# Auroral oval forecast on mobile platforms

F. Sigernes [1], S. E. Holmen [1], M. Dyrland [1], A. L. Bækken [2], P. Brekke [3], S. Chernouss [4], D.A. Lorentzen [1], and C. S. Deehr [5]

[1] The University Centre in Svalbard (UNIS), N-9171 Longyearbyen, Norway
[2] University of Oslo, Oslo, Norway
[3] Norwegian Space Centre, Oslo, Norway
[4] Polar Geophysical Institute, Murmansk Region, Apatity, Russia
[5] Geophysical Institute, University of Alaska, Fairbanks, USA

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# 2 MATEMATICAL REPRESENTATIONS OF THE AURORAL OVALS

## METHOD A: The Feldstein-Starkov ovals

Poleward and equatorward boundaries of auroral oval in geomagnetic co-latitude:

$$\theta_p \; or \; \theta_e = A_0 + A_1 \cos\left[15\left(t+\alpha_1\right)\right] + A_2 \cos\left[15\left(2t+\alpha_2\right)\right] + A_3 \cos\left[15\left(3t+\alpha_3\right)\right],$$

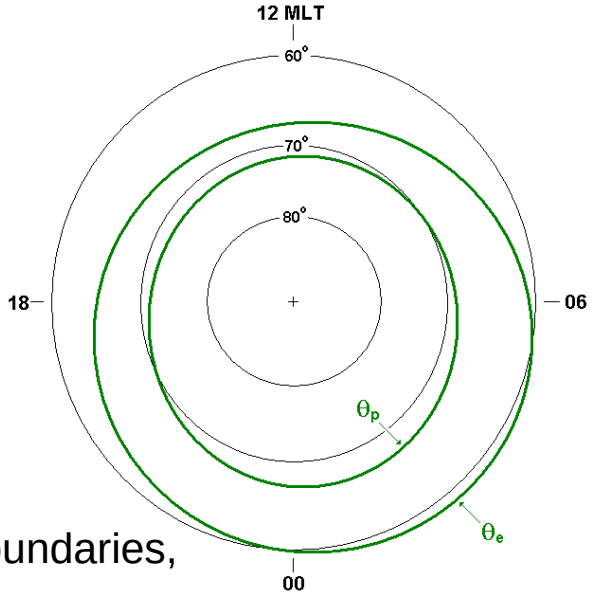
where amplitudes $A_i$ and phases $\alpha_i$ is given by

$$A_i \; or \; \alpha_i = b_0 + b_1 \log_{10}\left|AL\right| + b_2 \log_{10}^2\left|AL\right| + b_3 \log_{10}^3\left|AL\right|.$$

The AL index is the max negative excursion of the H component from several ground based magnetometers.

It relates to the planetary Kp index by

$$AL = 18 - 12.3 \cdot K_p + 27.2 \cdot K_p^2 - 2 \cdot K_p^3$$




## REFERENCES


[1] Starkov, G. V., Mathematical model of the auroral boundaries, Geomagnetism and Aeronomy, 34, 3, 331-336, 1994.

[2] Starkov, G. V., Statistical dependences between the magnetic activity indices, Geomagnetism and Aeronomy, 34, 1, 101-103, 1994.

# 2 MATEMATICAL REPRESENTATIONS OF THE AURORAL OVALS

## METHOD B: The Zhang-Paxton ovals

The electron energy flux is derived from GUVI imager data (TIMED satellite)

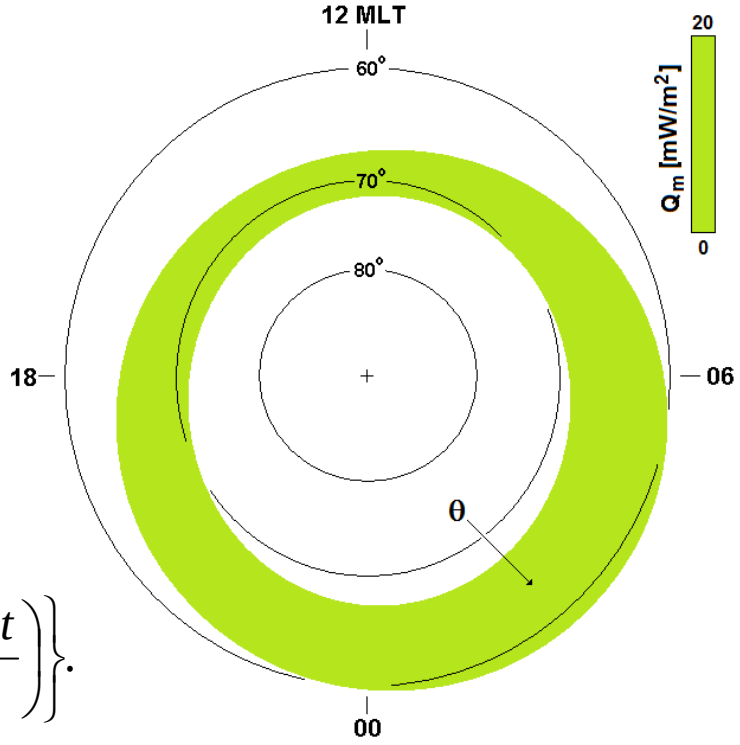
$$Q_m = \frac{A'_{0m} \cdot \exp\left[\left(x - A'_{1m}\right) / A'_{2m}\right]}{\left\{1 + \exp\left[\left(x - A'_{1m}\right) / A'_{3m}\right]\right\}^2},$$

