Correlation study and time-lag analysis between cosmic ray intensity and solar activity parameters at different geomagnetic cutoff rigidities

A. Mubashir*, A. Ashok**, E. H. Mudiyanselage*, E. Potdevin*, T. Hettiarachchi*, V. M. Sadykov*, X. He*,

* Department of Physics and Astronomy, ** Department of Computer Science, Georgia State University

Abstract

Variations in solar activity cause cosmic ray flux changes at different temporal scales and geopositions. Our aim is to determine the correlation and cross-correlation time lag between various space parameters and cosmic ray muon counts from two detectors installed at different geomagnetic positions (one in Atlanta, Georgia and the other at Mt Wilson, California, USA). These two detectors are part of the worldwide network of low-cost and portable cosmic ray muon detectors which is under development at Georgia State University for monitoring the space and terrestrial weather at a global scale. To validate our findings, we compare the muon flux measurements with measurements from the Oulu neutron monitor at low cutoff rigidity. The parameters under consideration include sunspot number, solar wind plasma, the interplanetary magnetic field, the Kp index, and the Dst index. Our results indicate significant correlations between cosmic ray intensities at different geomagnetic cutoff rigidities and the space activity parameters. Additionally, our time-lag analysis, employing cross-correlation techniques, aligns well with previously reported findings.

Introduction and Motivation

Space Weather Impact
- Can produce geomagnetic storms
- Can cause radio and GPS blackoutsand damage spacecraft electronics
- Can increase radiation exposure at aviation altitudes
- Can provide a potential danger for space exploration

GSU developed Detectors on World Map

- Monitor changes in Space and Earth weather using cosmic ray flux measurements simultaneously around the world
- Correlation between muon counts and space parameters is essential for better understanding and mitigating the impacts of space weather on spacecraft, astronauts, and terrestrial infrastructure.

Detector Setup

The distance between Layer 1&2 is the same as 2&3, which is 13 cm apart.

Muon telescope   4Paddle detector

"Muon Telescope" is part of Global Network of Cosmic Ray Detectors for Space and Terrestrial Weather Observation (gLOWCOST)

Results: Correlation and Time-Lag Analysis

Fig1: (a) General Trend of cosmic flux percentage change and space parameters from 2019-2024

Fig1: (b) Cross correlation using time lag analysis for Oulu and Atlanta Detecto from 2019-2024

Fig1: (c). Cross correlation for Oulu, Atlanta and Mt. Wilson detectors using time lag Analysis from 2022-2024

