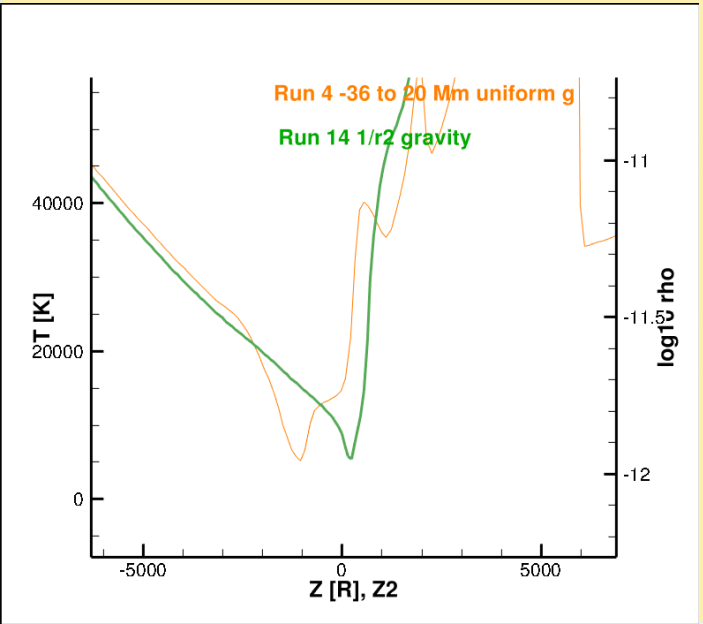
Simulating Solar Active Regions

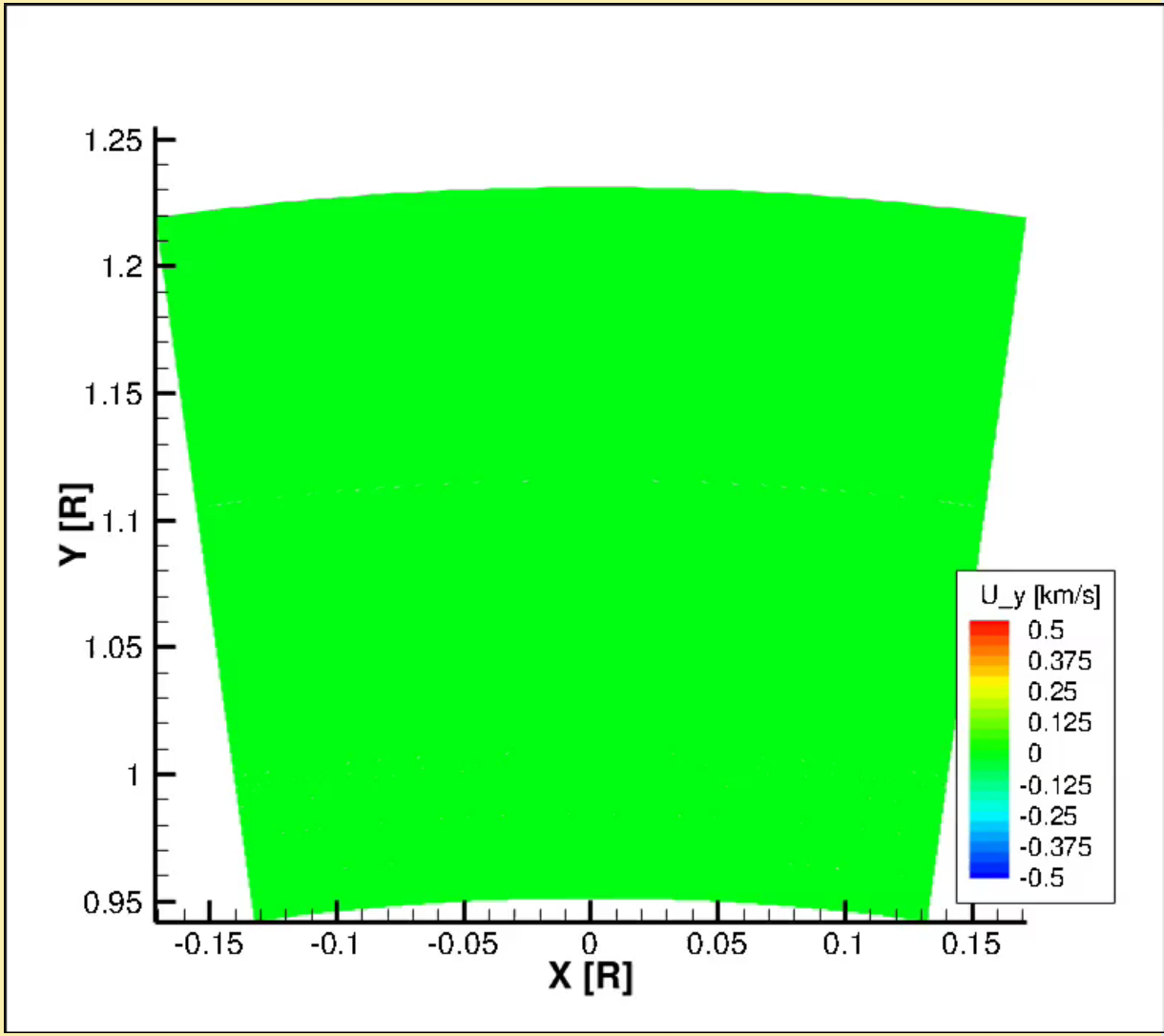
Chip Manchester, Bart van der Holst, and Gabor Toth

Atmospheric, Oceanic and Space Sciences
University of Michigan

Spherical Wedge Active Region Model (SWARM)

