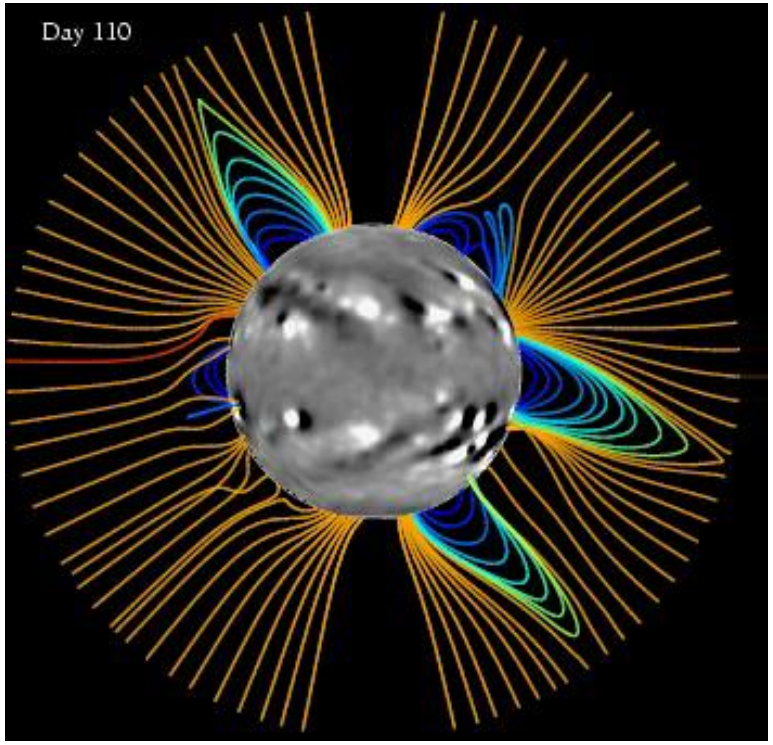
L5 Mission: Improving the Predictive Capability of Local and Global Magnetic Field Models



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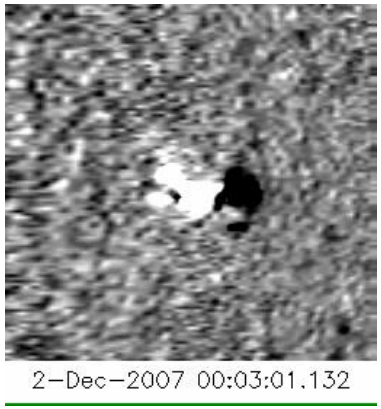
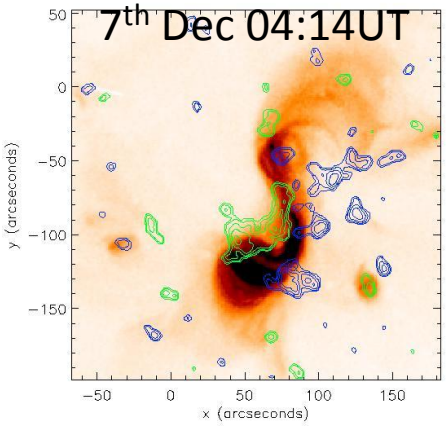
Local Simulations: Active Regions

- Use magnetogram observations and 3D NLFF modelling to determine the build-up of free magnetic energy (Mackay et al. 2011, Cheung and DeRosa 2012, Gibb et al. 2014).

