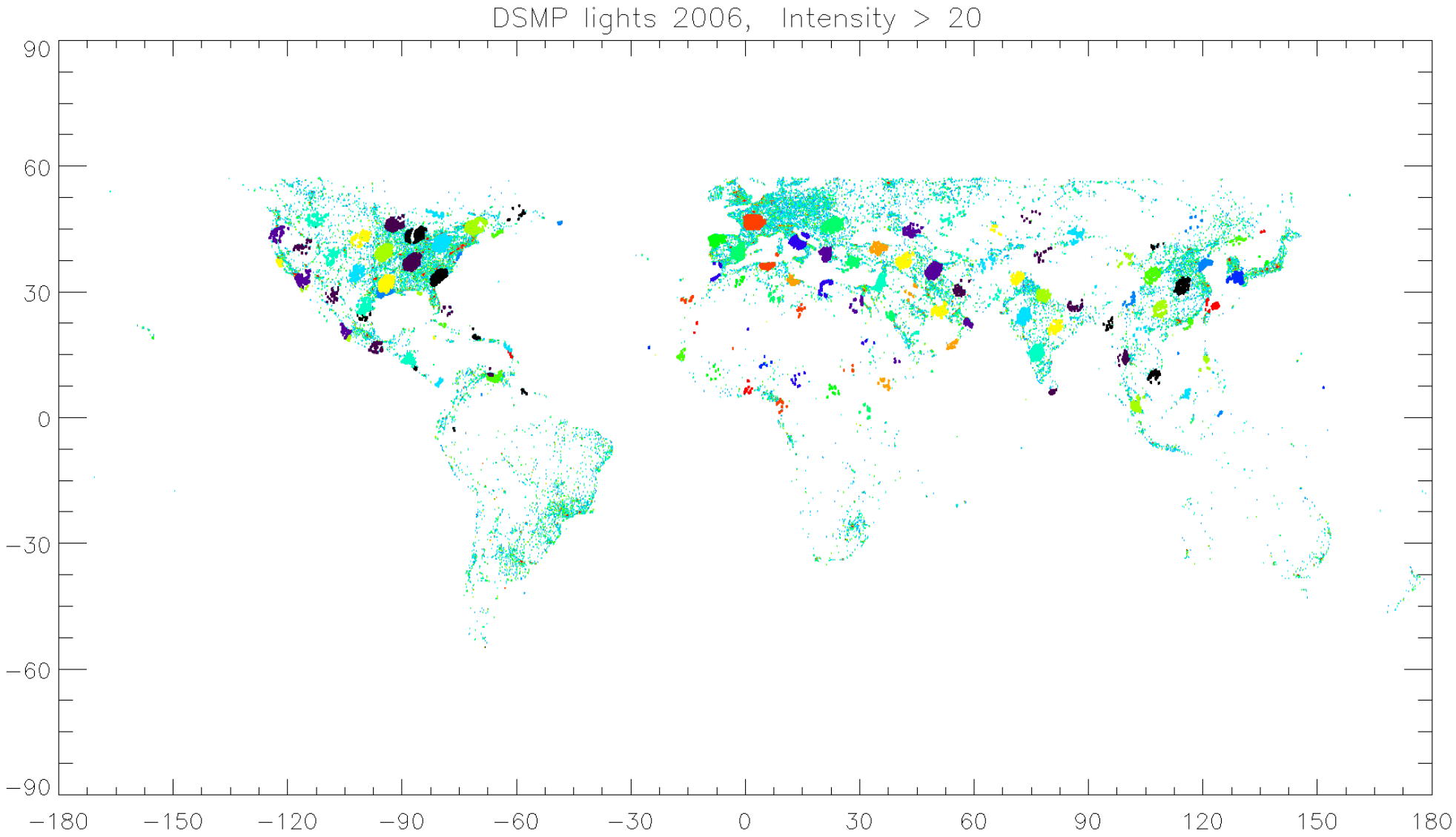








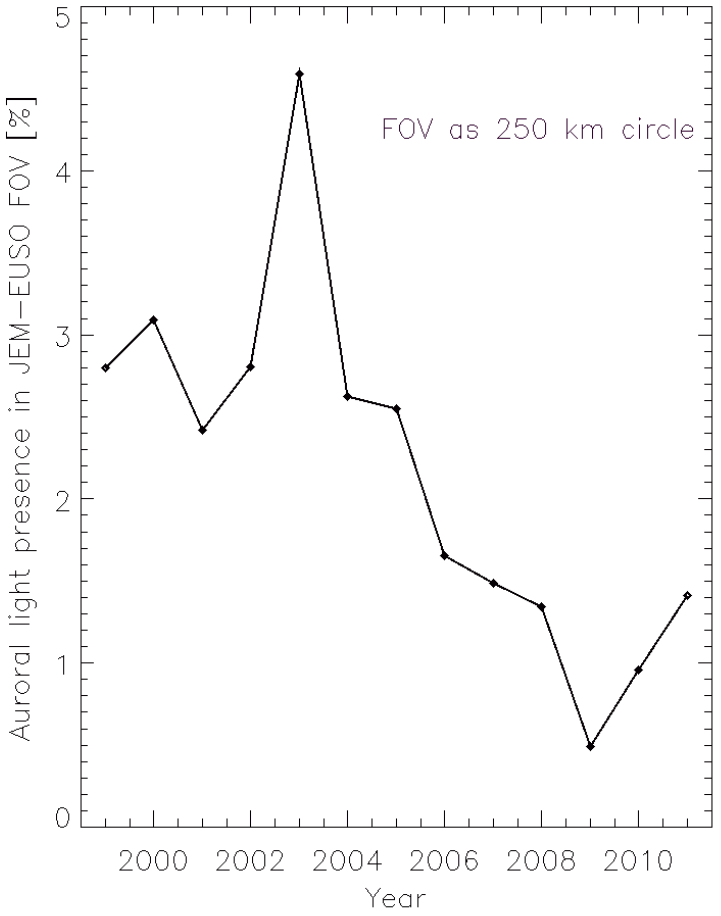


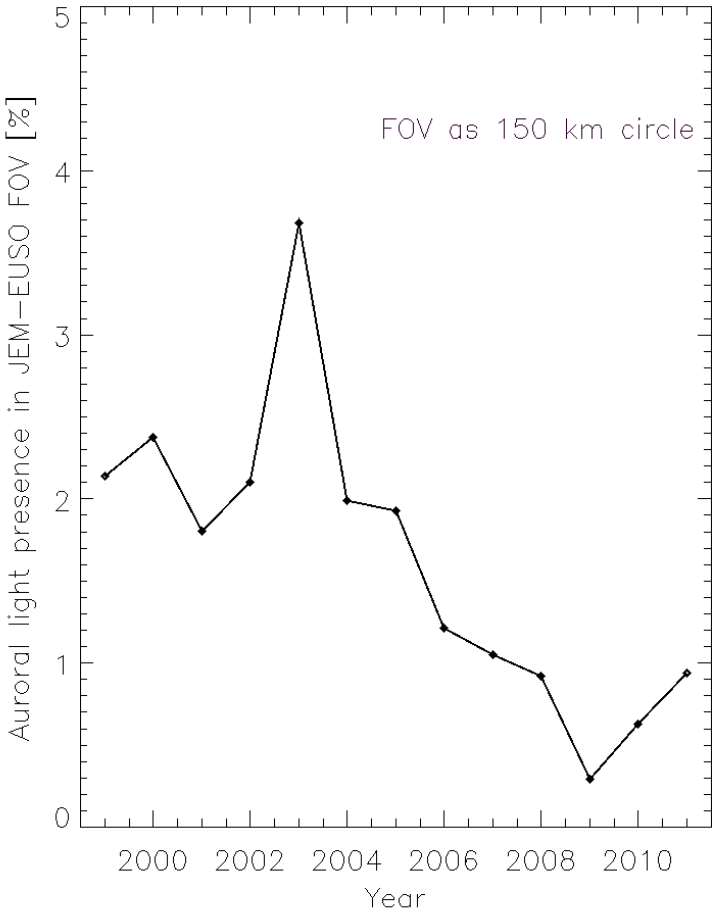


Till AdvSR submission strategy was simple – if Aurora appears in center of FOV we exclude this moment from duty cycle

So we switch off whole **detector** when we see Aurora in the center.