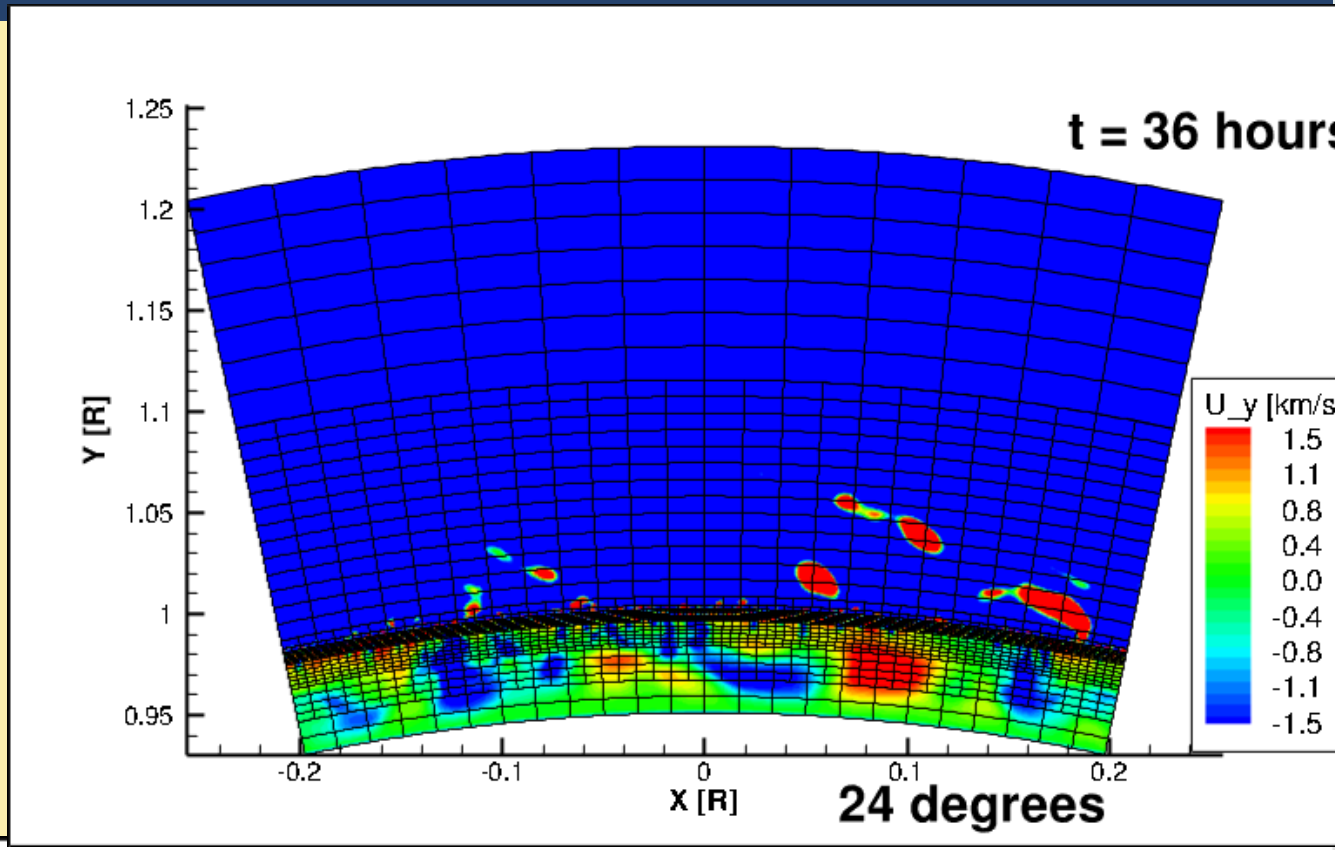
- Spherical Wedge
- Gravity 1/r^2 R
- Tabular EOS ionization
- Radiation: Abbett 2007
- 35 Mm deep (0.95 Rs)
- 5 levels of refinement
- 10x10x10 cell blocks

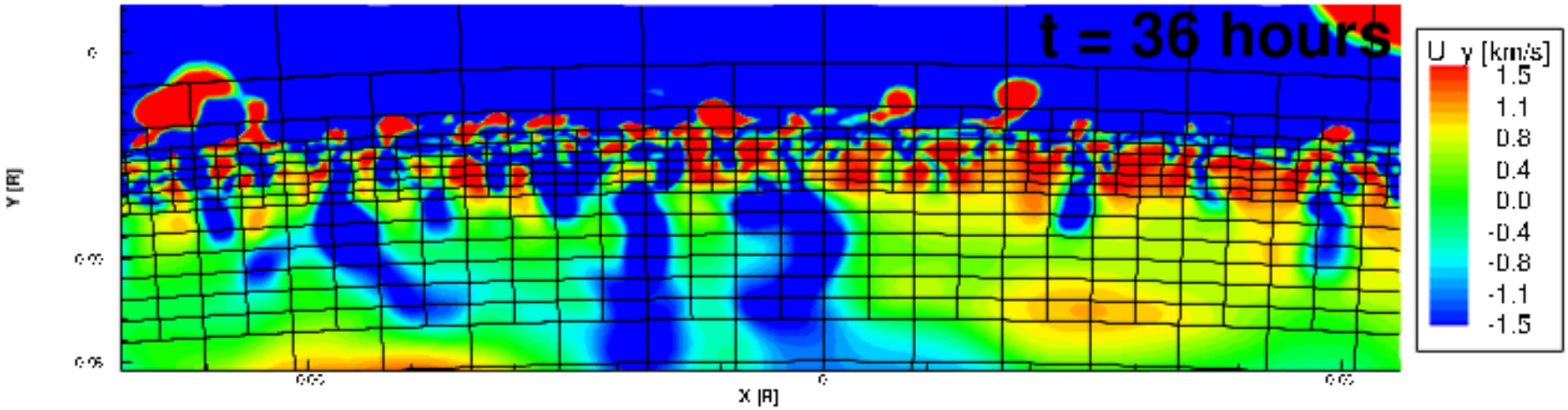




SWARM on Blue Waters

- 35 Mm deep (0.95 Rs)
- 150x300Mm (12x24 deg) Largest Ever
- 5 levels of refinement
- 160 million cells
- 3 million time steps ~10 million CPU hours

