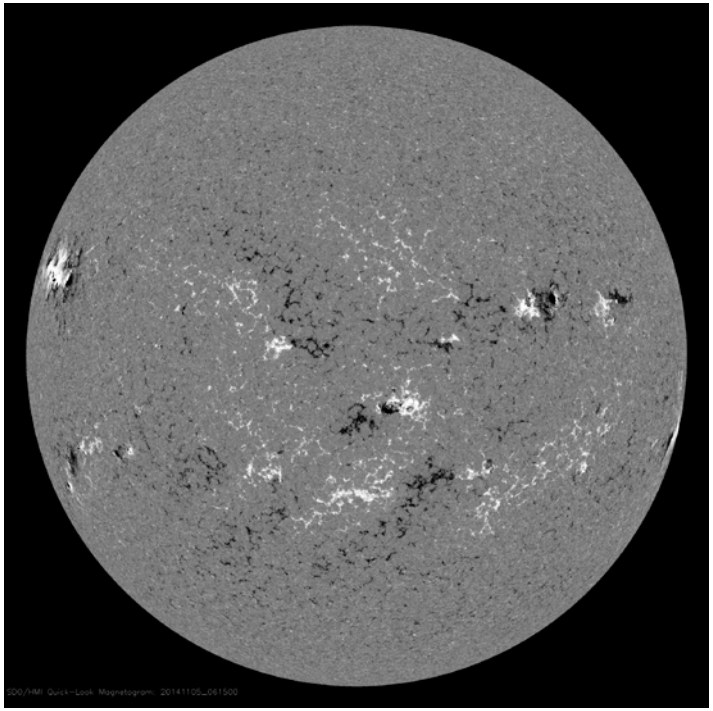
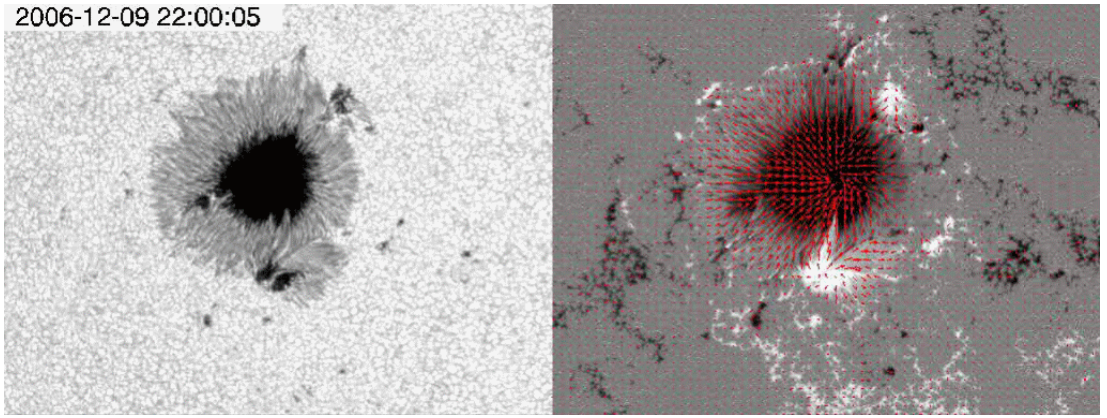
Photospheric Magnetic Fields: what are the remaining open questions?