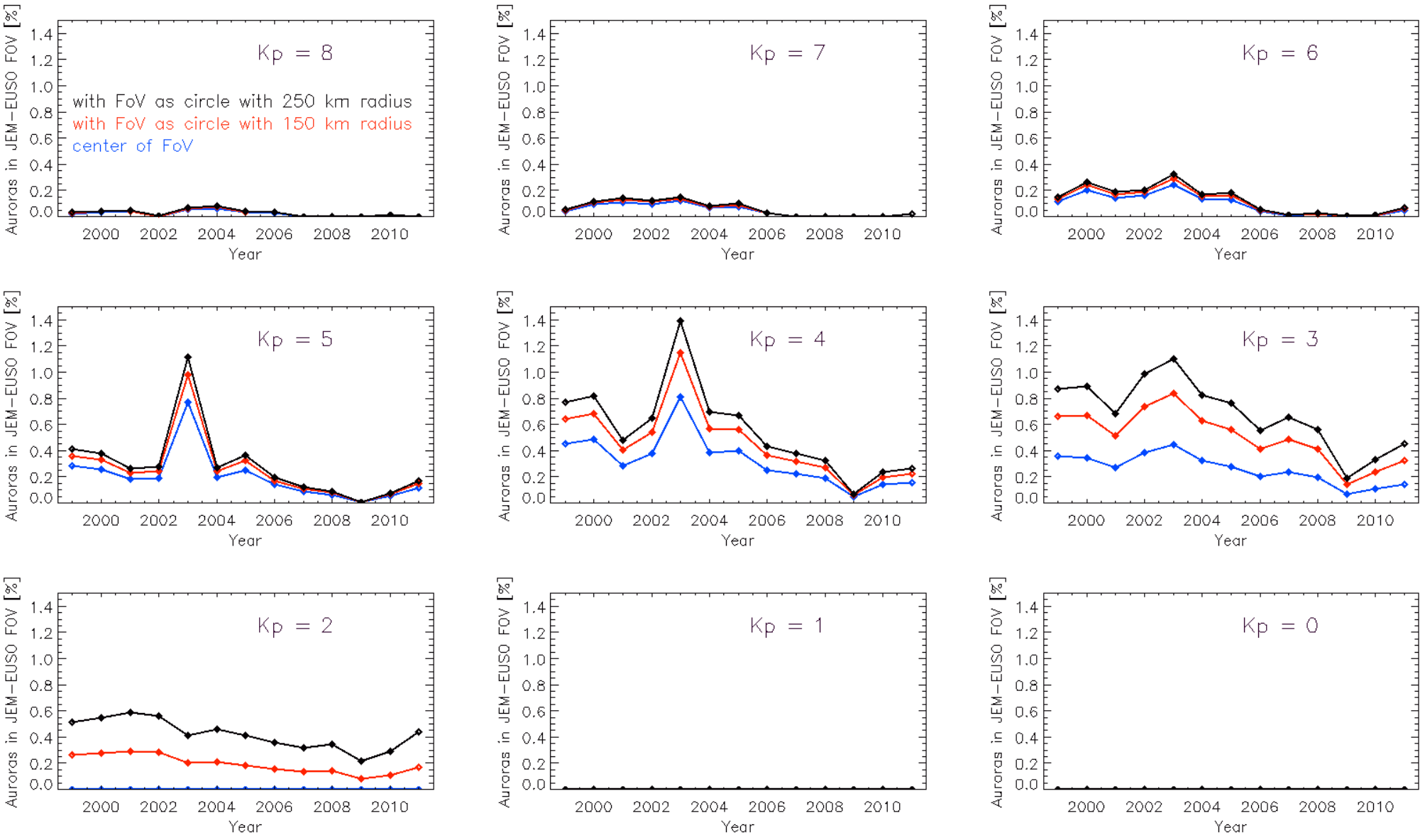
FOV Auroras appearance

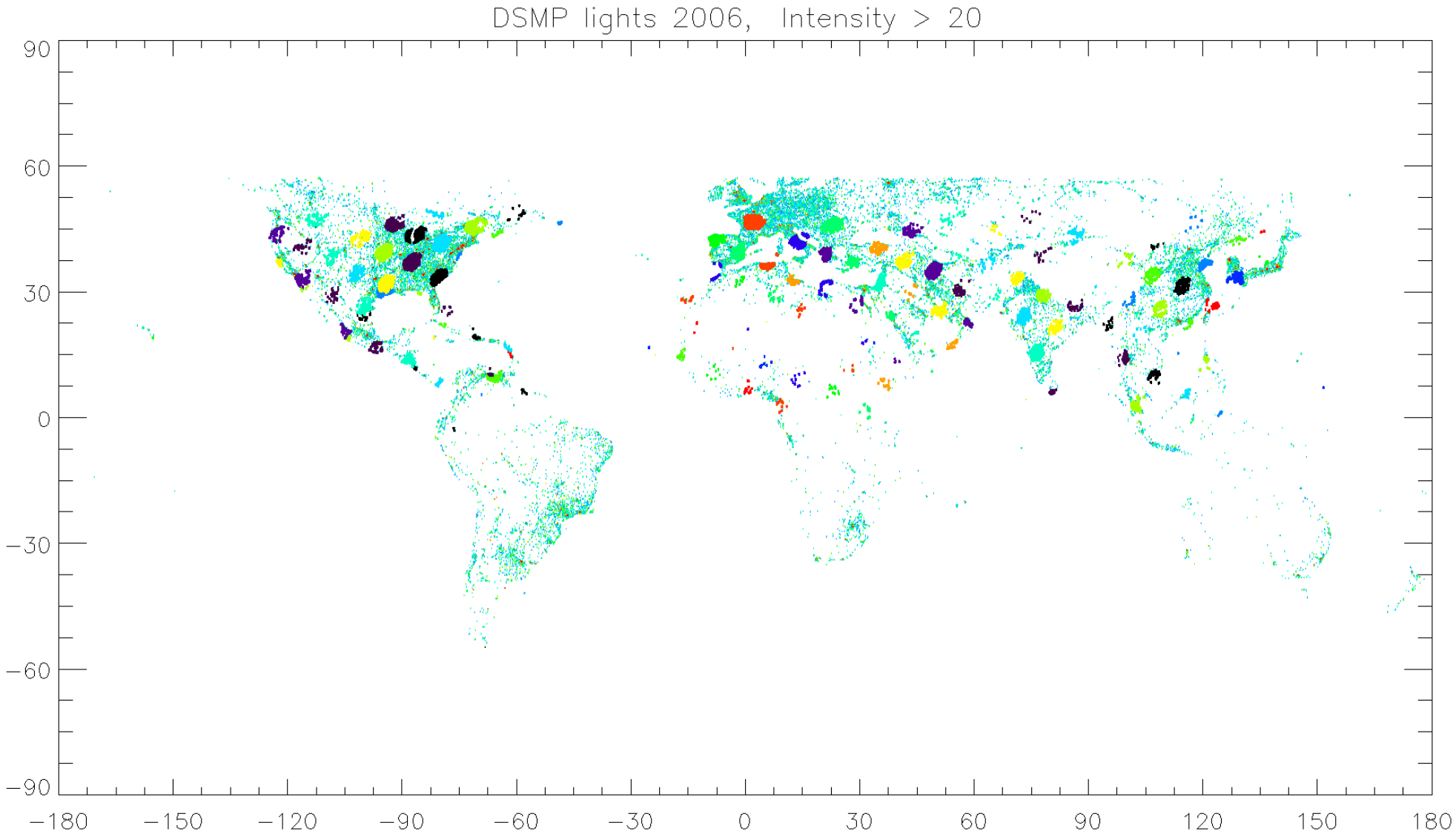




- What if Aurora appears at the border of FOV (more conservative approach) ?
- Still we switch off the whole detector when Aurora appears in FOV