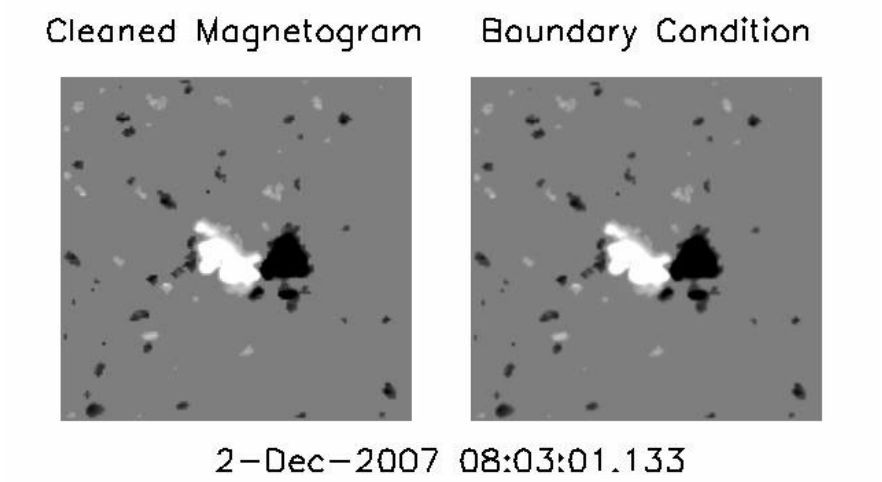
- Application (Gibb et al. 2014): AR10977, 2nd -10th Dec 2007





Main features:
Bipolar Form (cancellation, rotation).
Formtion / Eruption of X-Ray Sigmoid.
B1.4 GOES Flare.

- Photosphere – direct input of 96 min MDI obs.



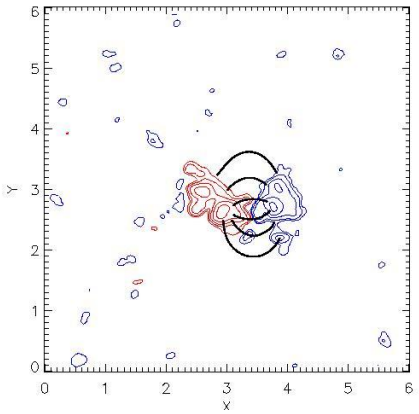
Corona – continuous sequence of non-linear force-free fields.

$$\frac{\partial \mathbf{A}}{\partial t} = \mathbf{v} \times \mathbf{B}$$

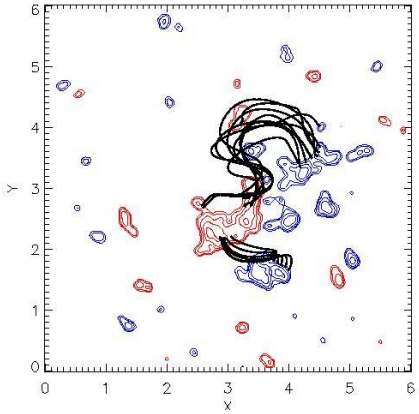
$$\mathbf{v} = \frac{1}{\nu} \frac{\mathbf{j} \times \mathbf{B}}{B^2}$$