Robert Cameron

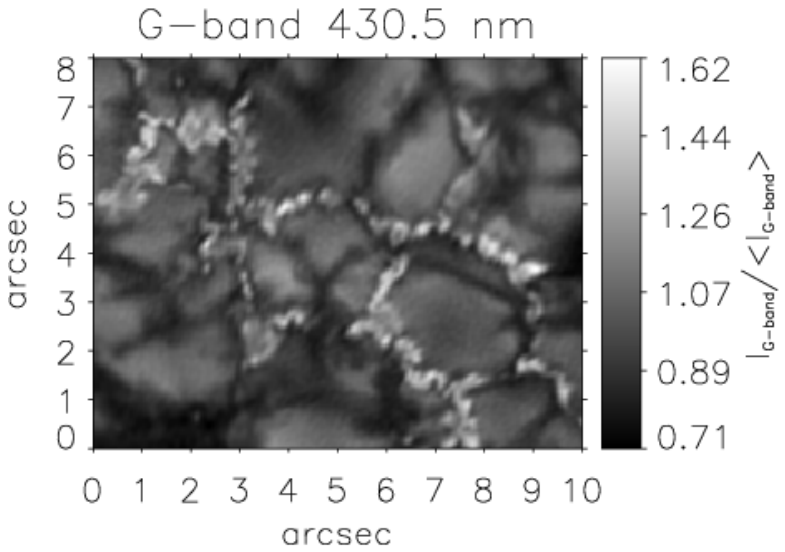
Scales of photospheric fields



SDO/HMI



Hinode (From Benz, LRSP)



V. Zakharov,A. Gandorfer ,
S. K. Solanki, M. Löfdahl (2005) (SST)

Photospheric Magnetic Fields: what are the remaining open questions?

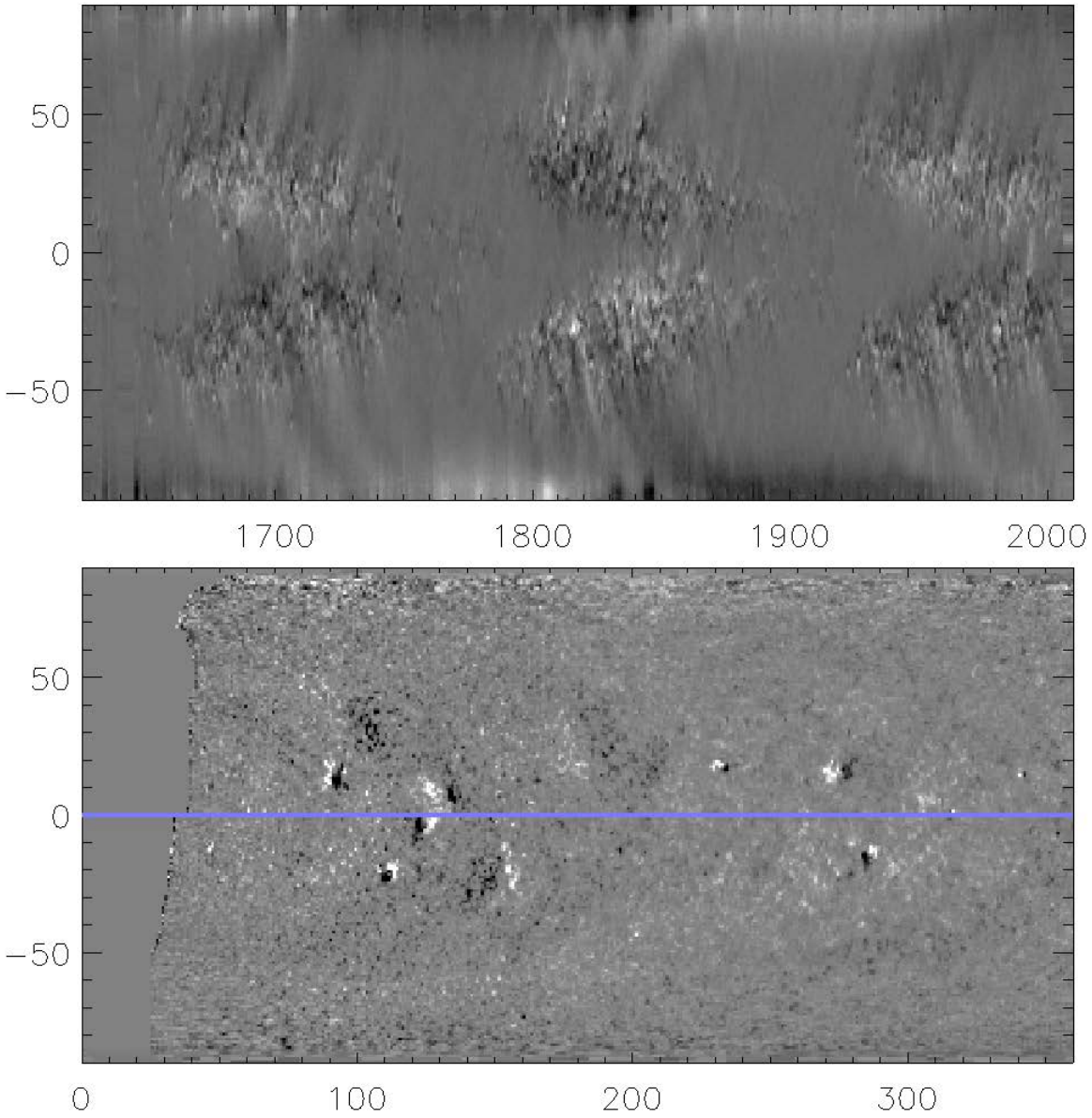
A: There is more to learn on every aspect