Cross Correlation for Bartel's Rotation

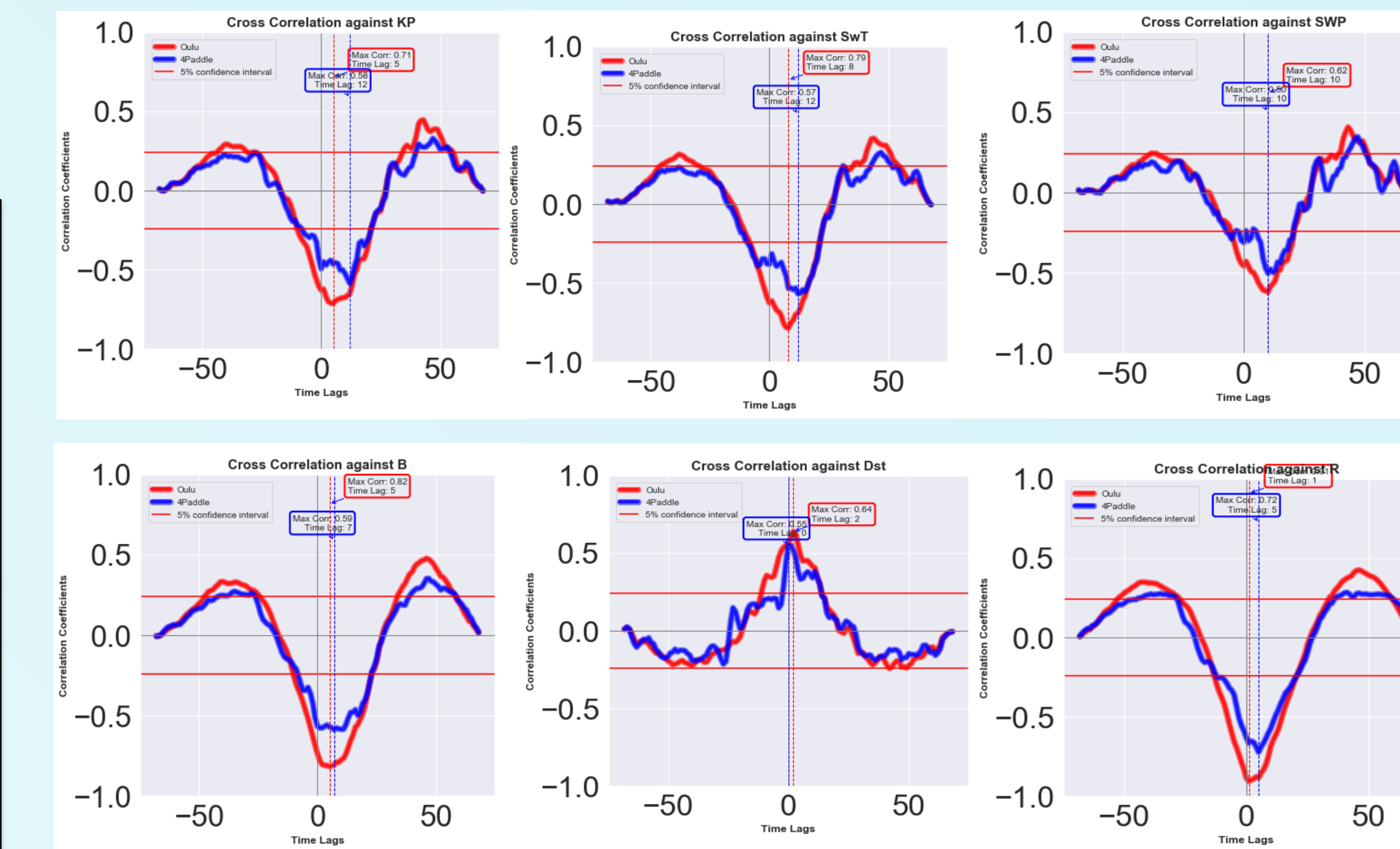