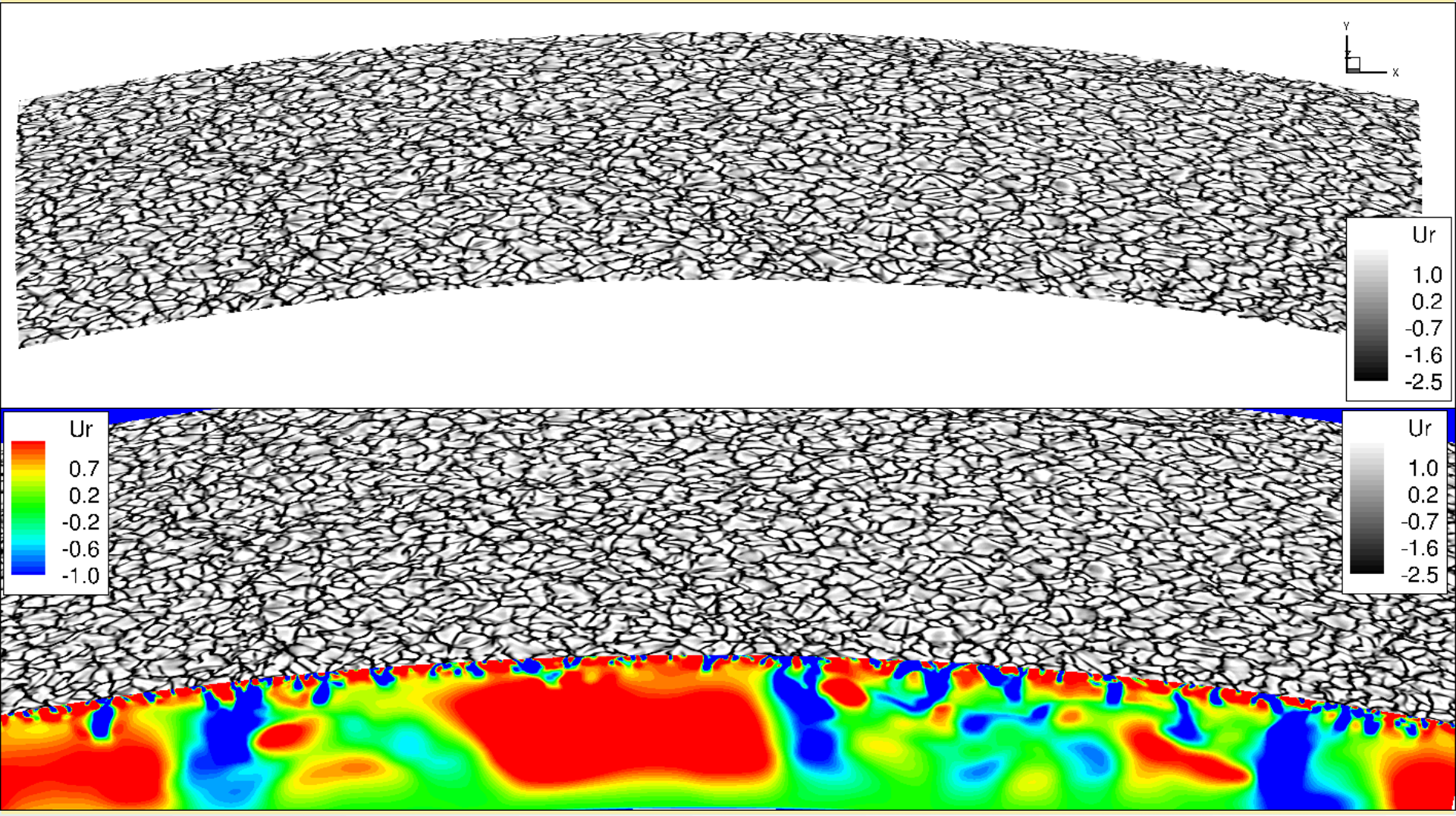




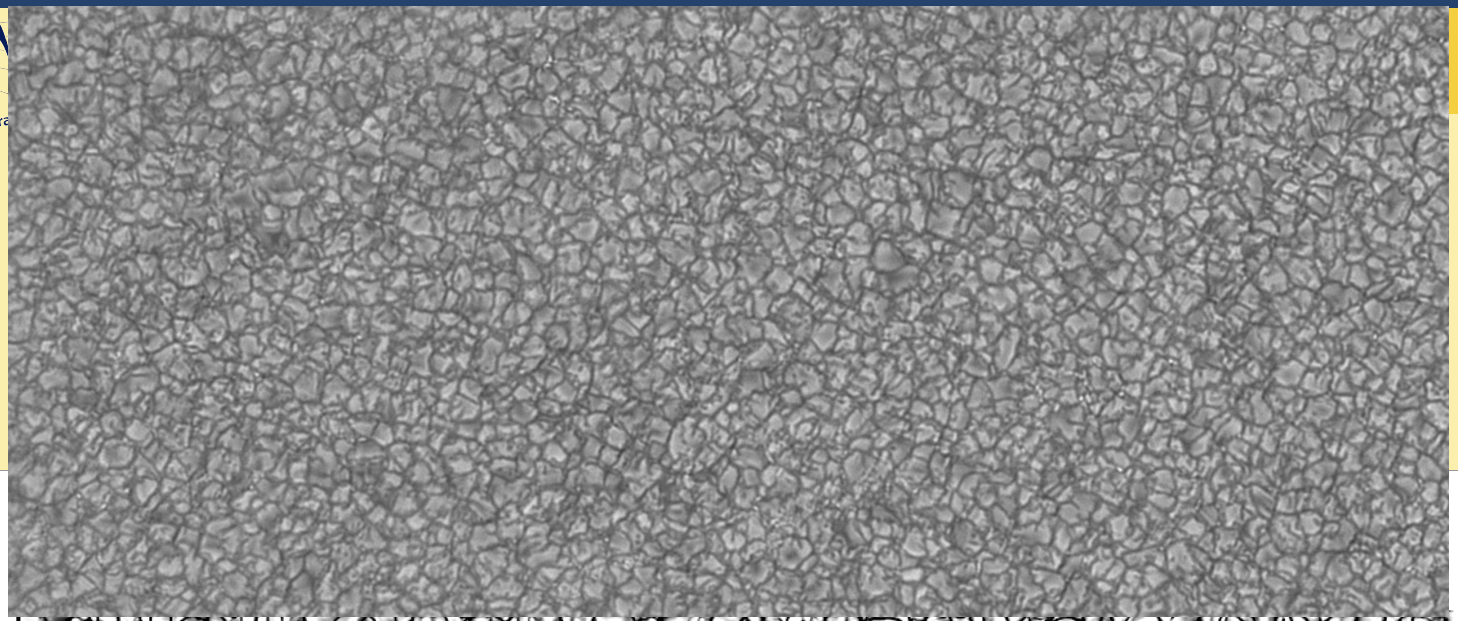
SWARM on Blue Waters