Photospheric Magnetic Fields: what are the most open questions?

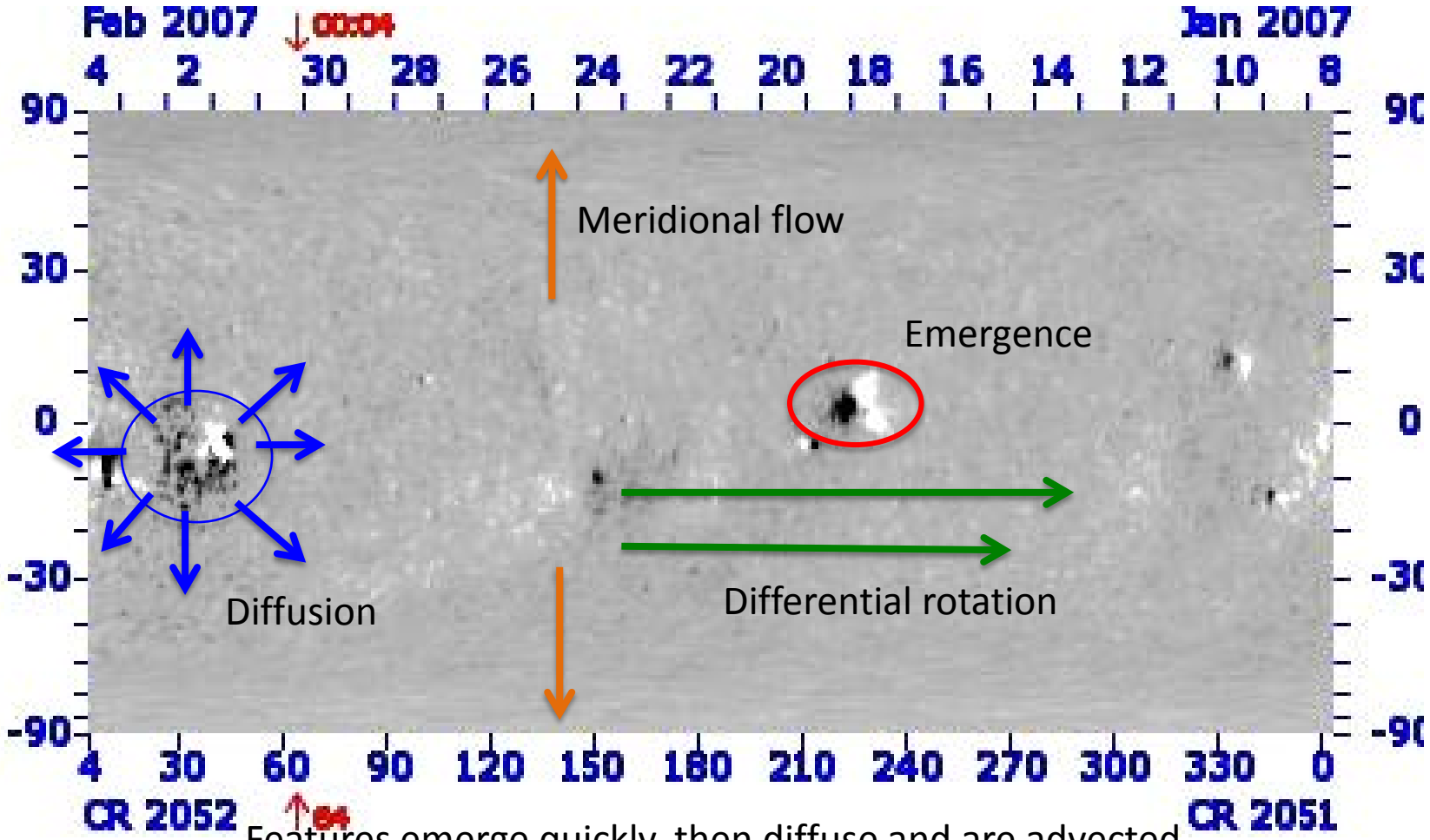
(Necessarily biased)