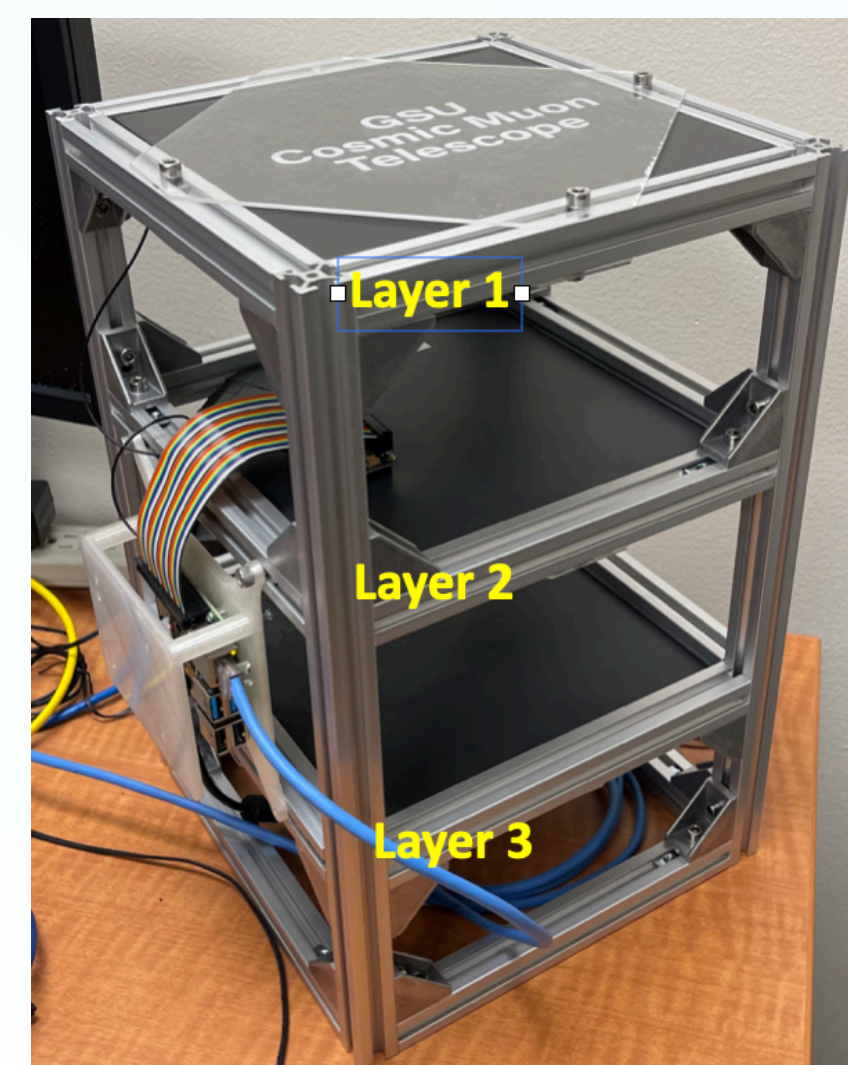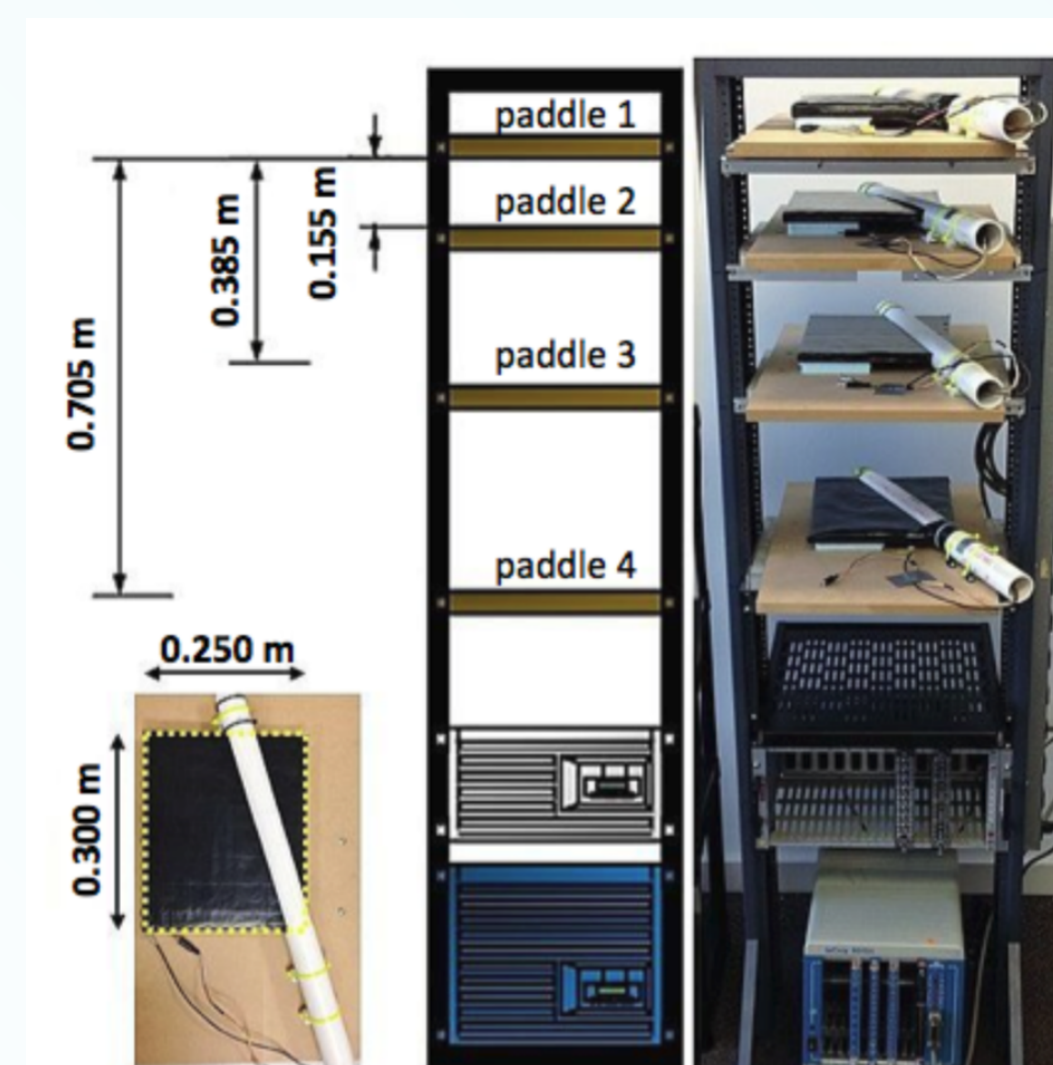