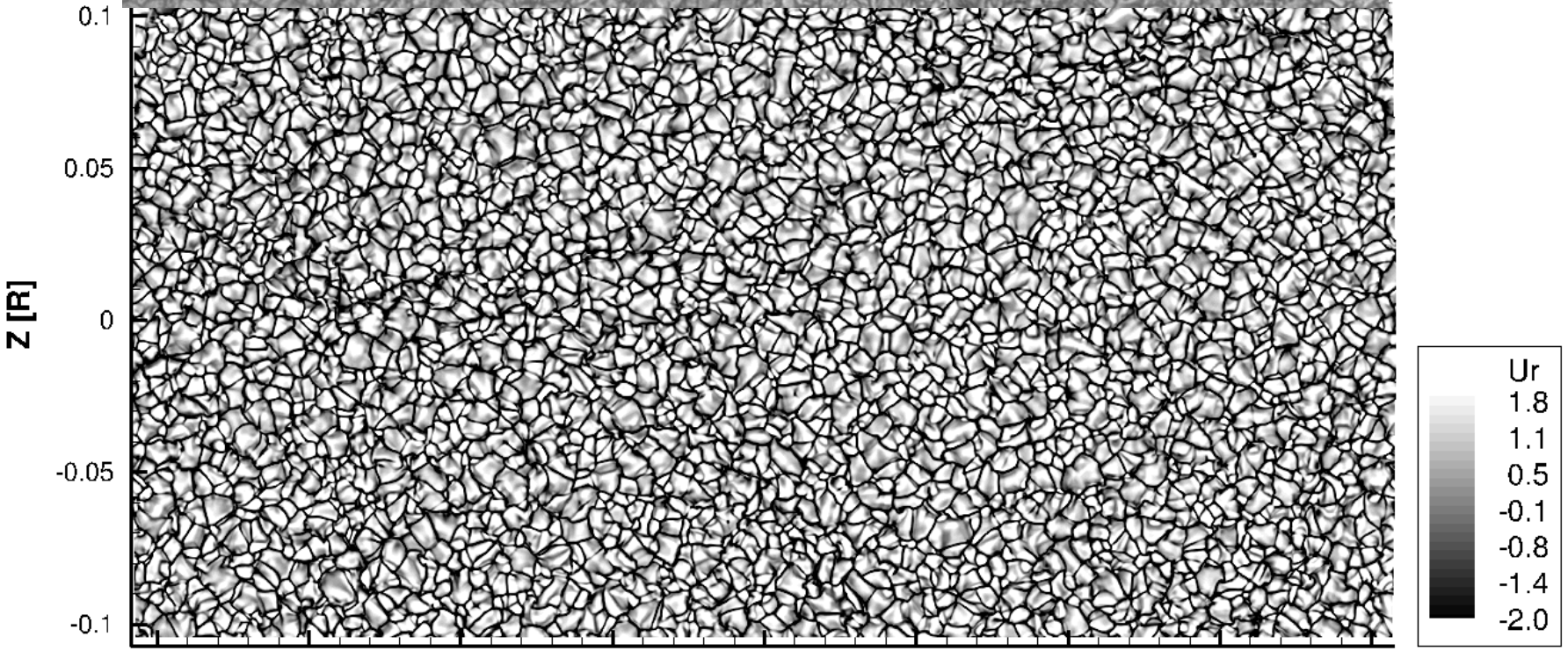
12x24 deg (150x300 Mm) Largest Scale Simulation of Near-Surface Solar Convecion in Spherical Geometry