Background:
We are doing surprisingly well.

Large Scales



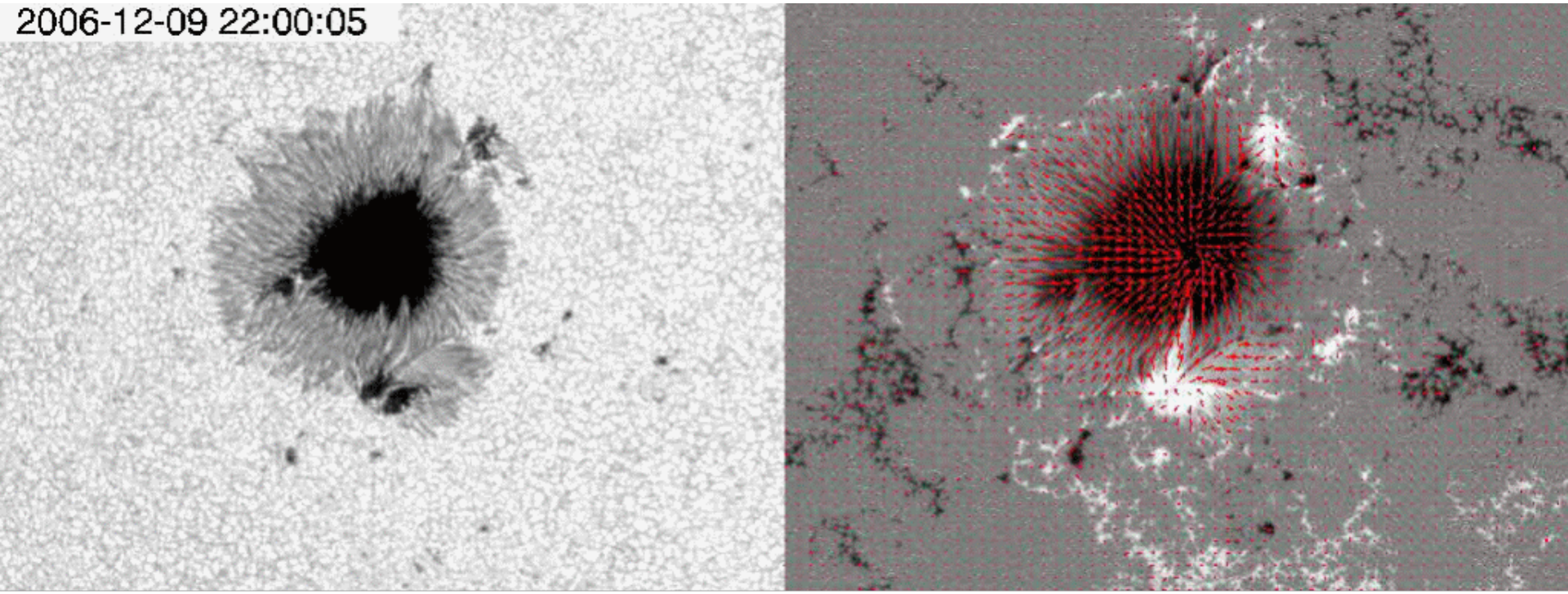
Evolution of magnetic fields at the solar surface



Features emerge quickly, then diffuse and are advected.