Results

I.C.: Potential Field
08:03 UT 2nd Dec

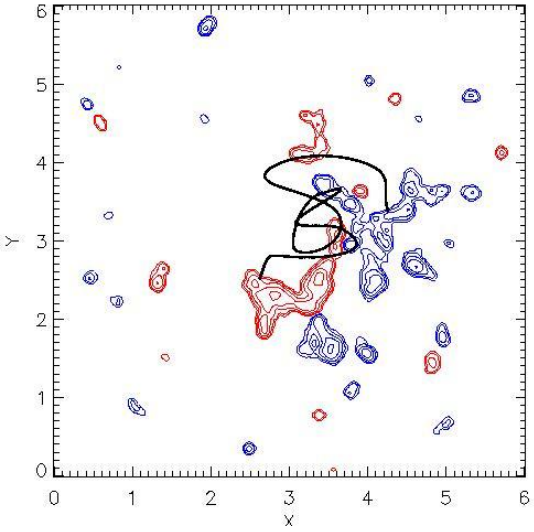


7th Dec 04:48 UT



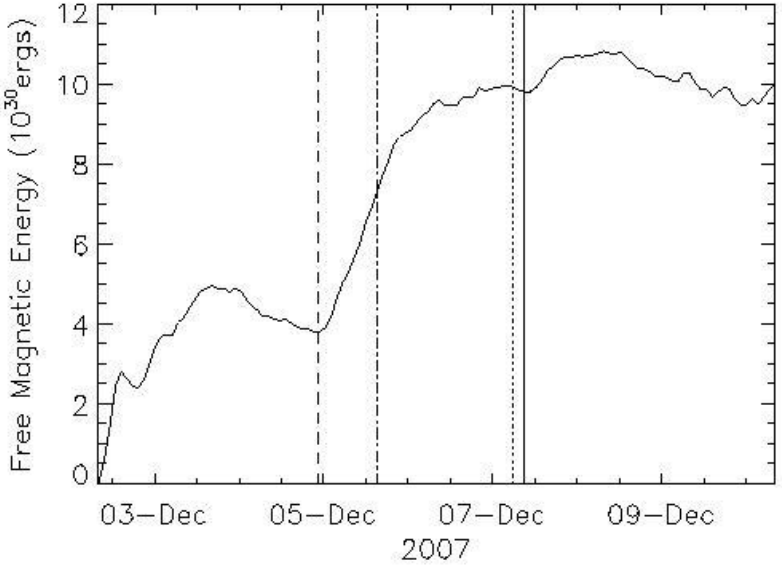
- GOES Flare 04:20 UT.
- Simulation breaks down (05.50 UT) just after time of B1.4 flare (dotted): free energy 10^{31} ergs.

7th Dec 05.50 UT



- Flux rope forms at the site of the sigmoid: flux cancellation.
- Varying I.C. improves southern fit (LFFF +ve α)
- Flux rope flux peaks: 20% of AR flux.

Free Magnetic Energy



Global Non-Potential Model

6 month: May-Aug 1999

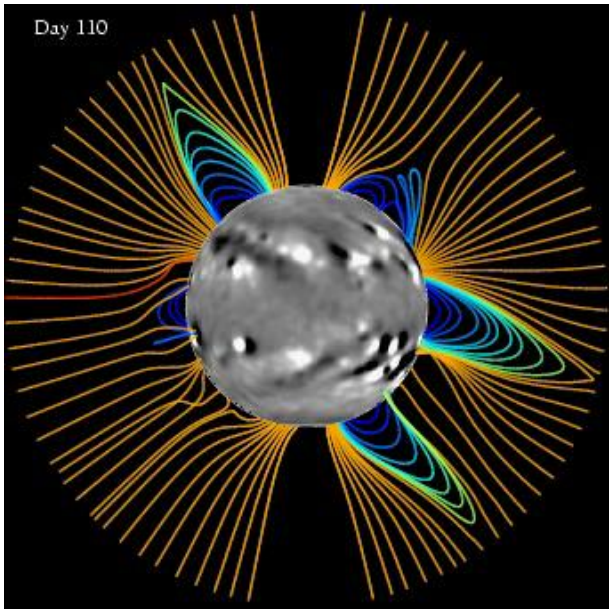
- Long Term continuous simulations (months to years).
  - Build up free magnetic energy

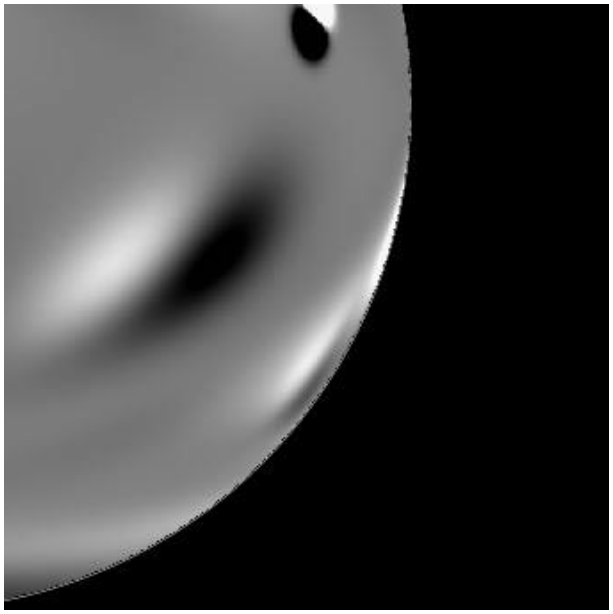
- Two coupled components:

Photosphere: Data Driven Flux Transport Model
- accurately reproduces B_r obs. on Sun.
- includes flux emergence (+/- ve helicity).