Gray: photosphere Ur Color: radial slice Ur



Top: Observed solar granulation Bottom: SWARM on BW



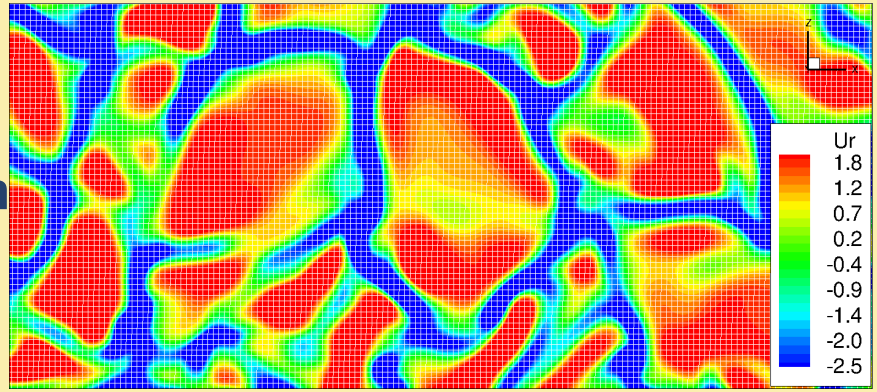


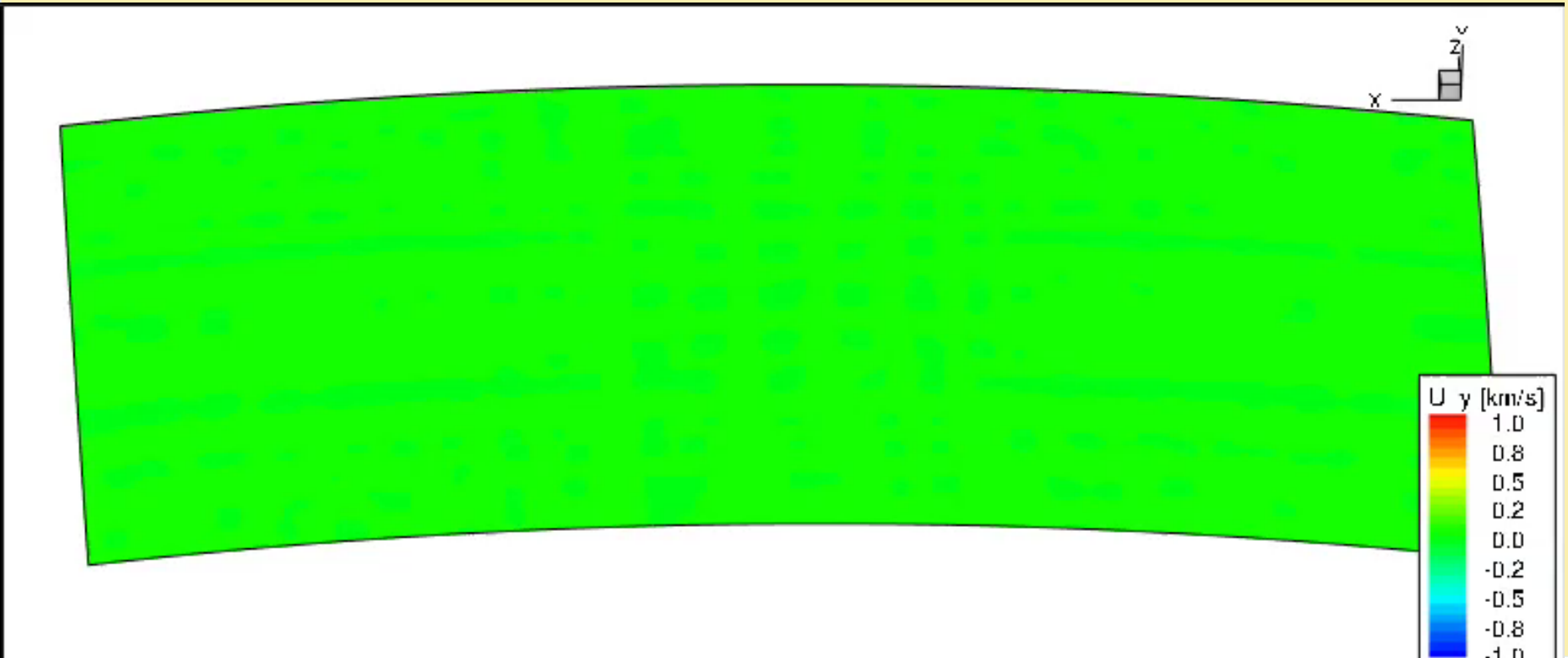
Spherical Wedge Active Region Model (SWARM)