Auroral efect vs. Kp index





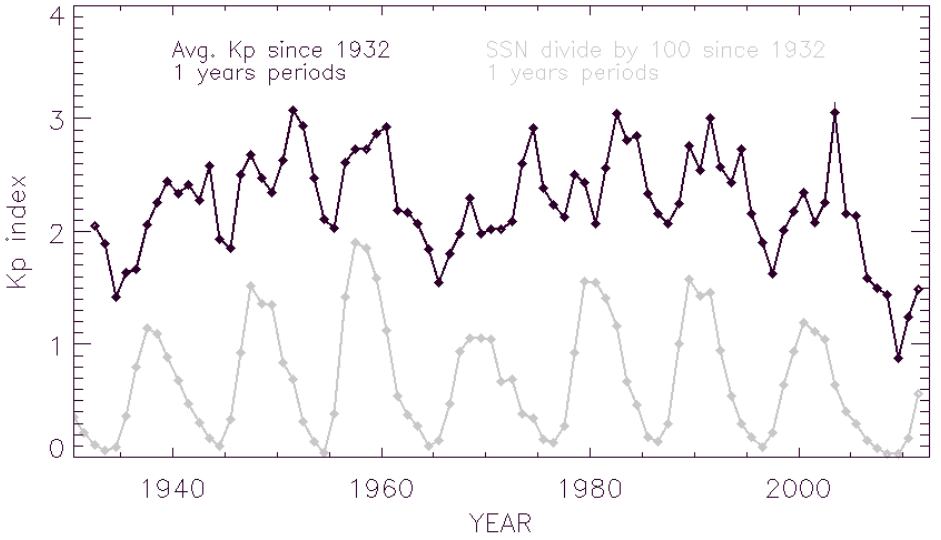
- PDM switch off strategy – same as in the city lights analysis
- When Aurora appears in the PDM FOV then PDM is excluded from duty cycle

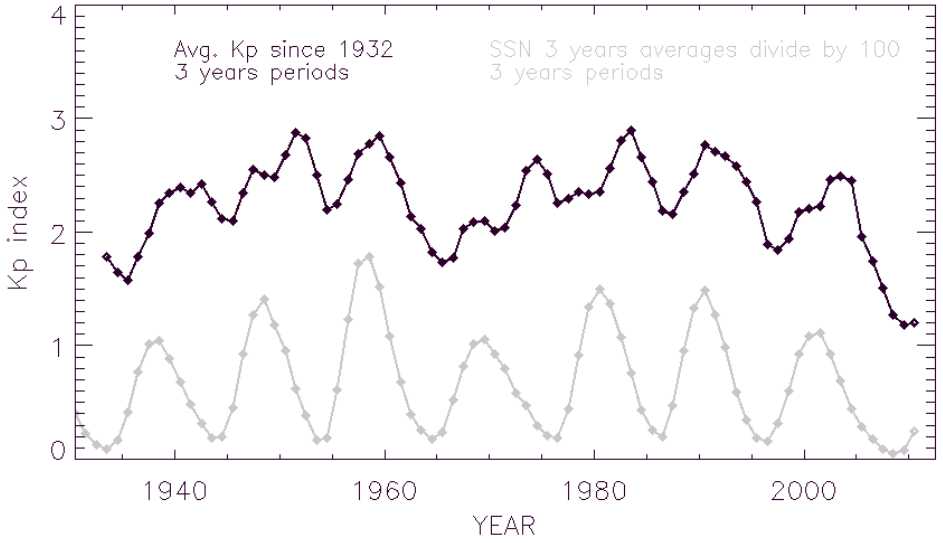
Aurora is different from city lights i.e. if appears then will be extended through many PDMs, but anyway, part of FOV stays ON – improvement of previous numbers.