where $x$ is co-magnetic latitude.

$$x = \pi / 2 - |\theta|$$

The coefficients $A'$ is are calculated as

$$A'_{im} = b'_{0m} + \sum_{n=1}^{6} \left\{ b'_{nm} \cos\left(\frac{n\pi t}{12}\right) + b''_{nm} \sin\left(\frac{n\pi t}{12}\right) \right\}.$$




The coefficients *b'* is tabulated as a function of six sub-intervals (*m*) of Kp index.

## REFERENCE


[3] Zhang Y., and L. J. Paxton, An empirical Kp-dependent global auroral model based on TIMED/GUVI data, *J. Atm. Solar-Terr. Phys.*, **70**, 1231-1242, 2008.

# GEOGRAPHICAL TRANSFORM

Cartesian components:

$$x_m = \sin\theta \cdot \cos\phi$$
$$y_m = \sin\theta \cdot \sin\phi$$
$$z_m = \cos\theta$$

$$\phi = 2\pi \cdot t / 24 + \Delta\phi(t)$$

$\Delta\phi(t)$ - is the longitudinal difference between the sub-solar point and the magnetic poles at time *t* (hours).

Geographical coordinates:

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} \cos\phi'_0 \cos\lambda & -\sin\phi'_0 & \cos\phi'_0 \sin\lambda \\ \sin\phi'_0 \cos\lambda & \cos\phi'_0 & \sin\phi'_0 \sin\lambda \\ -\sin\lambda & 0 & \cos\lambda \end{bmatrix} \cdot \begin{bmatrix} x_m \\ y_m \\ z_m \end{bmatrix}$$

$$\theta'_0 = 82.41^o\, N$$
$$\phi'_0 = -82.86^o\, E$$
$$\lambda = \pi / 2 - \theta'_0$$

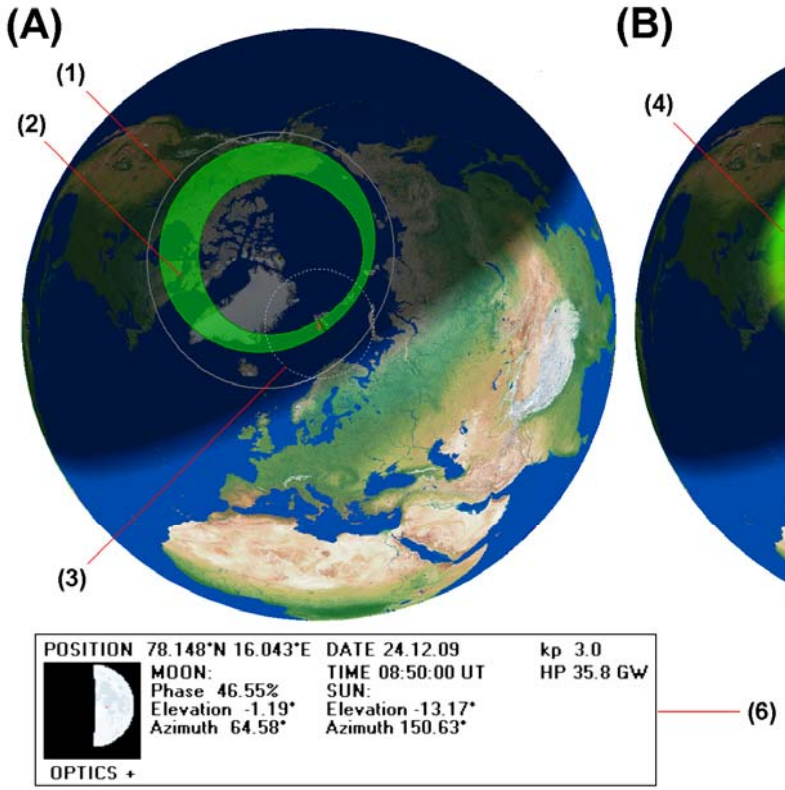
Latitude and longitude:

$$\theta' = \frac{\pi}{2} - \cos^{-1}(z)$$

$$\phi' = \begin{cases} \psi & \forall \quad x > 0 \\ \psi + \pi & x < 0 \end{cases}$$

$$\psi = \tan^{-1}(y / x)$$

# VISUALIZATION




The twilight zone, night- and dayside of the Earth are projected with grades of shade on the Globe as a function of time.

The ovals are visualized with a stand alone 32-bit executable Windows program called

**SvalTrackII.**

The program is written in Borland Delphi 5 – Pascal and uses a Geographic Information system (GIS) unit called TGlobe.

**Includes:**

**Method A**

(1) Equatorward boundary of the diffuse aurora
(2) Feldstein & Starkov oval
(3) Field of view aurora observer

**Method (B)**

(4) Zhang & Paxton oval
(5) Observer location
(6) Moon and Sun information at local site

# VISUALIZATION

## All-Sky Satellite View

Local auroral oval & satellite all-sky view

Based on Feldstein & Starkov and TLE element SGP4 code by [4]


[4] Vallado, D. A., P. Crawford, R. Hujsak, and T. S. Kelso, Revisiting Space track Report #3, American Institute of Aeronautics and Astronautics (AIAA), Report No. AIAA 2006-6753, 1-88, 2006.