Space Weather Modeling Framework

- Right: Photospheric granulation
- Bottom: Large-scale deep convection

Granule size scale with temperature

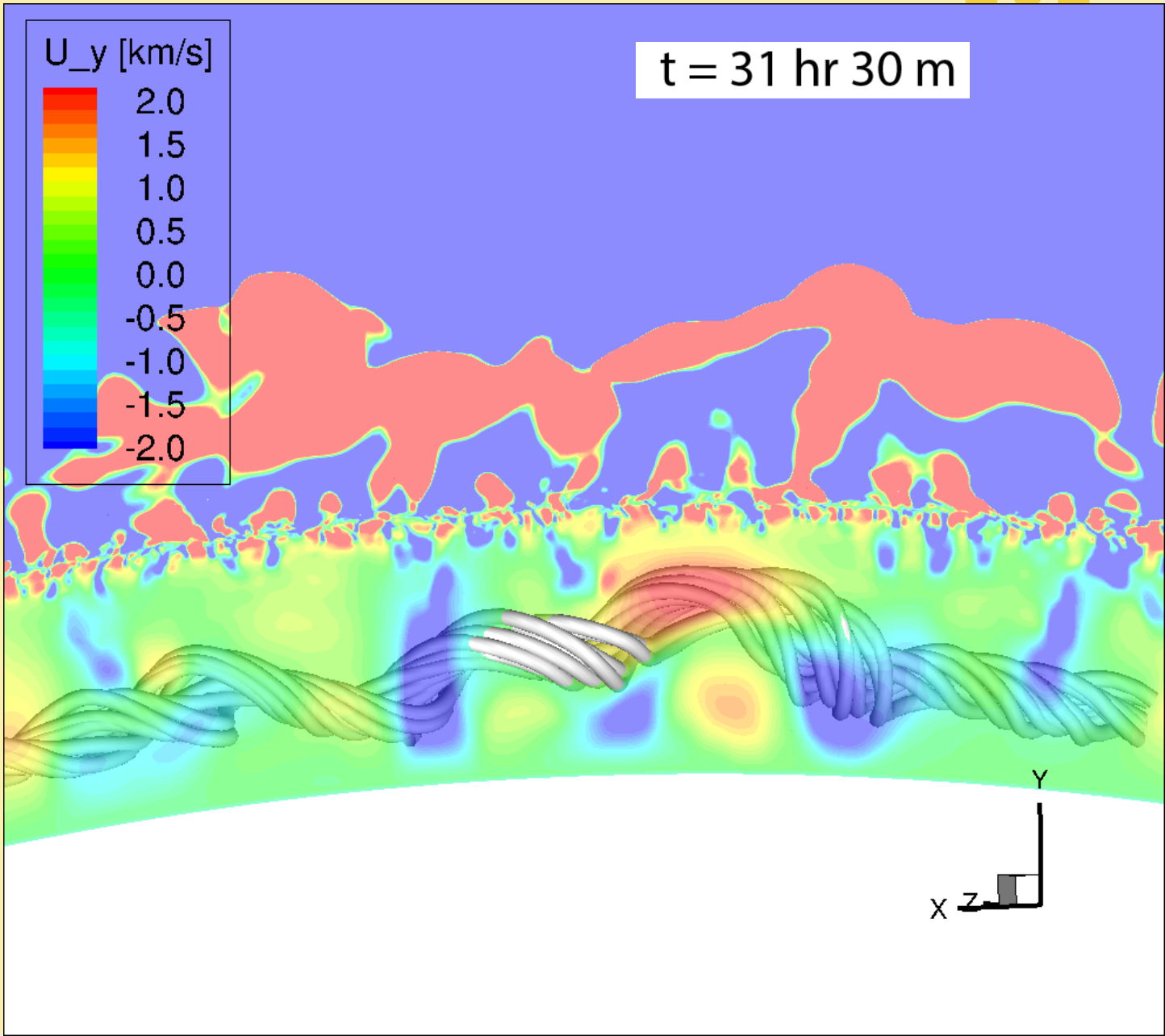




Active Region Scale Flux Emergence Simulation

Space Weather Modeling Framework

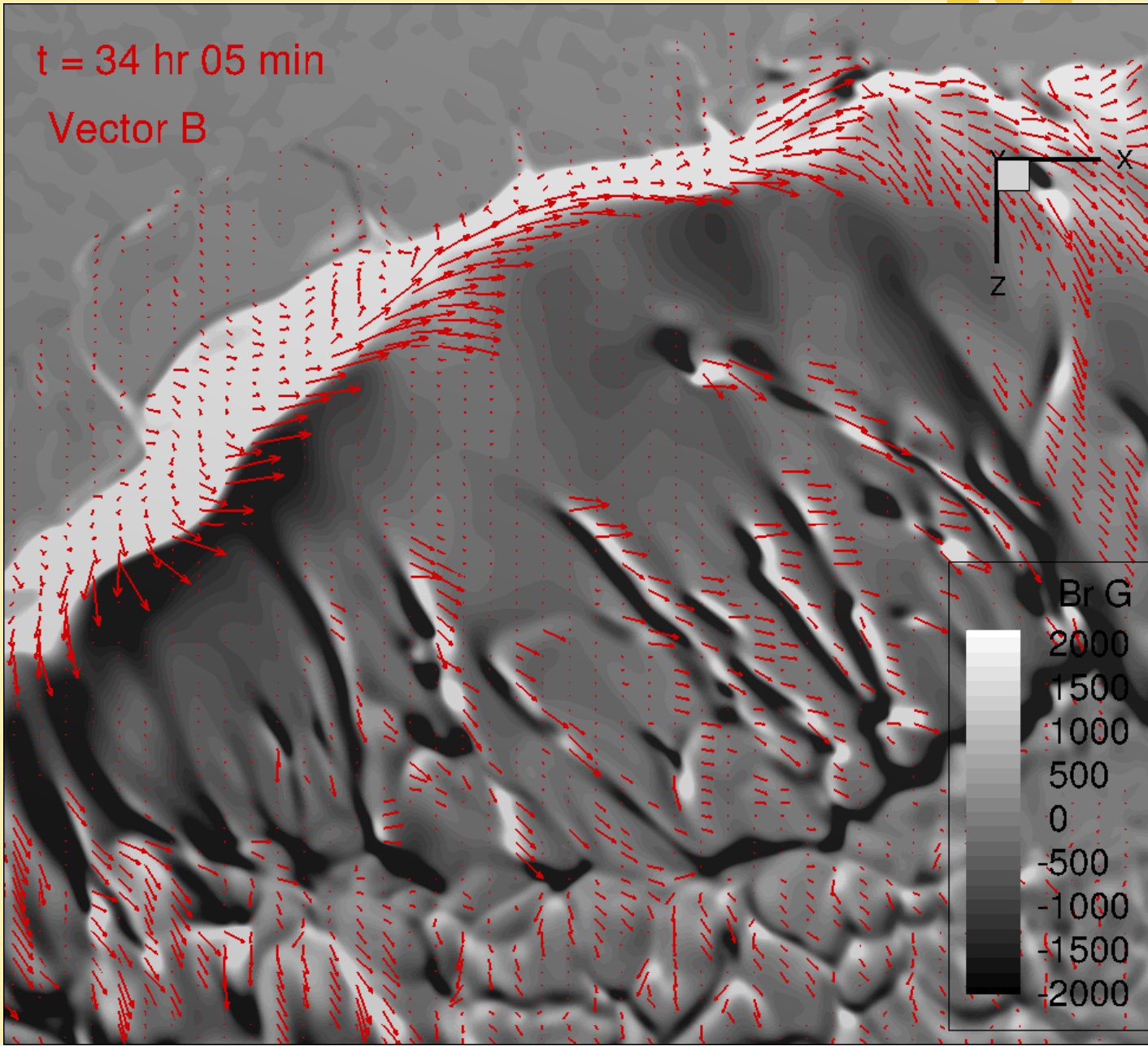
- Toroidal Rope
- 20 Mm deep (0.9714 Rs)
- 10^{23} Mx flux
- Twist factor =1



