First near-continuous monitoring of NOAA 13664 from emergence to decay: magnetic field evolution, complexity parameterization and flaring output

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Between April and August 2024, the Solar Orbiter mission monitored a significant portion of the Sun's far side, enabling near-continuous tracking of one of the most complex active regions ever recorded—from emergence to decay. We combined full-disk line-of-sight magnetograms from SO/PHI and SDO/HMI to construct a 94-day time series of deprojected maps of the line-of-sight magnetic field of NOAA AR 13664 and its follow-ups, NOAA 13697 and 13723. This dataset was complemented by EUV coronal imaging from EUI/FSI and AIA (171/174 Å), along with flare detections from STIX and GOES. The region evolved into an extremely complex configuration due to repeated flux emergence events, reaching peak complexity roughly one month after its initial appearance. This was followed by a prolonged, gradual decay phase lasting about six weeks, during which sporadic flux emergence continued, and subsequently by a more rapid decay that led to the region's disappearance. Flaring activity was exceptionally intense near the peak phase, with multiple X-class flares culminating in an X16 event. Although flare output decreased significantly afterward, it remained elevated for over one month before dropping sharply during the final two weeks. Using the combined magnetogram data, we derived time series of four non-potentiality parameters—the longest such dataset to date for a single active region. Despite originating from two different instruments, the parameter values are consistent, capturing the region's full evolution and showing strong correlation with the flare index. These results highlight the critical role of multi-vantage-point observations in understanding the evolution of the magnetic field during flux emergence and the causes of active region eruptivity.