Forecasting Solar and Geomagnetic Activity for Atmospheric Density Models

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Acknowledgements: David Beamish, Vivette Carlaw, Toby Clark, Ellen Clarke, Mike Firth, David Kerridge, Jess King, Sarah Reay, Pam White (BGS); Roberta Mugellesi-Dow, Heiner Klinkrad, Dirk Kuijper & Rene Zandbergen (ESOC)

A full scale Envisat model in Edinburgh in 2001

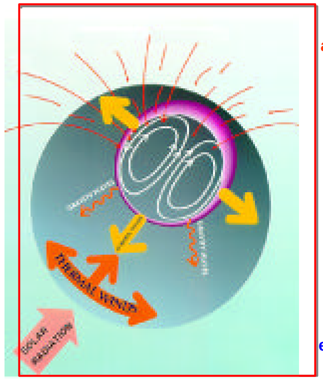
Review of a 14 year association with ESOC in long and short term solar and geomagnetic index prediction software

Brief description of the 'SOLMAG' and 'PDFLAP' algorithms and some examples of short-term forecast accuracy

Improved predictions of Ap index using neural networks and climatology: 'PDFLAP2' now in service (January 2003)

Future: Real time high-accuracy estimates of Ap, better models and better data

What ESOC Wanted



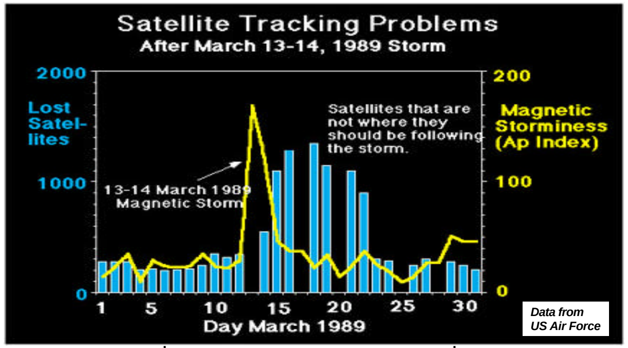
Forecasts of the Solar EUV Proxy $F_{10.7}$ and the Geomagnetic Heating Proxy *Ap*

Used in MSIS Thermospheric Density Code to Determine Frictional Drag on Low-Earth Orbit Satellites

Needed to Keep ERS-1, ERS-2 and now ENVISAT on a 1km Ground Track for High Quality Science Program

Better Forecasts and Low Drag Uncertainty = Better Orbit Management

Important for Satellite Lifetime & Re-entry Calculations, Collision Avoidance, Determining Fuel Requirements



Neutral Density Variations

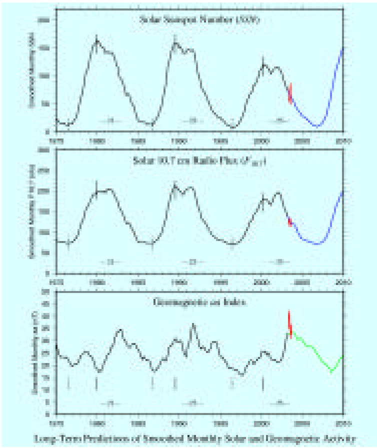
Variability (@400 km)	Factor	Time-Scale
Solar cycle	8.6	Years
Daily solar flux	1.15	Day
Geomagnetic storm	3.2	Hours

BGS Association with ESOC

Geomagnetic and Solar Activity Studies & Index Prediction Software:

- *'SOLMAG': solar cycle forecasts of monthly Ap, SSN, F10.7 (1989)*
- *'PDFLAP': 1-27 day ahead forecasts of daily Ap and F10.7 (1991)*
- *Report on potential for improving forecasts of Ap and F10.7 (e.g. solar active region correlation) and a simple satellite drag coefficient study (1993)*
- *Analysis of ERS-1 and ERS-2 thermospheric drag coefficient data: correlations with various solar and geomagnetic data and linear correction factors for Cd (2001)*
- *Review of PDFLAP prediction accuracy and development of improved prediction algorithm, 'PDFLAP2', for the Ap index (2002)*

http://www.estec.esa.nl/wmwww/wma/spweather/workshops/SPW_W3/PROCEEDINGS_W3/BGS_esoc.pdf