Photospheric Signatures of Flux Emergence

Space Weather Modeling Framework

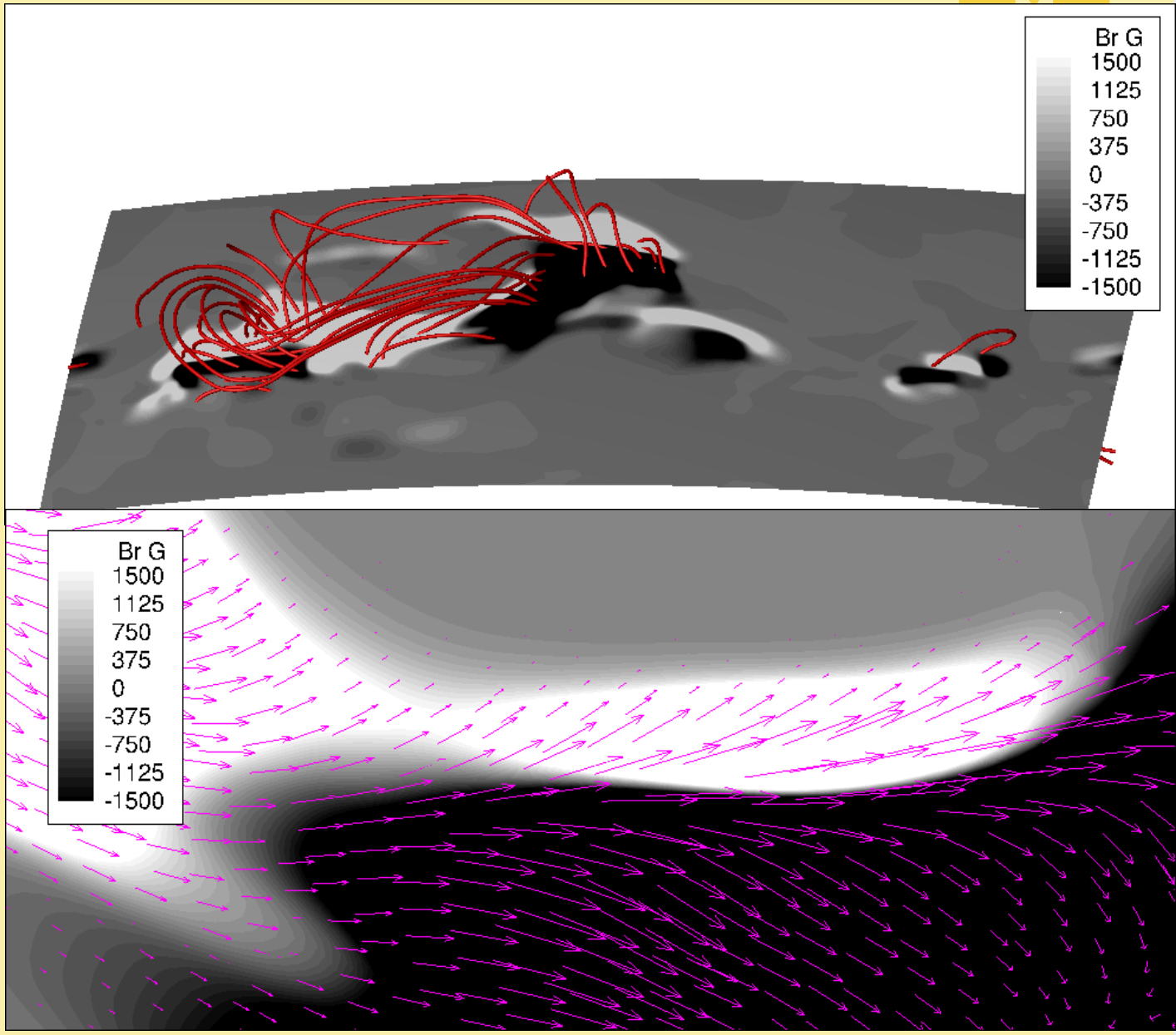
- R = 1 Rs
- Flux confined in downdrafts
- Magnetic field fragmented by small-scale convection
- Magnetic field evolves parallel to polarity inversion line
- Shear flows driven by the Lorentz force



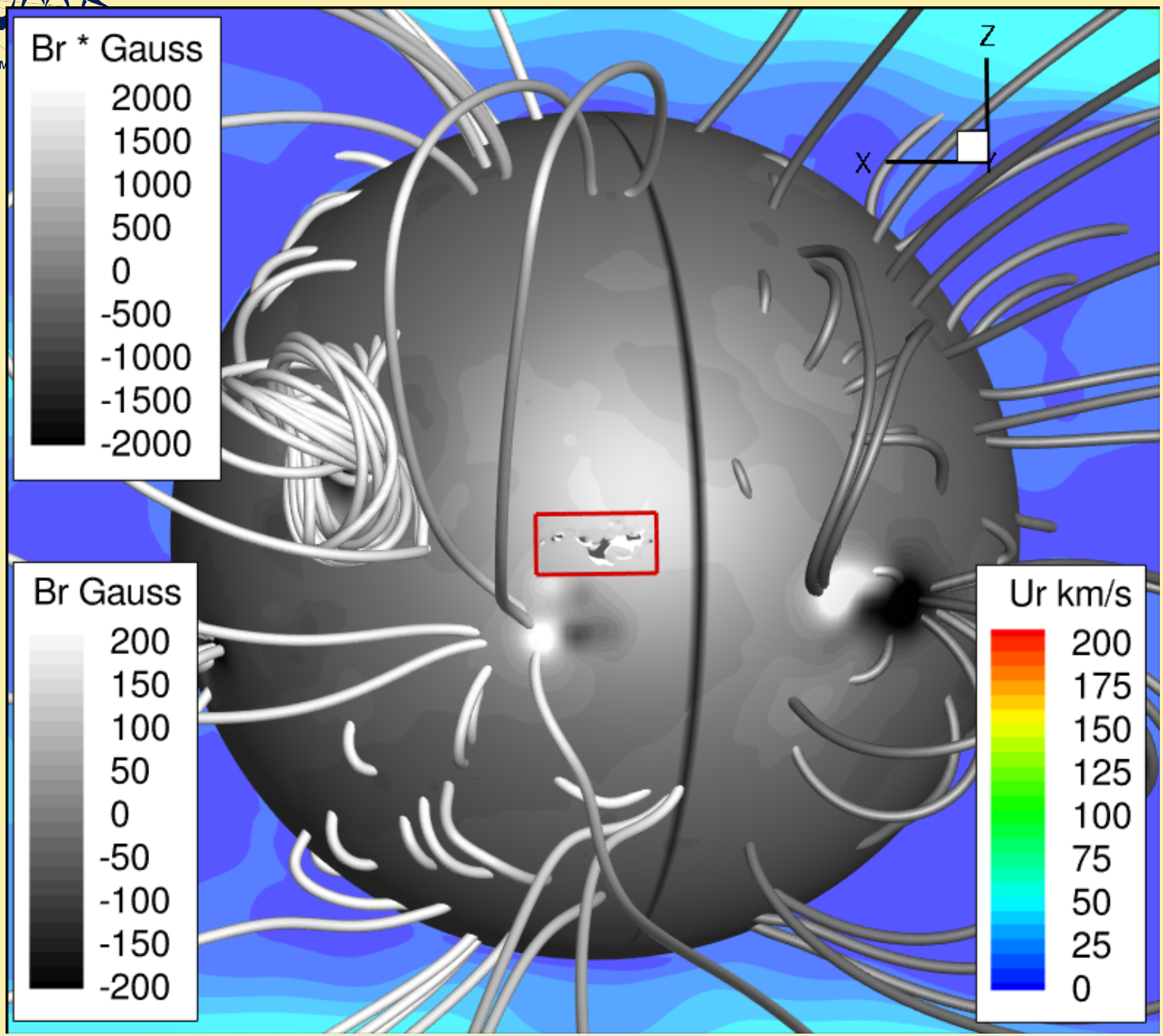
Magnetic Flux Emergence near the Photosphere

