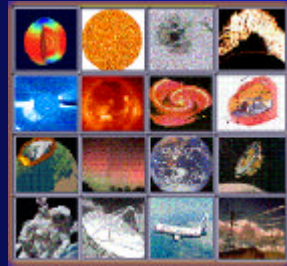


Space Weather Applications Activities in Lund



Henrik Lundstedt

Swedish Institute of Space Physics, Lund, Sweden

www.lund.irf.se

Space Weather Applications at different stages

Research and exploration stage

1) *Applications based on forecasting solar activity (i.e. the driver of space weather) and climate* (users: power and tourist industry and agriculture)

- Improved solar activity forecasts needed
- Improved solar-climate coupling knowledge needed

Implementation stage

2) *Applications based on forecasting GIC* (users: power industry)

- Integration of a current knowledge into an implementation
- Close collaboration with the users

Commercialization stage

3) *Applications based on forecasting aurora* (users: tourist industry and public)

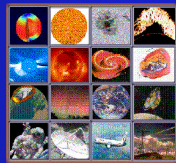
- Marketing
- Selling products

Forecasting solar activity and climate change: An application at research and exploration stage



Goal of LWS

"Develop the scientific understanding necessary to effectively address those aspects of the connected Sun-Earth system that directly affect life and society".



Highest Priority!

"Determine **how and why the Sun varies** (for assessment of past & future role in global climate change).

Identify and understand mechanisms by which solar variability affects climate (and possibly weather)" G. Withbroe

Our new research tools and approach

- Physics based neural network models
(the first of a series of papers has just been accepted GRL)
- New Wavelet transforms that can study very low S/N signals and detect new oscillations
(three papers are ongoing)

Download latest Lund Dst model in Java and Matlab (www.lund.irf.se/dst/models)

$$\frac{dDst^*}{dt} = Q - \lambda Dst^*$$

We have managed to extract new physics from this recurrent network (GRL paper).

Helioseismological results give new inputs to solar activity forecast models

$$\begin{aligned} \dot{A} &= 2DB - A, \\ \dot{B} &= iA - \frac{1}{2}i\Omega A^* - B, \\ \dot{\Omega} &= -iAB - \nu\Omega \end{aligned}$$

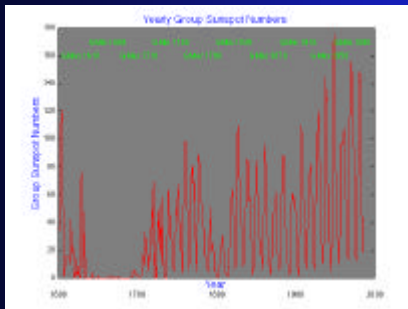
Dynamo equation, neural networks and solar input

Sunspots are footpoints of emerging magnetic flux tubes

MDI shows how the dynamo changes (1.3y)

MDI shows how magnetic elements form sunspots

Suddenly a Maunder minimum!

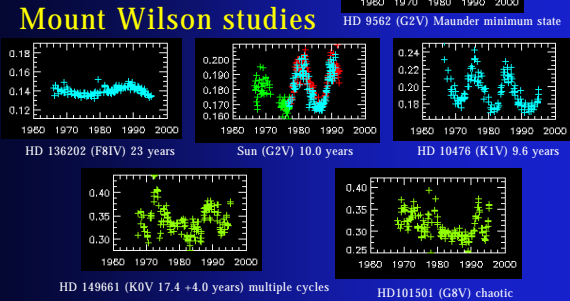


In the beginning of 1640 the sunspot number suddenly decreased to near zero.

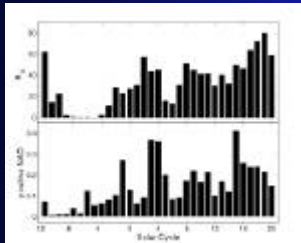
The Maunder Minimum started 1645 and ended 1715.