Forecast Models Used by ESOC

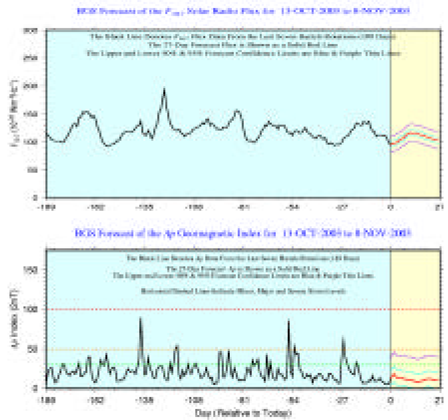
Solar Cycle Predictions

'SOLMAG'

A Modified McNish-Lincoln Method:

Forecasts of monthly departures from the long-term smoothed monthly mean curve

Similar to Marshall Space Fight Center model



BGS Forecast Models Used by ESOC

1-27 Day Solar and Geomagnetic Activity Prediction

'PDFLAP'

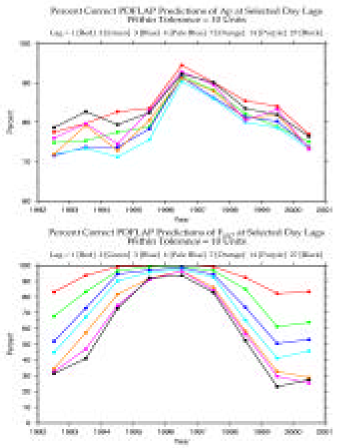
Linear Auto-Regressive Models, estimated from last 730/180 days for F10.7/Ap–model selected by experiment

60/30 Coefficients for F10.7/Ap

Model Re-computed Daily

1st and 3rd Estimated by Least Squares

ESTEC Space Weather Meeting 3-5 November 2003 http://www.geomag.bgsac.uk/ British Geological Survey



PDFLAP Performance Statistics

Accuracy to within a specified tolerance

±10 Units of Observed Value

Tolerances of better than ±10 for Ap and ±20 for F10.7 were said to be 'desirable' by ESOC

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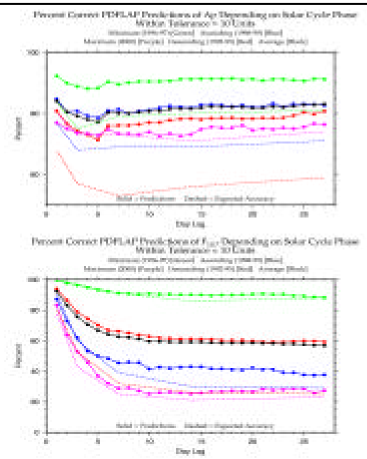

PDFLAP Performance Statistics

Accuracy compared to expected performance (from ESOC report of 1993)

Based on model tests on previous two solar cycles of data

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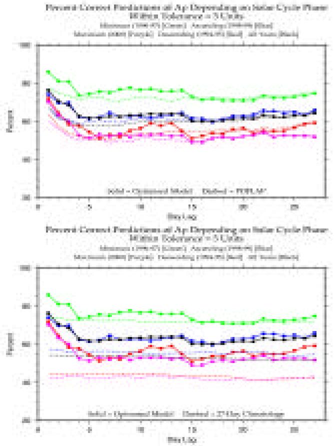
Improved PDFLAP Performance Statistics



New forecast model for Ap:

lags 1-3: neural net

lags 4-6: climatology

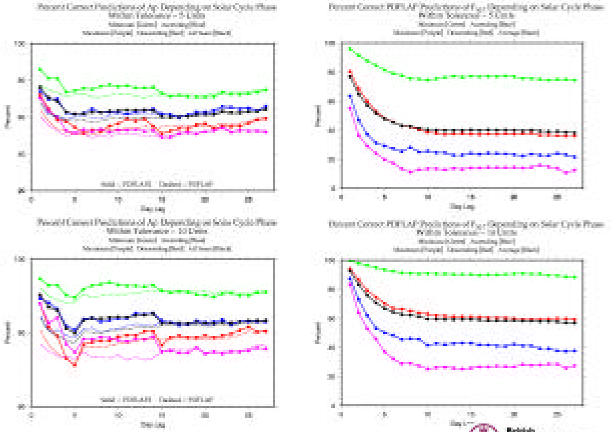
lags 7-15: PDFLAP

lags 16-27: minimum forecast between PDFLAP and climatology

Not physically based therefore needs regular checking for accuracy and relevance

No improvement suggested here for F10.7

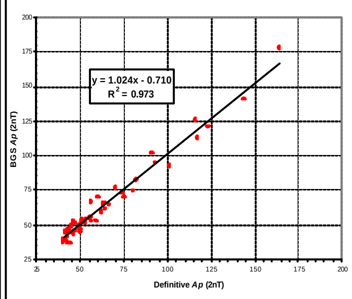
PDFLAP2 Expected Forecast Accuracy



The Future

1. Monitor prediction accuracy throughout the next solar cycle
2. Better (more appropriate) data for correlating density variations with ground based measurements:
   - E10.7 as solar EUV proxy?
   - Real time global and local geomagnetic activity indices/data, e.g. midlatitude or auroral regions (e.g. next slide)
3. Potential for modelling improvements:
   - Incorporating cusp and other localised heating effects (e.g. in CHAMP data)?
   - Calibrating the thermosphere using real time satellite data e.g. USAF (last slide)?

Real Time Ap: See poster by Ellen Clarke, Alan Thomson (BGS) and Hans Joachim Linthe (GFZ – The Official Institute for Ap)

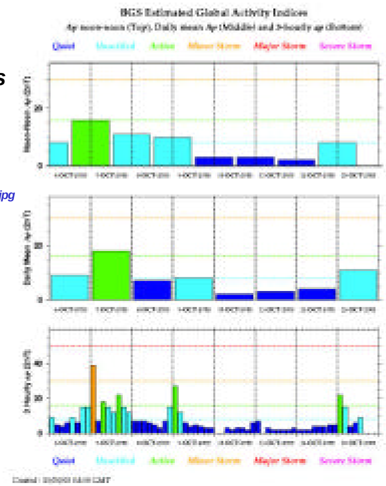


Ap (est) 1997-1999 using observatory data available by 0300 each day

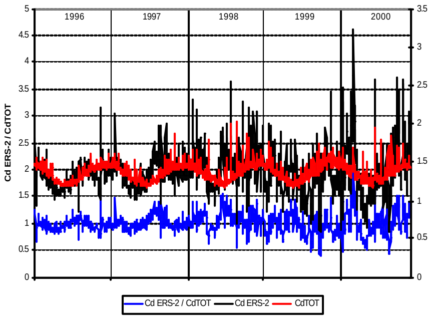
Real Time Ap Estimates

http://www.geomag.bgs.ac.uk/images/aphisto.jpg

- Can now deliver real time indices and daily forecasts of activity
- Would welcome opportunity to contribute these data to ESA programs



Using the Correlations between Satellite Drag Coefficients and Solar and Geomagnetic Data to Reduce Drag Variability



Black line is original Cd with outliers removed.

Linear regression model:

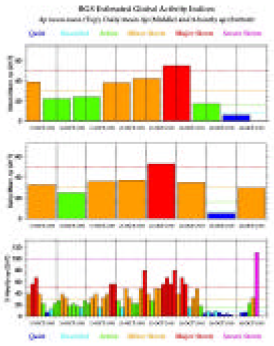
Cd_{TOT} = Cd(Ap, PCN, Dst, HPN, HPS, Solar Distance)

Blue Line is Cd/Cd_{TOT} i.e. taking into account the regression model.

Cd standard deviation is reduced to about two-thirds its uncorrected value on average and to about three-fifths during geomagnetic storms (*Ap*>40)

Poster - Ap in Real Time

Ellen Clarke (ecla@bgs.ac.uk), Alan Thomson (both at BGS, Edinburgh) and Hans-Joachim Linthe (GFZ, Postdam)



How is the Real Time *Ap* (see left) Derived?

How Accurate is the Real Time *Ap*? (see below)

Future Plans – Make Available via Swenet?

http://www.geomag.bgs.ac.uk/images/aphisto.jpg