Corona : Magnetofrictional Relaxation
- quasi-static evolution
- non-linear force-free states, **j** x **B = 0**
- development of sheared fields along PIL (van Ballegooijen and Martens 1989)

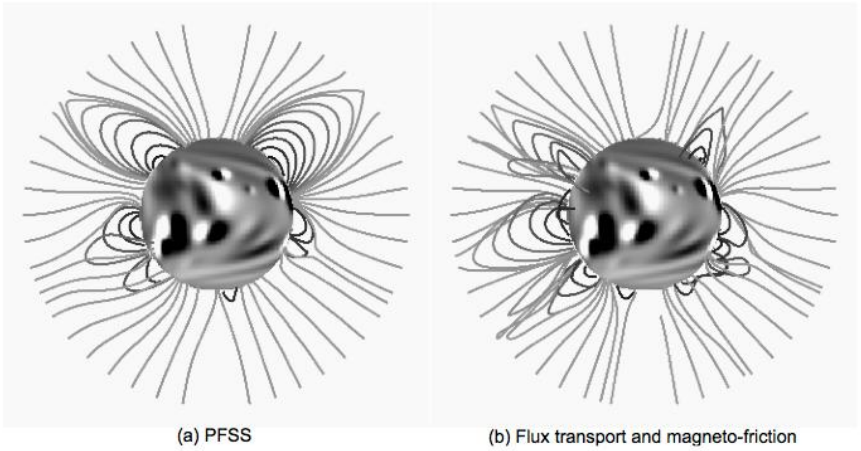
- Development and Application:
  van Ballegooijen et al 2000;
  Mackay and van Ballegooijen 2006a,b;
  Yeates et al. 2007, 2008a,b, 2009a,b.