Rapid changes for other solar type stars

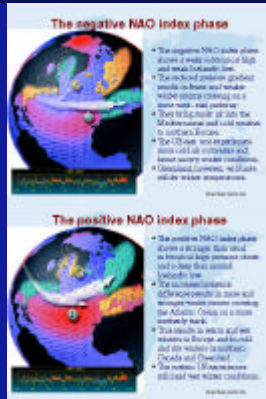
For a solar type star the luminosity decreased with 0.4% in just a few years. Similar rapid changes happened during the Maunder minimum! (compare 1640-1645!)



Solar Climate Coupling



Drew Shindell (NASA GSFC) showed that for low solar activity and herewith weak UV, the lowered ozone influences AO/NAO and results in a decrease of the temperature.



Lund during the Middle Ages and the Maunder minimum



The Danish kingdom during Knud the great (1016). During the Middle Ages Lund prospered, Lund was called the capital of Denmark (Metropolis Danica). Rich could drink excellent wine from England (e.g. from Abbey of Abingdon).

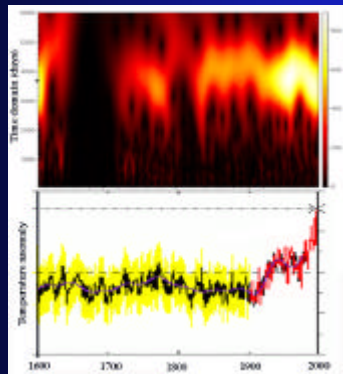
Today Bothy Vineyard, south of Oxford.



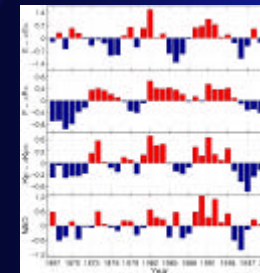
The Swedish king Karl X Gustaf looks at the ice before the crossing of the Belts 1658. The battle in Lund follows in December 4, 1676 and Lund becomes Swedish.



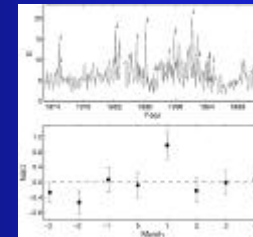
Wavelet studies of solar activity and global temperature - trends



Solar wind's effect on climate



11 ars, 1.3 variations are seen both in solar wind and NAO.



The NAO response on increased solar wind E, one month later! That might make forecasts one month ahead possible.

(GRL, Vol 29, No.15, 2002 - AGU Journal Highlight)

A user of climate forecasts

The positive NAO index phase

- The positive NAO index phase is characterized by a strong pressure gradient between Iceland and the Azores.
- The increased pressure differences result in more and stronger westerly winds bringing Atlantic air to Northern Europe.
- This results in milder winter weather in Europe and increased winter precipitation.
- The winter is generally wet and mild.

The negative NAO index phase

- The negative NAO index phase is characterized by a weak pressure gradient between Iceland and the Azores.
- The reduced pressure gradient results in weaker westerly winds and a more continental climate.
- There is less precipitation in Northern Europe.
- The US east coast experiences more severe winter weather conditions.
- Global warming, NAO shifts, and other factors may influence the NAO.

NAO and Energy in Norway

Heating Oil Consumption in Norway

- Norway experiences cold winters during a negative NAO phase.
- Heating Oil consumption in Norway rises by 20% in good (NAO) conditions with the NAO.
- Correlates with precipitation levels in variability in hydroelectric generation.

Power industry.

Our GIC Pilot Project An application at implementation stage

Real-time forecast service for geomagnetically induced currents

IRF - Real-time forecast service for geomagnetically induced currents

Local Space Weather Center / Division of Space Physics

IRF - Real-time forecast service for geomagnetically induced currents

Summary: The GIC Pilot Project is a real-time forecast service for geomagnetically induced currents (GIC) in power grids. It is based on a combination of solar wind data and a model of the Earth's magnetic field.

