# Data-driven Radiative Magnetohydrodynamics Simulations with the MURaM code

Feng Chen[1], Mark Cheung[2], Matthias Rempel[3], Georgios Chintzoglou[4]
[1] School of Astronomy and Space Science, Nanjing University, [2] CSIRO,
[3]High Altitude Observatory, National Center for Atmospheric Research,
[4]Lockheed Martin Solar & Astrophysics Laboratory
e-mail (speaker): chenfeng@nju.edu.cn

Radiative magnetohydrodynamic simulations account for the radiative and conductive energy transport in the solar atmosphere (usually incorporated with a realistic equation of state). With these treatments in the energy equation, the model and synthetic observations have a sufficient degree of realism to be compared quantitatively with real observations and reveal the connection between crucial structure for solar eruptions and their observable counterpart. This method has successfully modeled, for example, fine structures of sunspots[1], emergence of magnetic flux[2][3], heating of the solar corona[4][5][6], as well as in solar flares[7], respectively.

Meanwhile, investigating a particular eruption event or a particular active region (e.g., those are extremely flare-productive) is a primary focus in the field of the solar physics. However, the one-to-one connection between a "**realistic**" active region model as mentioned above and a **real** solar active region has been largely omitted in the past. To bridge this gap, we developed a method of conducting data-driven simulations of solar active regions and flux emergence with the MURaM code[8].

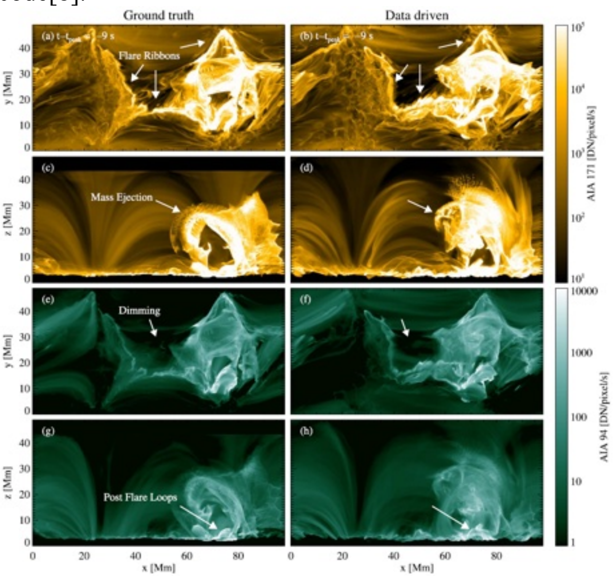


Figure 1: A comparison between the synthesized AIA observations of the eruption in the ground truth simulation and those in the data-driven simulation.

To validate the method, the photospheric data from a comprehensive radiative MHD simulation of solar eruption[7] (the ground truth) are used to drive a series of numerical experiments. The data-driven simulation reproduces the accumulation of free magnetic energy and the time of the eruption in the ground truth simulation and captures key eruption-related emission features and plasma dynamics. Recently, this method has been applied on actual active regions including well-know flare-CME productive AR11158. We also employ this method on non-eruptive emerging active region, which allows us to study the formation and evolution of active region coronal loops.

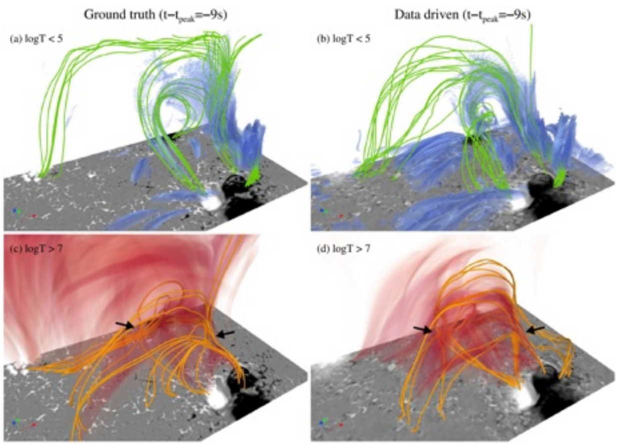


Figure 2: A comparison between the magnetic structures that are responsible for the eruptions in the ground truth and data-driven simulations.

References

[1] Rempel, M. & et al., 2009, ApJ, 691,640
[2] Cheung, M. C. M. & et al., 2010, ApJ, 720, 233
[3] Chen, F. & et al., 2022, ApJ 937, 91
[4] Gudiksen, B. V. & Nordlund, A., 2005, ApJ, 618, 1020
[5] Hansteen V. & et al., 2015, ApJ, 811, 106
[6] Rempel, M., 2017, ApJ, 834, 10
[7] Cheung, M. C. M. & et al., 2019, Nature Astronomy, 3, 160
[8] Chen. F. & et al., 2023, ApJ, 949, 11