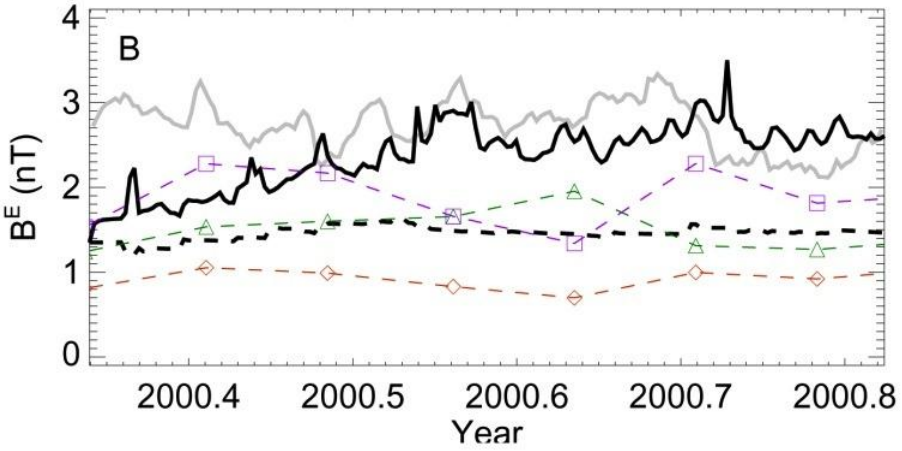




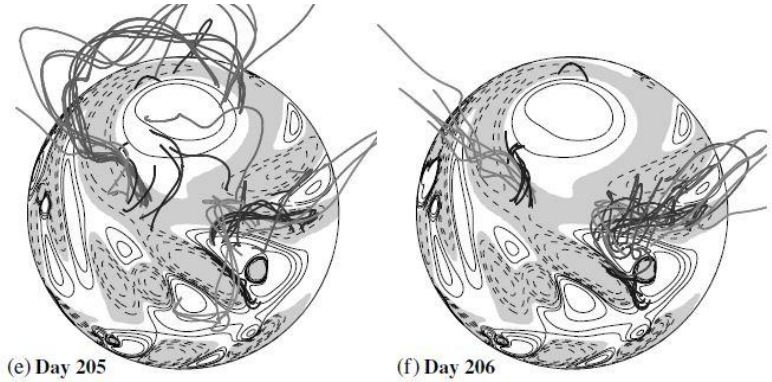
Space Weather Applications

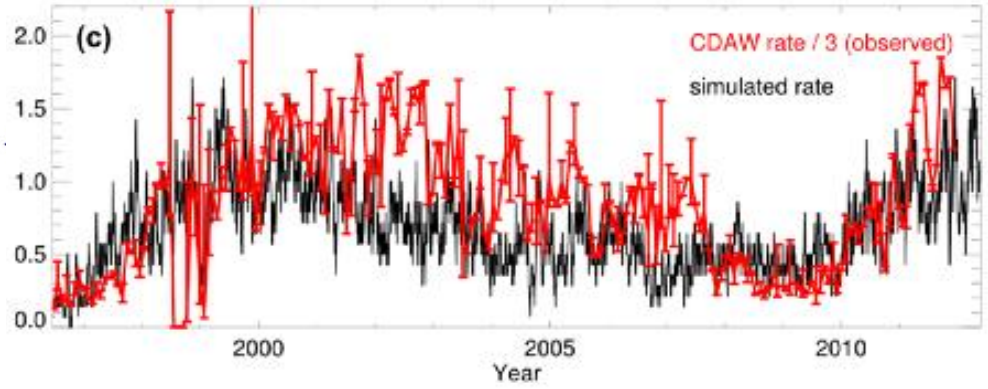
- Improved Open Flux estimates compared to PFSS models.





- Flux rope ejection/CME rates (Yeates 2014)





- Chirality and helicity in solar filaments (Yeates, Mackay and van Ballegooijen.

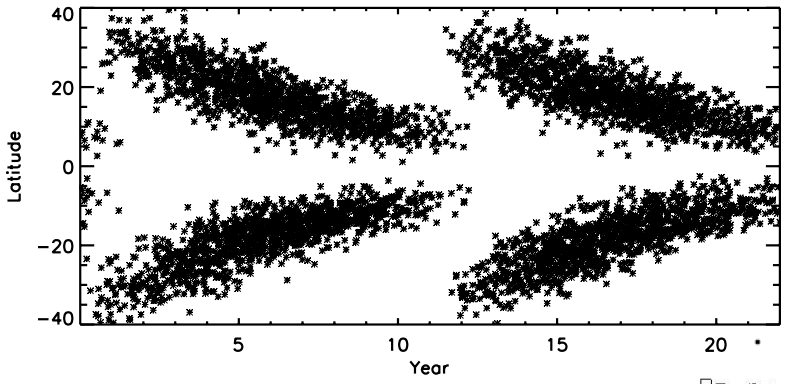
- Results limited in predictive capability due to limited real time observations.