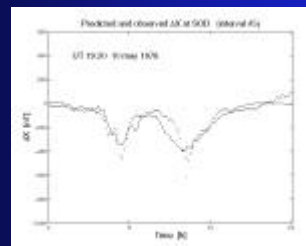
Introduction: The GIC Pilot Project is a real-time forecast service for geomagnetically induced currents (GIC) in power grids. It is based on a combination of solar wind data and a model of the Earth's magnetic field.

Forecast Models: The GIC Pilot Project uses a combination of solar wind data and a model of the Earth's magnetic field to forecast GIC. The model is based on the physical principles of electromagnetic induction.

Operational Status: The GIC Pilot Project is currently in the implementation stage. It is expected to be fully operational in the near future.

ESA logo

Forecasting local geomagnetic activity and GICs



A hybrid (MLP, RBF) neural network was applied to data from Sodankylä Geomagnetic Observatory. It was shown that 73% of the ΔX variance is predicted from solar and solar wind data as input.

Geomagnetically induced currents (GIC) can be forecasted either directly from solar wind data or via local dB_x/dt , E and σ .

Collaboration with power industry

We started to collaborate for over 20 years ago with the Swedish power company Sydkraft. Today we collaborate with all the Swedish power companies through ELFORSK. The Nordic GIC Network was established in Lund 1993. The GIC pilot project will further strengthen the collaboration, e.g. involve Norway.

sydkraft
- ett företag i E.ON koncernen

MARCH 13, 1989

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

23:00

00:00

01:00

02:00

03:00

04:00

05:00

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

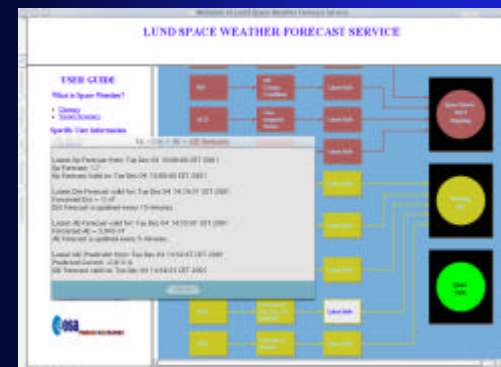
20:00

21:

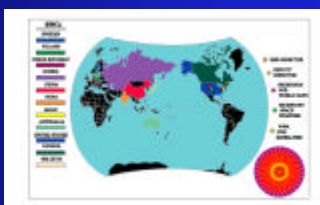
The forecast service tool to be used



Latest information on forecasts of Kp, Dst, AE and GIC

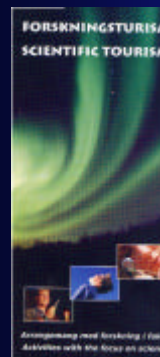


Today general forecast service is given by RWCs within ISES



ISES Director: D. Boteler
 Deputy Director: H. Lundstedt
 Sec. for World days: H. Coffey
 Sec. Space Weather: J. Kunches
 WWW for Satellites: J. King

Aurora forecasts An application at commercialization stage



Several years ago we started with Today's forecasts of aurora as SMS, voice messages from Lund.

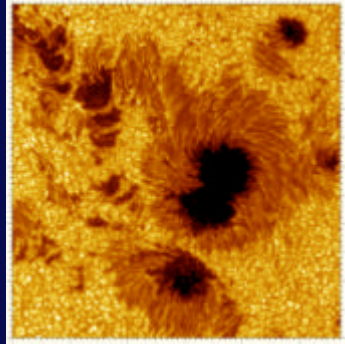
Much more service is under development.

Northern light tonight?
 Aurora forecast™
 Dial 0900-100 10 40

Kivimäki Scientific Tourism and the Swedish Institute of Space Physics have developed a northern lights forecast. Lund Space Weather Centre produces the forecasts using data from solar observation satellites.

The forecast is updated every hour between 18:00 - 24:00 and is valid for 3 hours. The forecast is delivered in English and is available from 1 September to 30 April. Calls cost 16,99 SEK/min.

The End



Sunspots observed with the Swedish solar telescope on La Palma