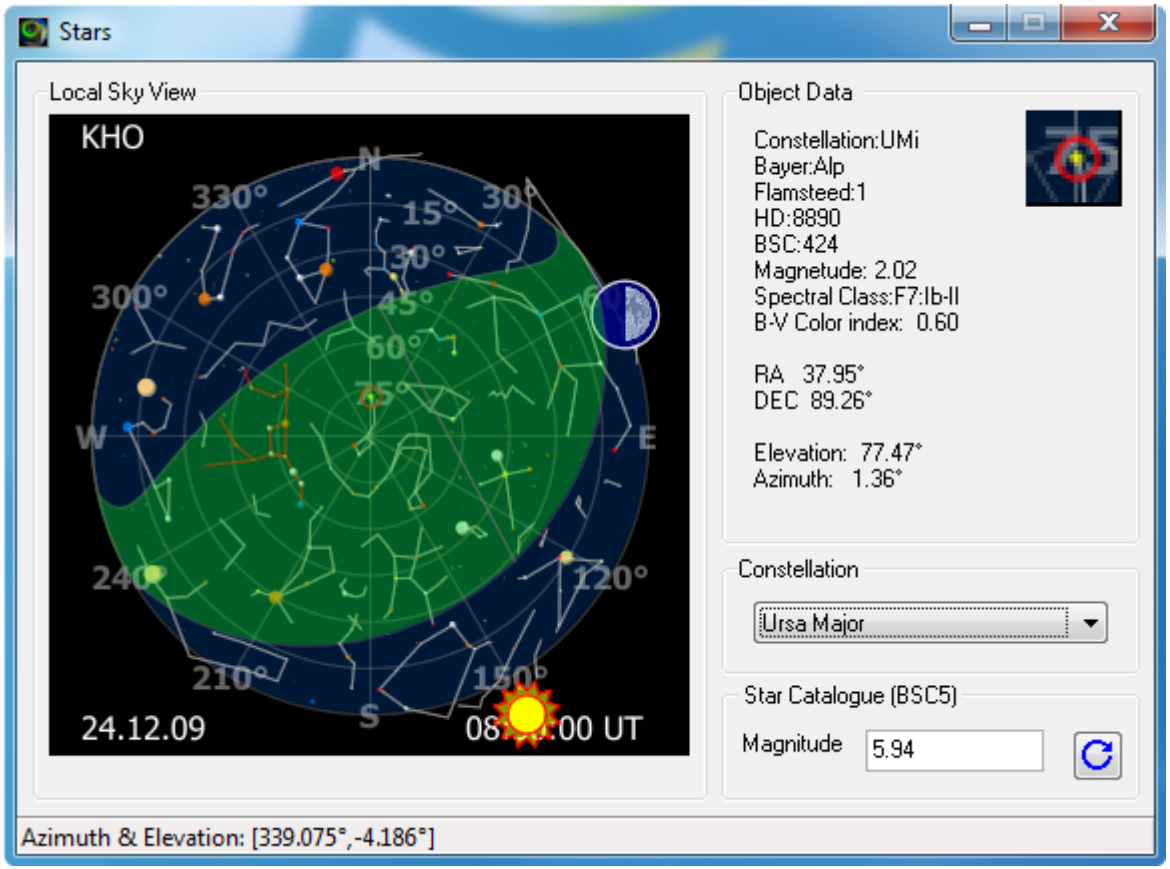
**NEW!**

# All-Sky Star View

Local auroral oval & star map all-sky view

Based on Feldstein & Starkov ovals and Sky Charts software by [5]

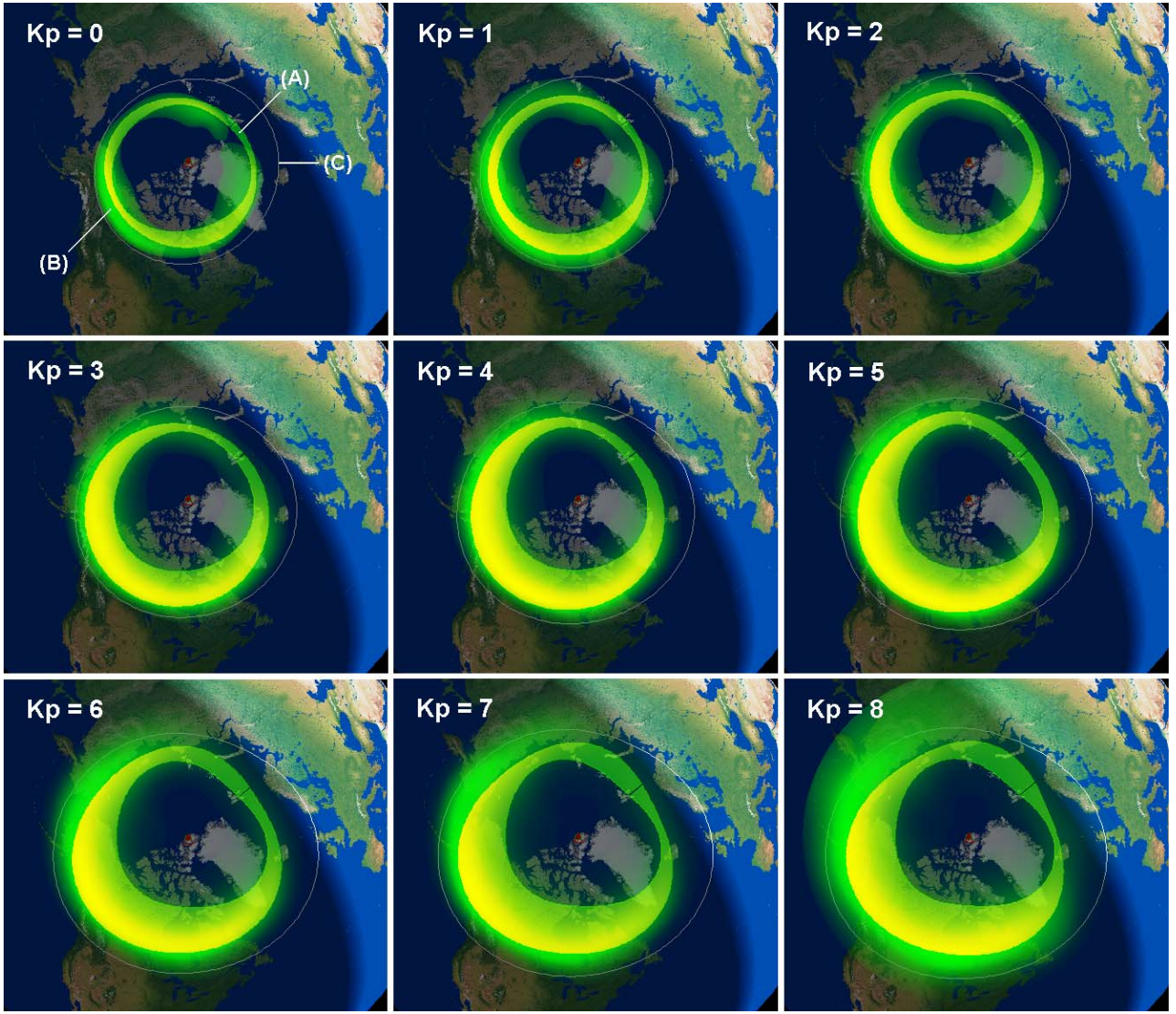
Catalog: BSC5




[5] Cartes du Ciel, http://www.ap-i.net/skychart/

# ANIMATION

Animated aurora ovals as a function of *Kp* index [0…8] at 08:50 UT, 24th December 2009