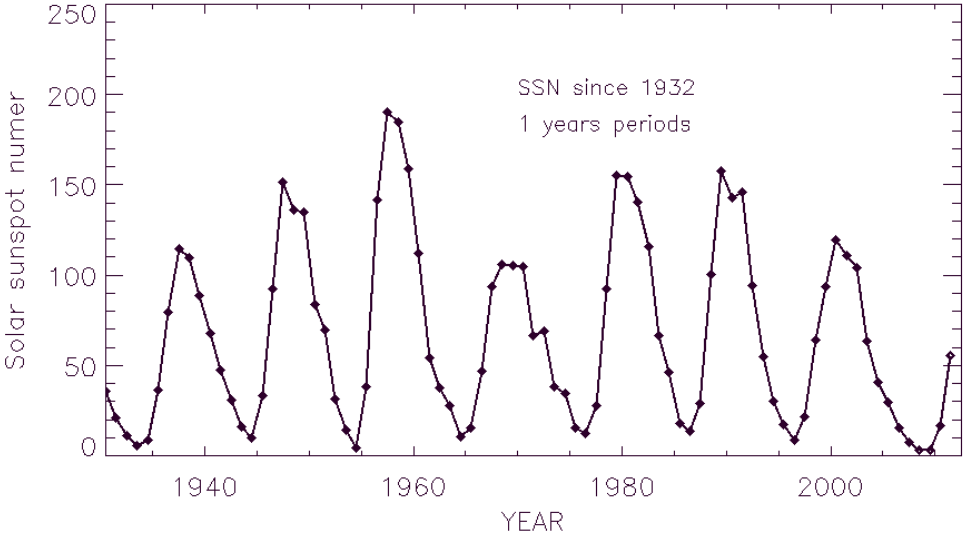
Aurora effect on JEM-EUSO operational efficiency

Evolution of yearly averaged Kp index in last decades since 1932 (upper panel) and Solar sunspot number (bottom panel).

3 year averages for Kp index and solar sunspot number (moving time window i.e. periods 1932-1934, 1933-1935, ..., 2009-2011)







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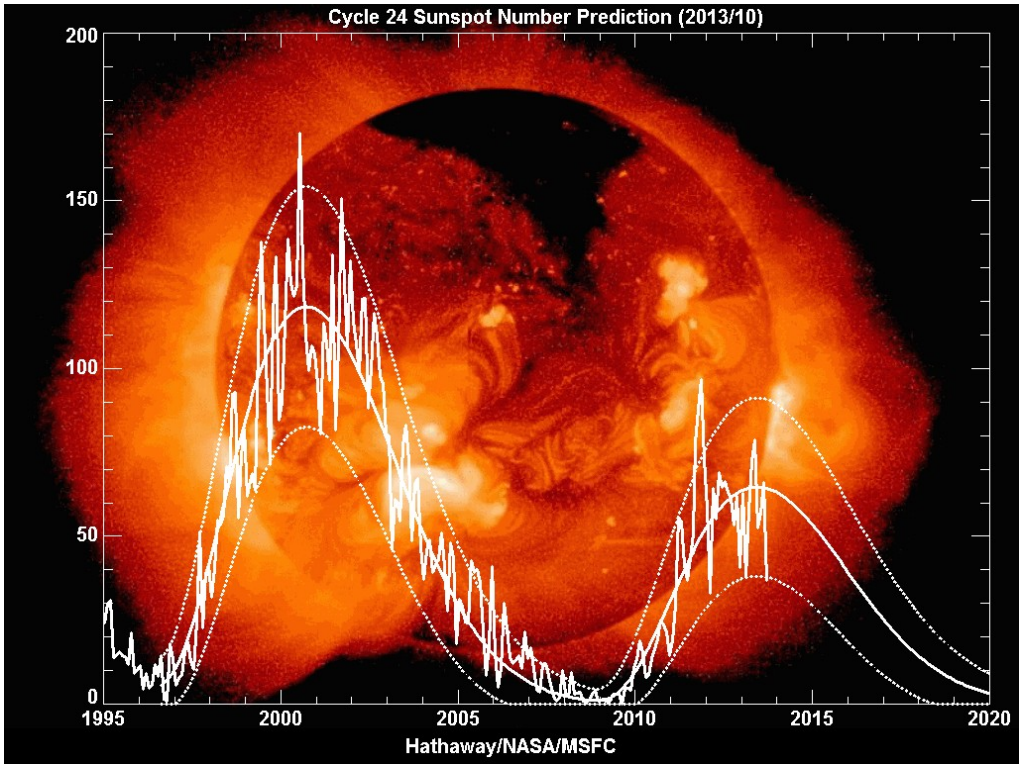
Kp index prediction

