Real-time short-term forecast of the F10.7 solar index at SIDC

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Introduction

Measurements of the solar microwave flux at 10.7 cm by Penticton Observatory, Canada are widely used as a solar proxy index for the modelling of the upper atmosphere. SIDC currently provides 3-day forecasts for the F10.7 index - based on a manual analysis of the index values during the last three Carrington rotations. We present recent results on the development of a new autonomous tool, the Self-Adjusted Solar Flux Forecasting (SASFF) (http://solwww.oma.be/users/olenapo/F10.7_realtime/). The solar radioflux dynamics is modelled by a non-stationary random walk with a variable drift - and the forecast of the F10.7 index is based on an adaptive Kalman filter model which is used to identify the a priori unknown drift and variance. SASFF provides solar flux forecasts, for the next 3 days, including forecasting uncertainties. It issues alerts when the F10.7 index values are elevated due to the appearance of solar activity events.

I. Empirical Methods used at SIDC

A. Manual SIDC Forecast

B. Persistence

C. Recurrence

D. Corrected Recurrence

E. Linear fit

Manual forecast

Same value as yesterday

with a time shift of 14 days and 27 days: value of one (or half) rotation ago

on observations of past 4 days

II. Adaptive Kalman Filtering

We developed an adaptive Kalman filtering algorithm that uses a series of daily F10.7 cm radio emissions measurements \(Z_{k} = (x_{k-1}, \ldots, x_{k-4})\), containing statistical noise, and forecasts unknown estimates of F10.7 index values \(x_{k+1} \ldots x_{k+21}\) that tend to be more accurate than those based on a single measurement. Method shows very efficient results when the deterministic laws describing the non-stationary radioflux evolution cannot be identified.

Space State Model

The sequence of F10.7 cm radioflux increments \(x_{k+1} \ldots x_{k+21}\) is characterized by a very weak correlation. Autocorrelation coefficient is \(r = 0.042\). The Figure below reveals the dynamics of radioflux increments measured from 26.04.2013-06.01.2017:

- Very small autocorrelation coefficient:
- Therefore, the dynamics of radioflux can be described well by the random walk model.

III. SASFF tool forecast

The autonomous Self-Adjusting Solar Flux Forecasting (SASFF) tool performs 3 times a day at fixed hours according the following sequence:

Retrieval of Penticton data

Correction of data and automatic email alert if any eruption

Adaptive Kalman Filtering Algorithm:

- Prediction of the next value
- Computation of associated error

Adaptive Kalman Filter Algorithm

Algorithm efficiency

- Persistence

Forecasting (SASFF)

Manual SIDC Forecast

Mean Error

Day1

Day2

Day3

-1.5

-1

0

1

5

10

15

Manual SIDC Forecast

IV. Forecasting Validation

Characteristics of forecasting errors

- RMS values with their uncertainties. Automatic corrections of the atmospheric drag coefficients will be given and alerts will be issued for sudden index increases attributed to solar flare occurrence. SASFF outputs are expected to contribute to navigation and aviation services.

V. Summary and Perspectives

Advantages of SASFF tool forecasting versus SIDC manual forecast

- Higher precision of forecasting
- Automation of forecasting procedure
- Method provides forecasting errors simultaneously with the forecast
- Method of adaptive for F10.7 index forecast allows correction of the forecasting values using a additional measurements

Perspectives:

SASFF tool will be calibrated using solar radioflux measurements of several radio-observatories and further optimized to provide uninterrupted forecasts of the F10.7 index values with their uncertainties. Automatic corrections of the atmospheric drag coefficients will be given and alerts will be issued for sudden index increases attributed to solar flare occurrence. SASFF outputs are expected to contribute to navigation and aviation services.

REFERENCES

- A. Devos, C. Verbeeck, E. Robbrecht, Verification of space weather forecasting at the Regional Warning Center in Belgium. SWSC, 4 (2014) A29
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Figure reveals that exponential smoothing of the radioflux increments makes possible to define their short term trends and improve the predictable power of the Kalman filter.

Figure reveals that forecasting errors strongly depend on the solar cycle phase. Forecasting errors are small during solar minimum epoch and large during solar maximum period.

Dynamics of root mean square errors (RMS) of forecasts as the function of solar cycle evolution.