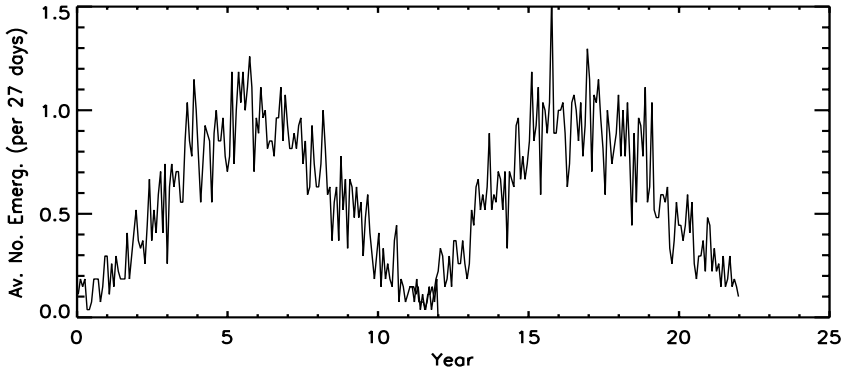
Improvements from L5 Mission

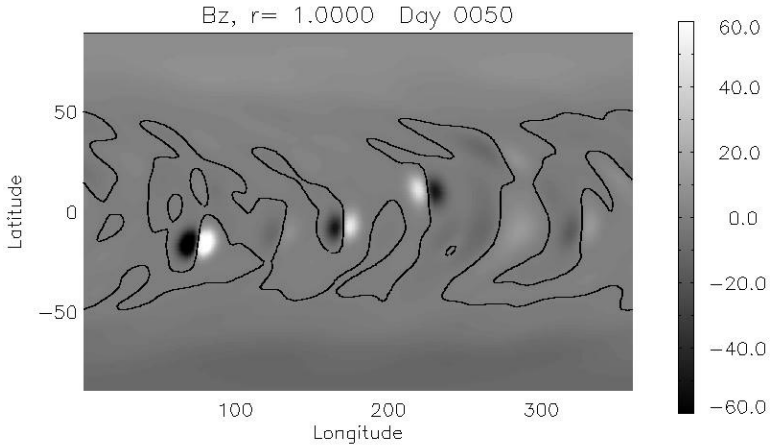
- Aim: Determine what effect having increased magnetogram data will have on accuracy of global NLFFF simulations.

  "back of envelope" calculation – three simulations.

- Reference Simulation: 22yr 3D NLFFF simulation with random emergences of bipole at all longitudes.