- based on solar activity, specifically on SSN prediction
- Sun conveyor belt slowing down



http://solarscience.msfc.nasa.gov/predict.shtml

List of solar cycles

From Wikipedia, the free encyclopedia

The following is a **list of solar cycles** (sometimes called sunspot cycles), tracked since 1755.[1][2][3]

Cycle	Started	Finished	Duration (years)	Maximum (monthly SSN (Smoothed Sunspot Number))[4]	Minimum (monthly SSN; end of cycle)[5][6]	Spotless days (end of cycle)[7][8][9]
Solar cycle 1	March 1755	June 1766	11.3	86.5	11.2	
Solar cycle 2	June 1766	June 1775	9.0	115.8	7.2	
Solar cycle 3	June 1775	September 1784	9.3	158.5	9.5	
Solar cycle 4	September 1784	May 1798	13.7	141.1	3.2	
Solar cycle 5	May 1798	December 1810	12.6	49.2	0.0	
Solar cycle 6	December 1810	May 1823	12.4	48.7	0.1	
Solar cycle 7	May 1823	November 1833	10.5	71.5	7.3	
Solar cycle 8	November 1833	July 1843	9.8	146.9	10.6	
Solar cycle 9	July 1843	December 1855	12.4	131.9	3.2	~654
Solar cycle 10	December 1855	March 1867	11.3	97.3	5.2	~406
Solar cycle 11	March 1867	December 1878	11.8	140.3	2.2	~1028
Solar cycle 12	December 1878	March 1890	11.3	74.6	5.0	~736
Solar cycle 13	March 1890	February 1902	11.9	87.9 (Jan 1894)	2.7	~938
Solar cycle 14	February 1902	August 1913	11.5	64.2 (Feb 1906)	1.5	~1019
Solar cycle 15	August 1913	August 1923	10.0	105.4 (Aug 1917)	5.6	534
Solar cycle 16	August 1923	September 1933	10.1	78.1 (Apr 1928)	3.5	568
Solar cycle 17	September 1933	February 1944	10.4	119.2 (Apr 1937)	7.7	269
Solar cycle 18	February 1944	April 1954	10.2	151.8 (May 1947)	3.4	446
Solar cycle 19	April 1954	October 1964	10.5	201.3 (Mar 1958)	9.6	227
Solar cycle 20	October 1964	June 1976	11.7	110.6 (Nov 1968)	12.2	272
Solar cycle 21	June 1976	September 1986	10.3	164.5 (Dec 1979)	12.3	273
Solar cycle 22	September 1986	May 1996	9.7	158.5 (Jul 1989)	8.0	309
Solar cycle 23	May 1996	December 2008 [10]	12.6	120.8 (Mar 2000)	1.7	821 [11]
Solar cycle 24	December 2008 [10]					
Mean			10.6	114.1	5.8	

References

[edit]

1. ^ Kane, R.P. (2002). "Some Implications Using the Group Sunspot Number Reconstruction". *Solar Physics* **205(2)**, 383-401.
2. ^ "Did You Say the Sun Has Spots?". *Space Today Online*.
3. ^ Phillips, A. (2008). "Solar Cycle 24 Begins". *Science @ NASA*.
4. ^ SIDC Monthly Smoothed Sunspot Number. "[1]"
5. ^ Monthly solar cycle data. "[2]"
6. ^ Solar Cycle Progression: Recent Solar Indices. "[3]"
7. ^ Spotless Days. "[4]"
8. ^ What's Wrong with the Sun? (Nothing) more information: Spotless Days. "[5]"
9. ^ Solaemon's Spotless Days Page. "[6]"
10. ^ **a** **b** Recent Solar Indices. "[7]"
11. ^ Spotless days. "[8]"