Long-Term Datasets for the Understanding of Solar and Stellar Magnetic Cycles
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Solar-Cycle variation in the photospheric mean velocity flows: GONG observations

Brajesh Kumar

Udaipur Solar Observatory, Physical Research Laboratory,
Dewali, Badi Road, Udaipur 313004, Rajasthan, India
email: brajesh@prl.res.in

Abstract. The solar oscillation frequencies have shown variation over the solar activity cycle, which is believed to be the indicator of the structural and magnetic changes taking place in the Sun. The ground-based network of six identical solar telescopes in the Global Oscillation Network Group (GONG) program has been nearly-continuously observing the Sun since the last quarter of the year 1995 for Doppler imaging of the solar-disk aimed to study the oscillations and velocity flows on the surface of the Sun. In this work, we study the variations in the solar disk-integrated mean velocity flows on the solar surface as observed with the GONG over the complete Solar Cycle 23 and ongoing Cycle 24. The correlation analysis of these solar photospheric mean velocity flows relative to the various solar activity indicators is also discussed.

Keywords. Sun: activity, Sun: photosphere, Sun: atmospheric motions

1. Motivation

The global oscillations (or, p-modes) of the Sun are believed to be stochastically excited due to the high turbulence in the convection zone of the Sun (Leibacher & Stein 1971). The p-mode frequencies vary with the solar activity cycle and usually they have shown good correlation with the various solar activity indicators (Jain *et al.* 2009). However, these resonant mode frequencies have shown anti-correlation with the activity indicators during the deep unusual minimum at the end of Cycle 23 (Tripathy *et al.* 2010). The solar photospheric Dopplergrams consist of signals from the p-mode oscillations, supergranular flows, solar rotation gradients, meridional circulations, as well as velocity flows due to the various dynamic features on the solar surface. Here, we study the variations in the solar disk-integrated mean velocity flows on the solar surface for the complete Solar Cycle 23 and ongoing Cycle 24.

2. The Observational Data

The Global Oscillation Network Group (GONG; Harvey *et al.* 1995) consists of six identical solar telescopes located around the globe for near-continuous observations of the Sun mainly aimed for Helioseismology. We have used the site-merged solar full-disk photospheric Dopplergrams obtained from the GONG instrument covering the different phases of the Solar Cycle 23 and 24. The data from the GONG observations used in this study comprise of the following two epochs:
GONG-classic: 1 January 1996 - 31 May 2001 (spatial scale ∼8 arc-sec per pixel)
GONG+: 1 August 2001 - 14 August 2017 (spatial scale ∼2 arc-sec per pixel)

We have also used the daily sunspot number, solar disk-integrated daily 10.7 cm radio flux, and daily averages of total solar irradiance for the Solar Cycle 23 and 24 to perform

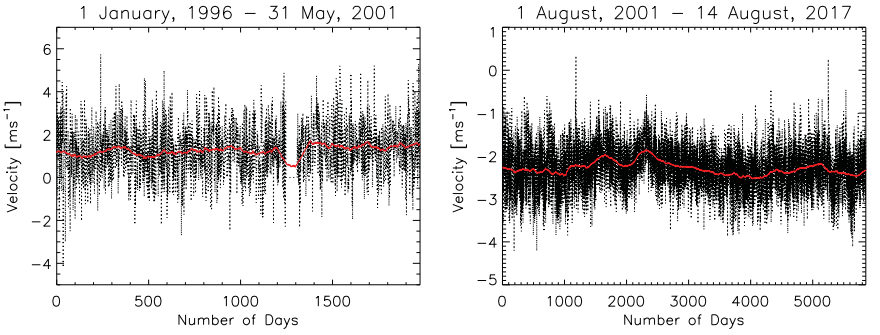

Figure 1. Temporal evolution of daily disk-integrated photospheric mean velocity flows (black dashed lines) as observed with GONG-classic (left panel) and GONG+ (right panel) instruments covering the different phases of Solar Cycle 23 and 24. The red solid lines show a smoothed fit applied to these velocity signals to illustrate the mean level of changes over the aforementioned period. The zero values indicate discontinuity in the observations.

the correlation study between the evolution of mean velocity flows and the solar activity indices.

3. Analysis and Results

The disk-integrated photospheric velocity signals from the site-merged full-disk GONG Dopplergrams have been used to study the variations in the mean velocity flows on the solar surface over the solar activity cycle. It is to be noted that the solar rotation signals are removed in these site-merged Doppler images. In Fig. 1, we show the temporal evolution of daily mean velocity flows over the Solar Cycle 23 and 24 using the Doppler observations from GONG-classic and GONG+. We observe changes in the mean levels of these velocity signals during the different phases of the solar activity cycle. Hence, we have performed correlation analysis between these daily values of velocity signals and the different solar activity indicators. The preliminary results of correlation analysis do not show a substantial correlation between the changes in the mean surface velocity flows and the various solar activity indices. The lack of correspondence between the evolution of solar surface mean velocity flows and the various activity proxies over the solar cycle is being further investigated.

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