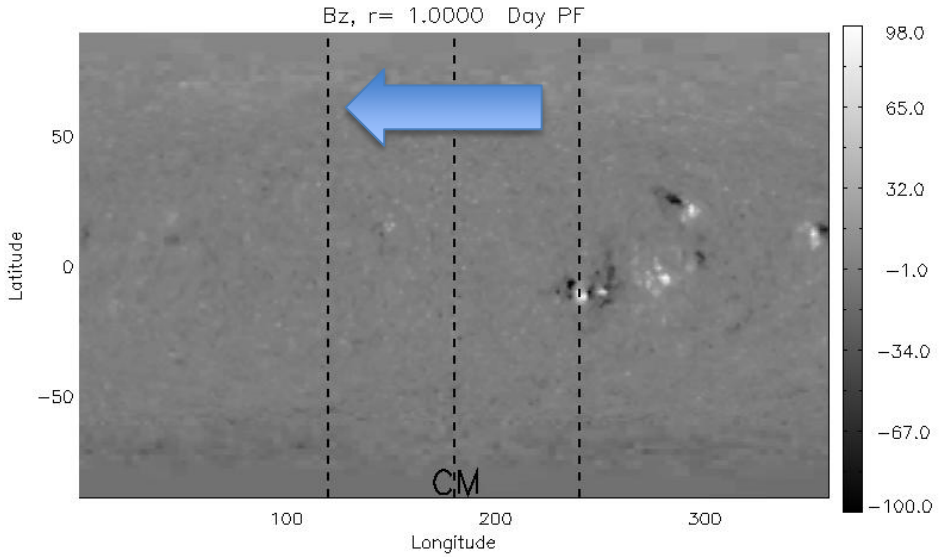




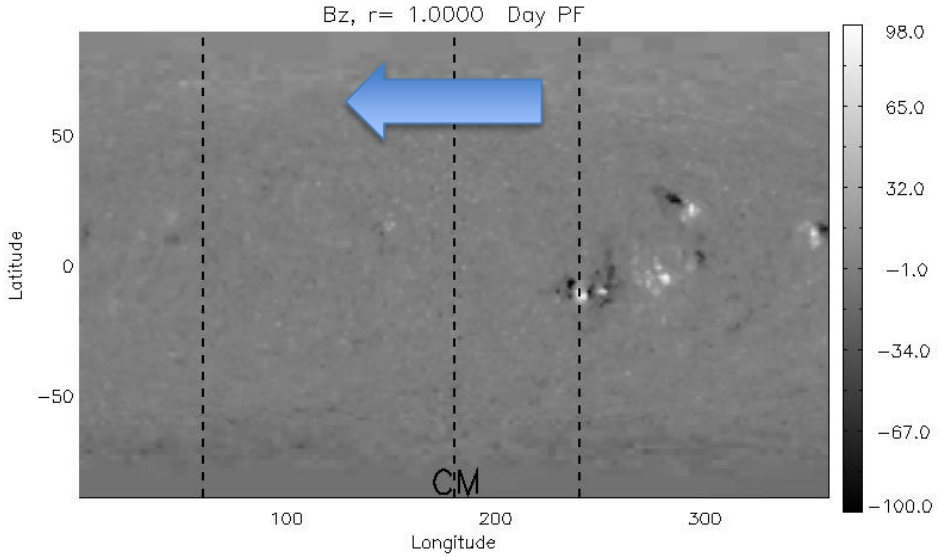


Limited Data Simulations

- Consider bipole emergence within moving window of observations
- Earth based: Emergences of bipoles at longitudes visible from Earth

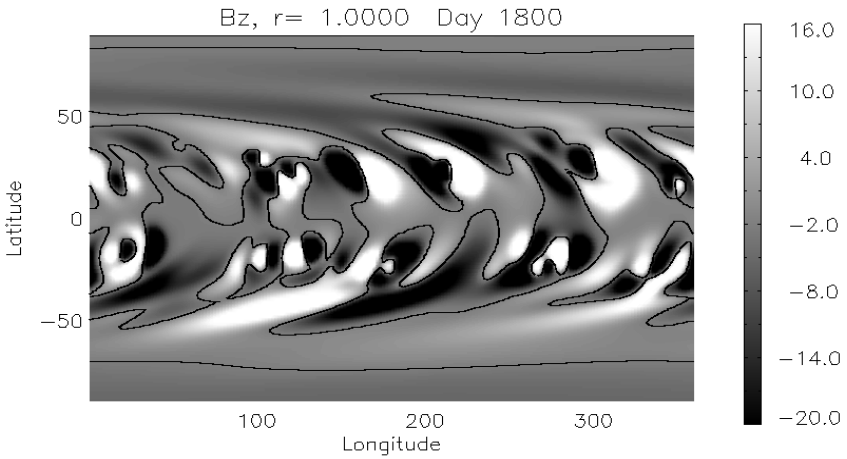


- Earth & L5: Emergences of bipoles at longitudes visible from L5 & Earth.
- Important : only considering real time emergences in window of obs – not considering synoptic updates from outside if window