Space Weather Modeling Framework

- R = 1 Rs
- Magnetic field distribution dominated by convection
- Flux concentrated in downdrafts
- Magnetic field evolves parallel to polarity inversion line
- Shear flows driven by the Lorentz force

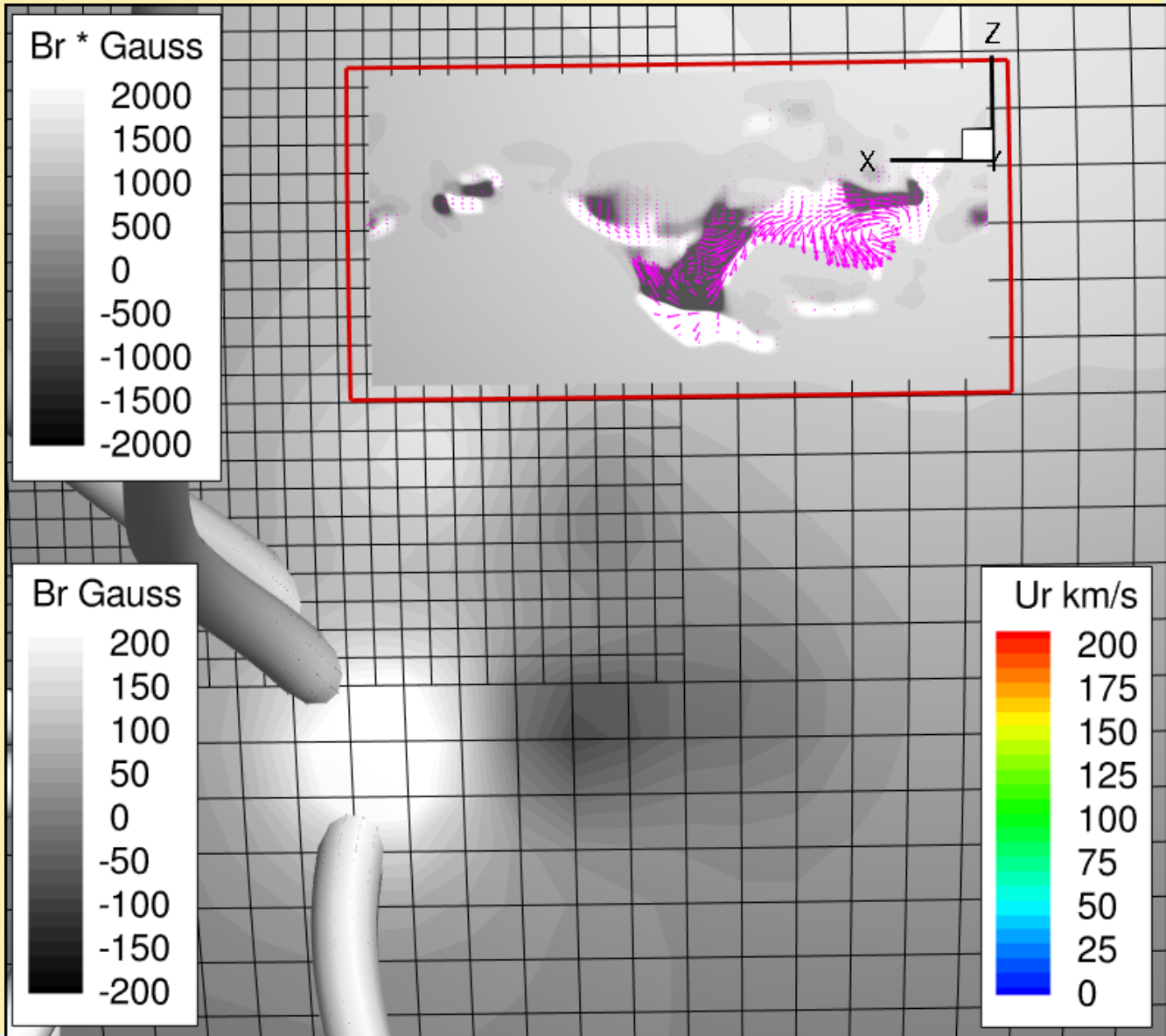


SWARM + AWSoM Convection Zone Corona Coupling



SWARM + AWSoM Convection Zone Corona Coupling

- Realistic actiive regions interact with the corona
- Allow erupting flux to expand into corona
- 2-way Couple SC + CZ at outer boundary of CZ above r = 1.01 Rs
- Couple every time step



Summary

1. Spherical Wedge Active Region Model (SWARM) 100x200Mm x35Mm deep convection zone model
2. Total: 36 runs, 8 hours each on 16384 cores
3. Realistically captures large scale convection structure and simulate full scale active regions
4. Emergence of a magnetic flux rope of 10^{23} Mx
5. Magnetic field fragmented by small-scale convection near the photosphere, confined in large deep convective downdrafts
6. The magnetic field drawn parallel to the polarity inversion line by shear flows driven by the Lorentz force providing free energy for CMEs & flares
7. Just completed coupling of SWARM & AWSoM with the SWMF