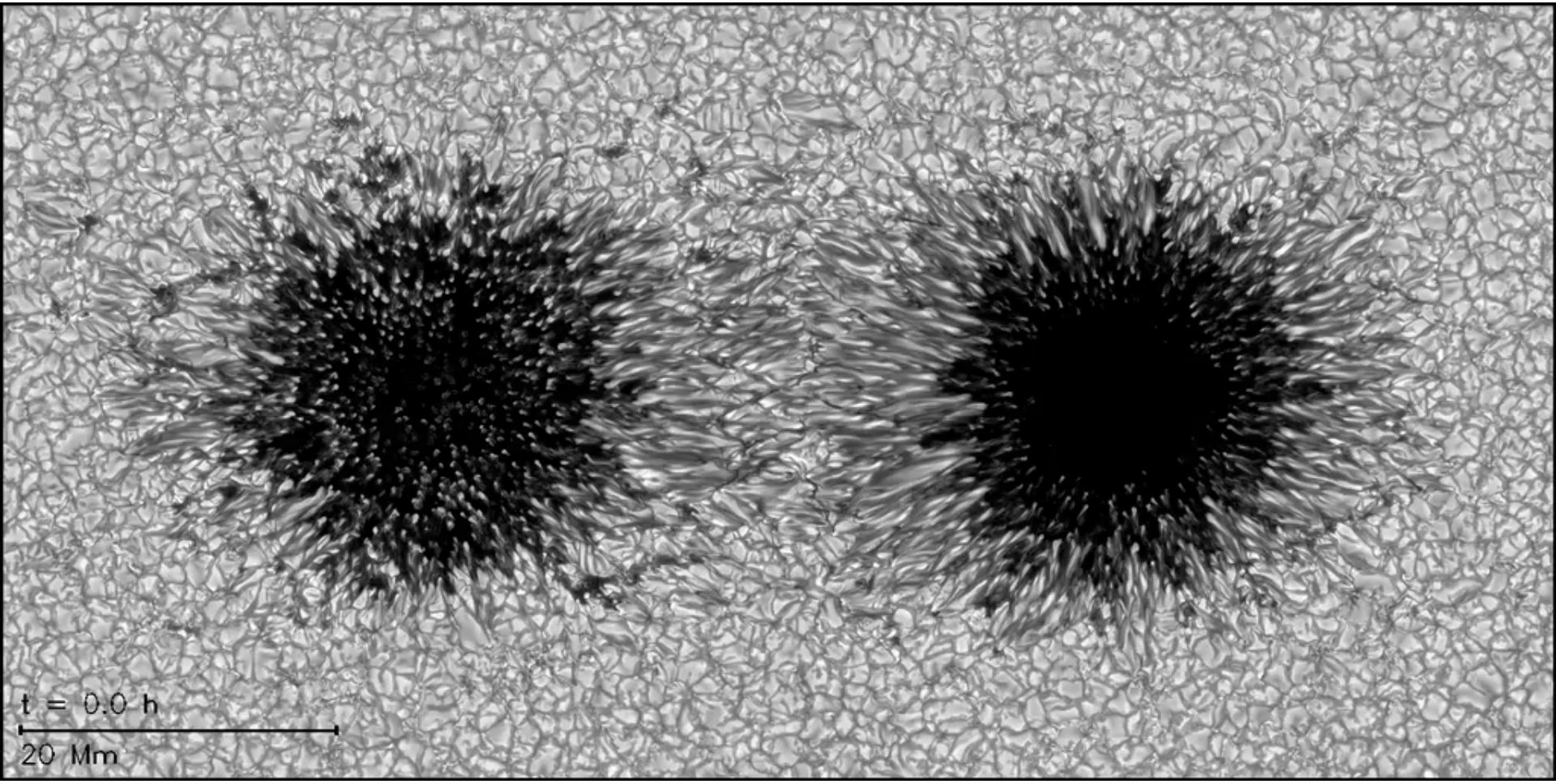
Leighton 1964, Schatten 1972
DeVore, Sheeley & Boris 1984
Wang, Nash & Sheeley 1989
etc.