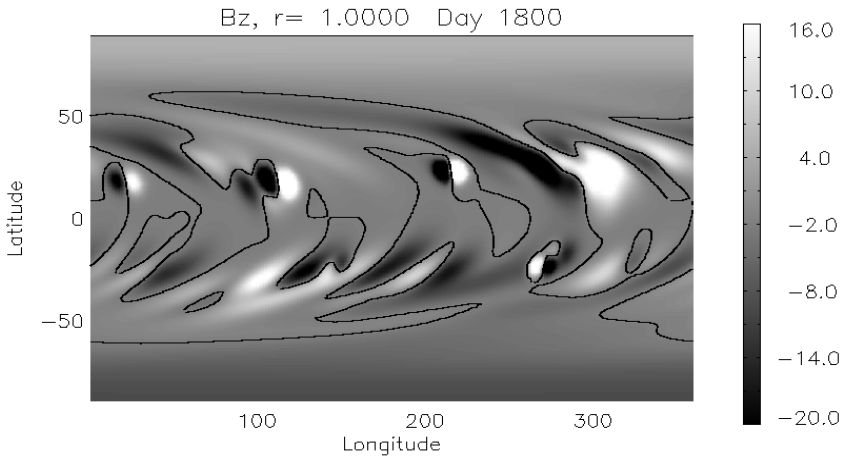


Results

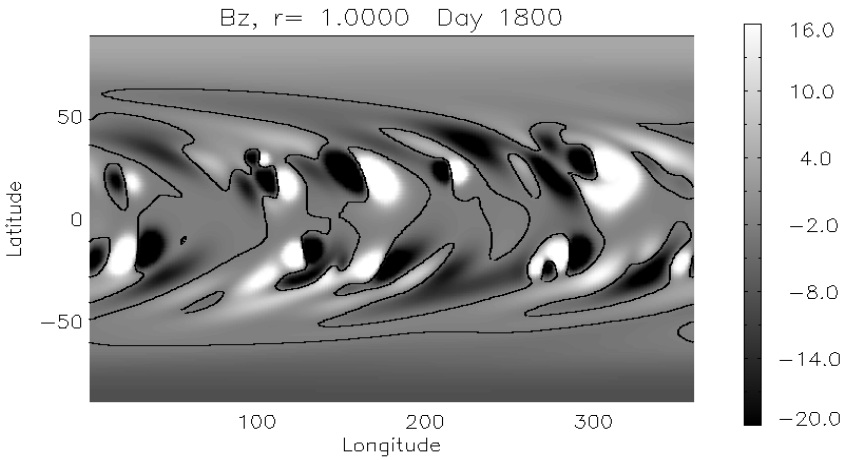
Reference simulation

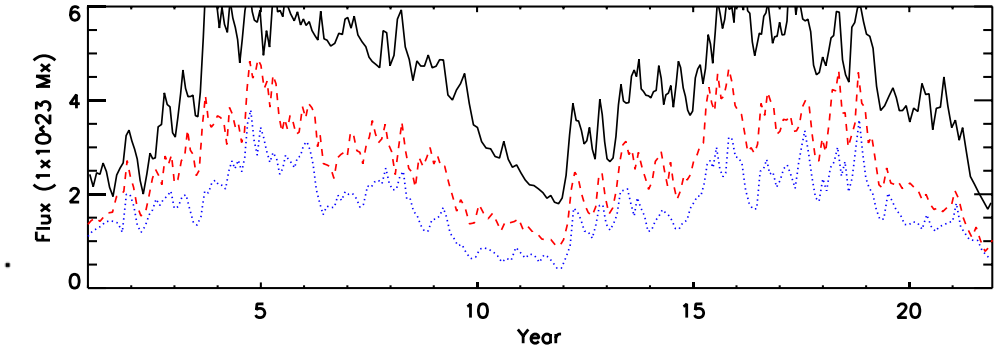


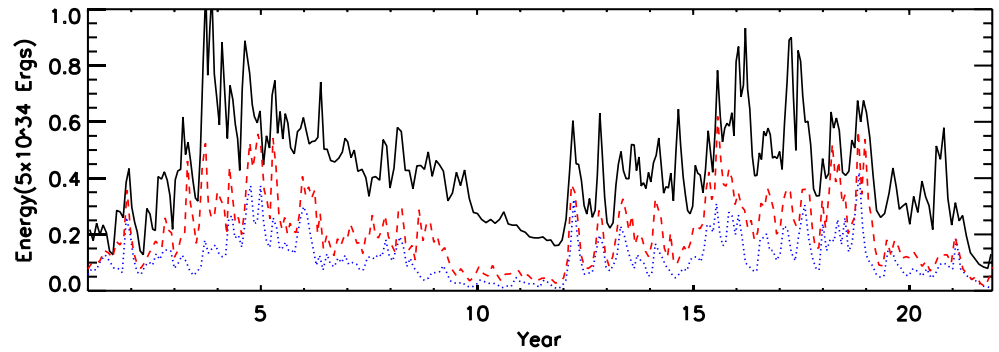
Earth Based



L5 + Earth







Conclusions

- Active Region Simulations: successfully applied nlfff simulations to a time series of magnetograms to reproduce coronal observations.

  Loss of equilibrium of flux rope close to time of flare.

  Deduced free energy sufficient to account for flare.

  AR10977: fortunate to catch early development of emerging AR on disk and rotation to CM.

  Increased longitudinal range of L5 magnetograms significantly enhances opportunities to simulate AR evolution "in real-time" towards CM
  (256^3, 96 min real time -> 10-15 min, 24cpus)

- Global Model: initial L5 test simulations indicate significant improvement.

  Include real-time emergences + synoptic updates (ADAPT)
  Study accuracy of surface field.
  Global Quantities: Open Flux, Total & Free Energy.
  Flux rope ejections: location and number
  Accuracy of simulations in reproducing flux rope ejections towards Earth