# MODEL COMPARISION

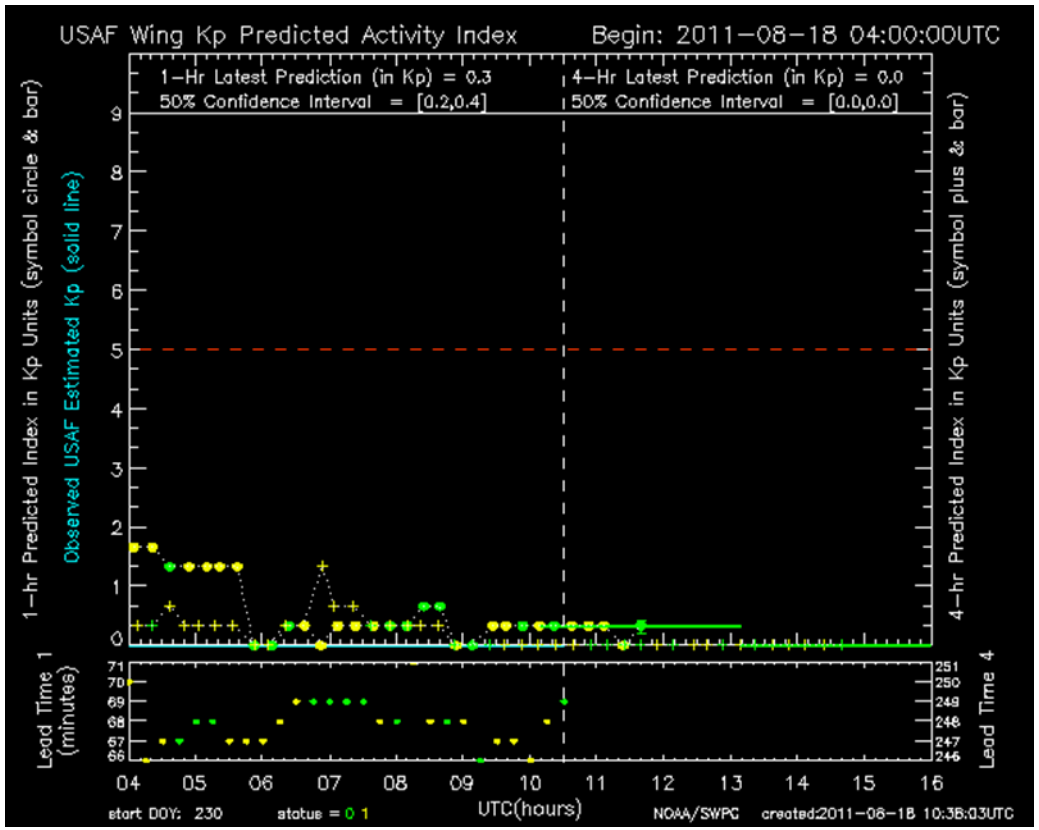
| *Kp* | Auroral activity | Level | A∩B [%] | B∩C [%] | $Q_{max}$ [mW/m$^2$] |
|---|---|---|---|---|---|
| 0 | Very low | Low normal conditions | 32 | 99 | 1.65 |
| 1 | Low | | 26 | 86 | 2.10 |
| 2 | Low normal | | 33 | 87 | 3.20 |
| 3 | Normal | | 35 | 87 | 4.34 |
| 4 | Calm storm | | 36 | 89 | 5.34 |
| 5 | Minor storm | Storm conditions | 35 | 88 | 6.45 |
| 6 | Moderate storm | | 32 | 84 | 8.36 |
| 7 | Strong storm | | 30 | 83 | 12.18 |
| 8 | Severe storm | | 24 | 68 | 12.91 |
| 9 | Extreme storm | | 22 | 62 | 18.10 |

**Auroral intersections:** **(A)** Zhang-Paxton, **(B)** Feldstein-Starkov and **(C)** Equatorward boundary of diffuse aurora

$Q_{min}$= 0.25 *ergs cm$^{-2}$ s$^{-1}$*.