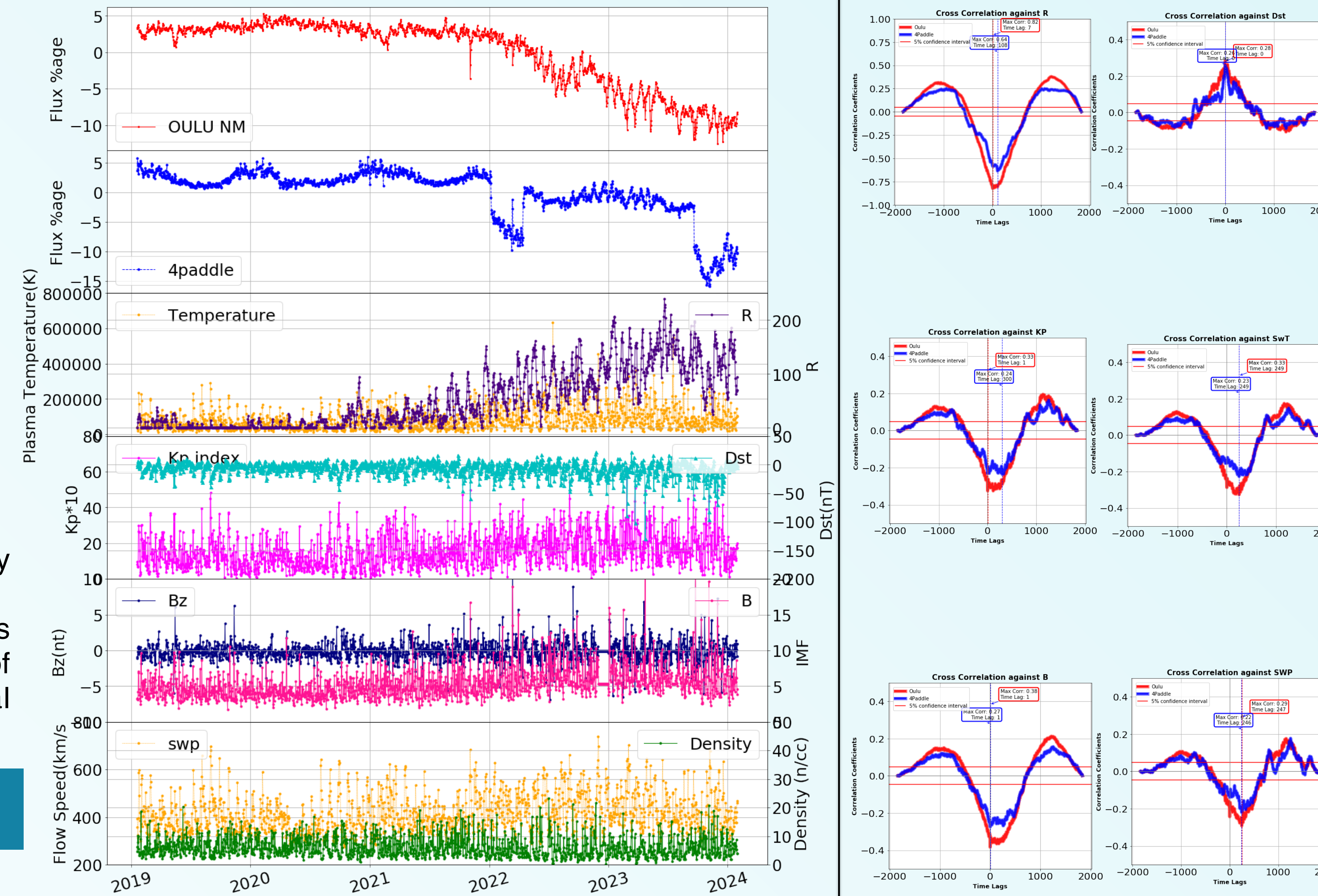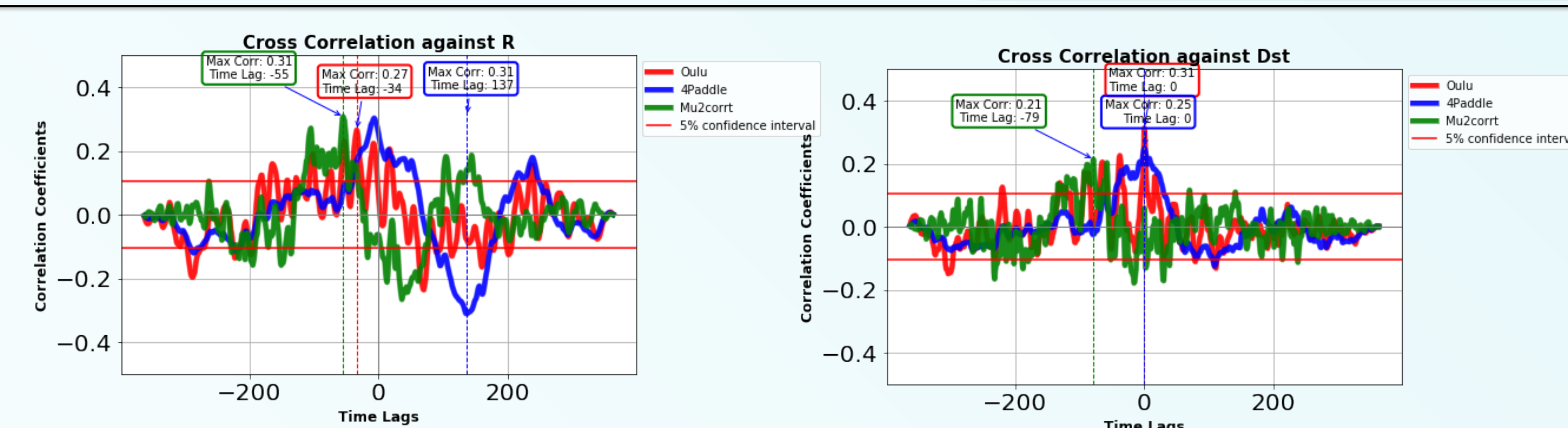Bartels' Rotation Number: count of apparent Sun rotations from Earth, each lasting 27 days,