# THE +1 or +4 HOUR PREDICTED Kp INDEX

**SOURCE:** Space Weather Prediction Centre (SWPC) at the National Oceanic and Atmospheric Administration (NOAA).




**The Wing Kp predicted Activity Index model.**

**Reference**

Wing, S., J. R. Johnson, J. Jen, C.-I. Meng, D. G. Sibeck, K. Bechtold, J. Freeman, K. Costello, M. Balikhin, and K. Takahashi, Kp forecast models, *J. Geophys. Res.*, 110, A04203, doi:10.1029/ 2004JA010500, 2005.

It is a neural network algorithm that trains on the response of the Kp geomagnetic activity index to solar wind parameters / data. It predicts +1 or+ 4 hours ahead.

The model returns an one hour prediction in units of Kp. It updates / predicts every 15 minutes.

**15 minutes oval update:**

**http://kho.unis.no**

http://www.swpc.noaa.gov/wingkp/

# THE KHO AURORAL OVAL FORECAST SERVICE

Internet

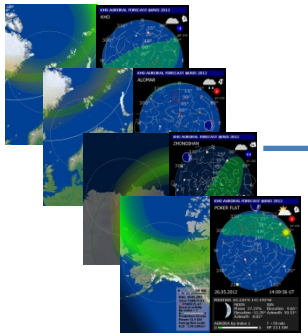
SERVER / PC
RUNS
SVALTRACKII.EXE

WEB SERVER
http://kho.unis.no

Kp index
NOAA-SWPC
(15 min. updates)

NEW
Weather forecasts
YR.NO (60 min.)

Stations x 007
(60 sec.)



+1 or +4 hours predictions

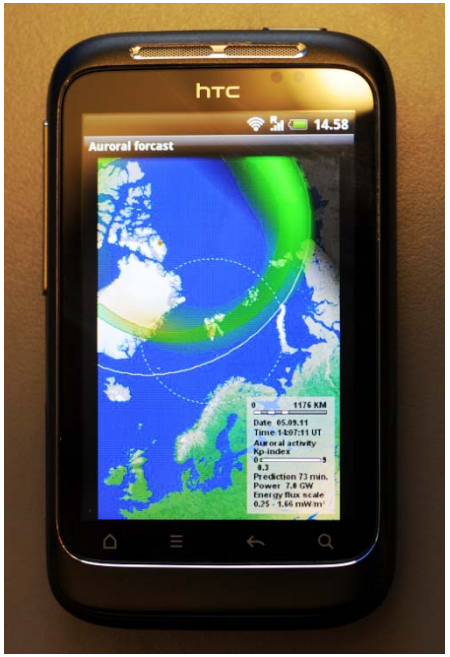
Mobile Auroral
forecast
applications (apps)

# THE KHO MOBILE AURORAL OVAL FORECAST SERVICE

Today, as part of the Andøya rocket range 50 years celebration, we now release mobile applications for all smart phones:

1)Android
2)iPhone
3)Windows Phone

Company
http://appex.no




The auroral forecast on a HTC wildfire phone.

## Some REMARKS and QUESTIONS

**1)** As expected the Zhang-Paxton ovals deduced by space borne data are wider than the ground based Feldstein-Starkov ovals.

**2)** In spite of difference in methods and platforms, the model ovals coincide fairly well in shape for low to normal conditions on the nightside.

**3)** The equatorward border of the diffuse aurora is well defined by both methods on the nightside for $Kp<7$.

**4)** On the dayside, there is a need to study further oval shapes for all levels of auroral activity, especially the equatorward border of the diffuse aurora.

**5)** Is it possible to derive / predict the *Kp* index from the Norwegian chain of magnetometers, as a real time service?

**6)** Can other data sources like our new HF radar looking east and future GPS scintillations receiver chains contribute?

**7)** Optical validation, local light pollution, etc., etc…


## Acknowledgement

**We wish to thank**

**1)** The National Oceanic and Atmospheric Administration (NOAA) - Space Weather Prediction Centre for allowing us to download the predicted value of the $K_p$ index every 15 minutes.

**2)** The Research Council of Norway through the project named: Norwegian and Russian Upper Atmosphere Co-operation On Svalbard part 2 # 196173/S30 (NORUSCA2).

**3)** The Nordic Council of Ministers: Arctic cooperation program # A10162.

**PS!**
The Svaltrack II program is *fredware*…it cost II beers.