Fig2: Cross correlation using time lag analysis for one Bartel's rotation
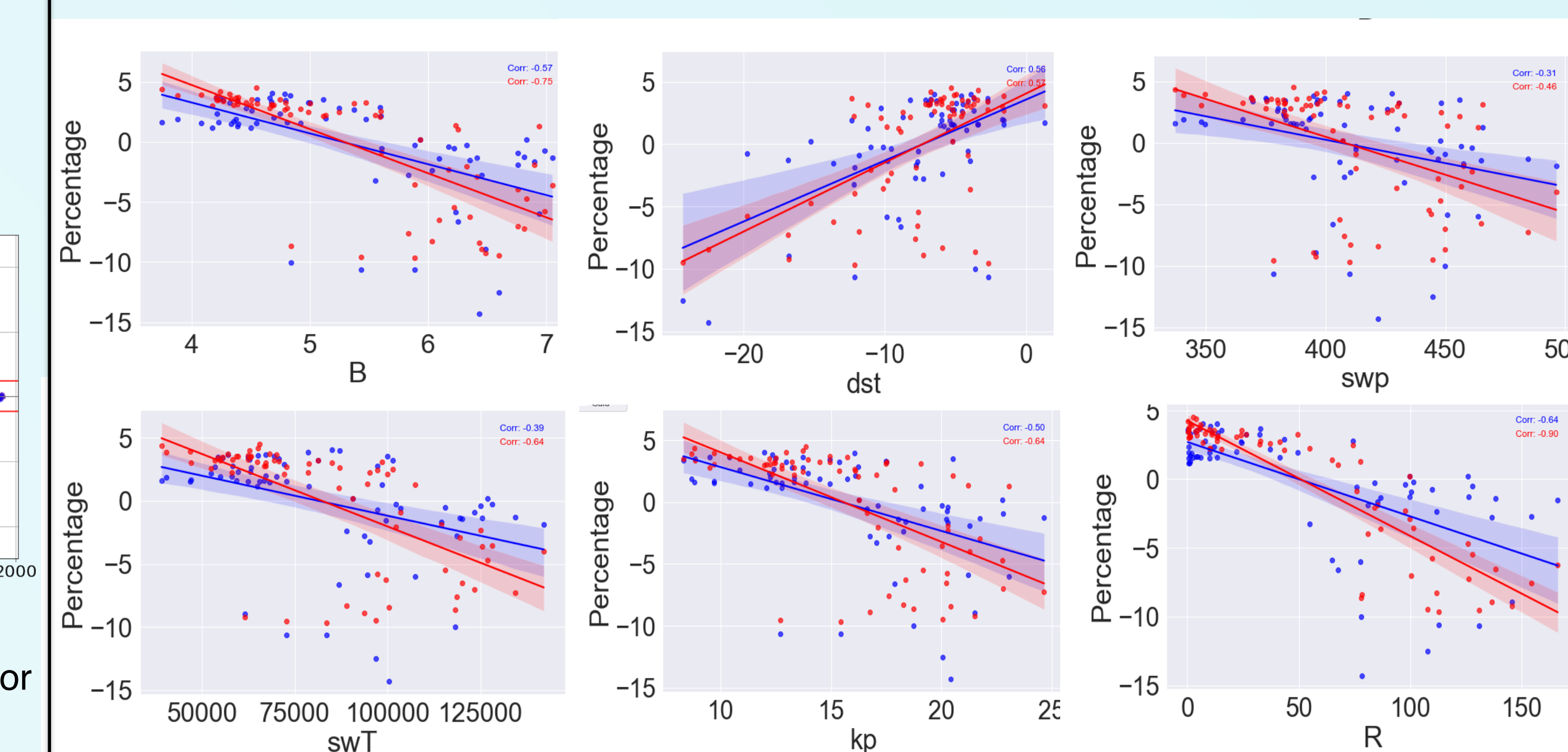
Scatter Plots

Fig3: Correlation Analysis with no time lag (scatter plots/regression analysis)

Summary and Outlook

- Time-lag cross-correlation analysis between CR values and considered variables showed similar results to previous investigations.
- Further studies can be done for multi variable regression analysis
- Predictive modeling for space weather and earth weather studies
- Global data from detectors worldwide
- Analyzing extensive datasets
- National and International collaboration