Medium Scales



Hinode (From Benz, LRSP)

Sunspots

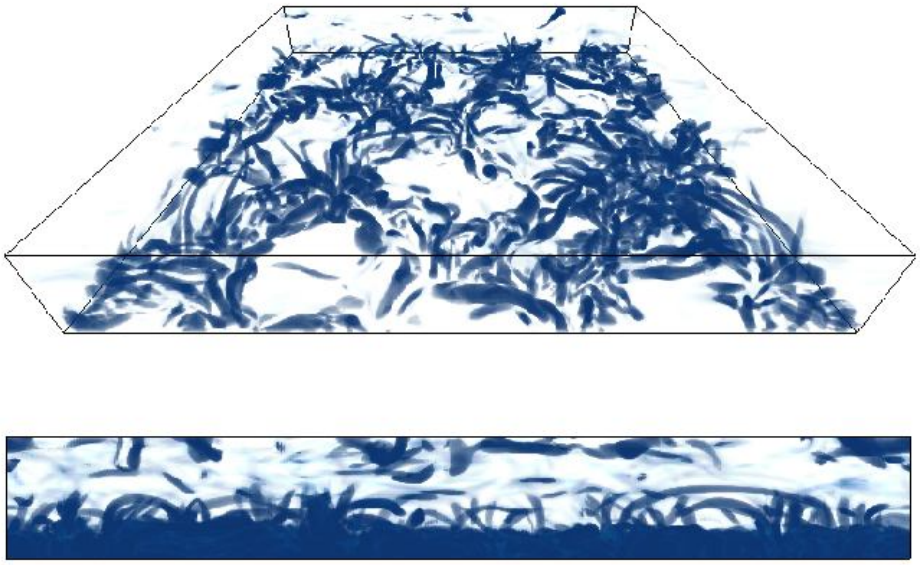


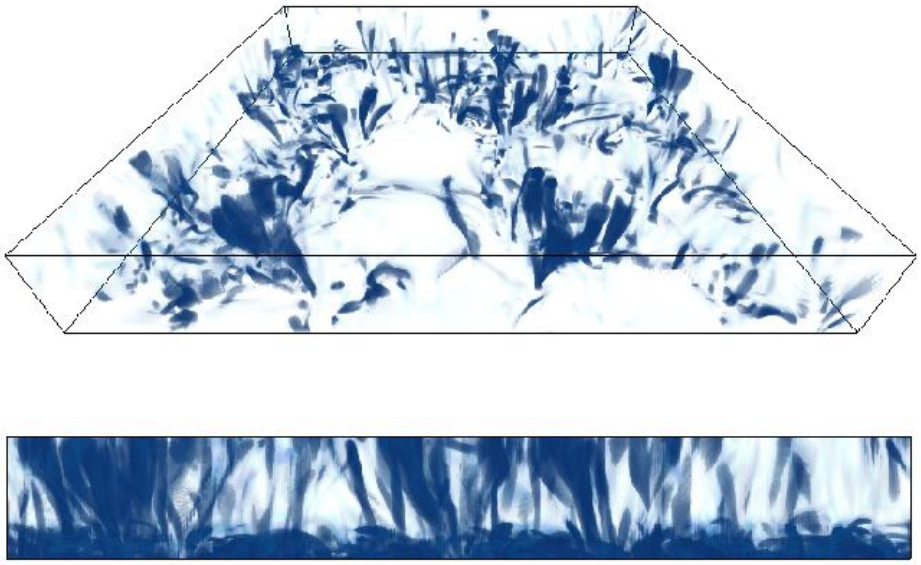
Rempel et al 2009

Flux emergence photospheric simulation

Cheung et al 2010

Small scales





Non-magnetic vortices

magnetic vortices
(Couple the atmosphere to the turbulence in the downflow lanes)

(Moll et al 2012)

Why are we doing so well?

- Large scale:
  - Apparently no significant large-scale field transverse to the solar surface (bouyancy)
  - Apparently no diffusion of horizontal field through the surface.

- Small scale:
  - We resolve the pressure and density scale heights
  - We can resolve (in simulations) the physics near the tau=1 surface which are relevant near the tau=1 surface.

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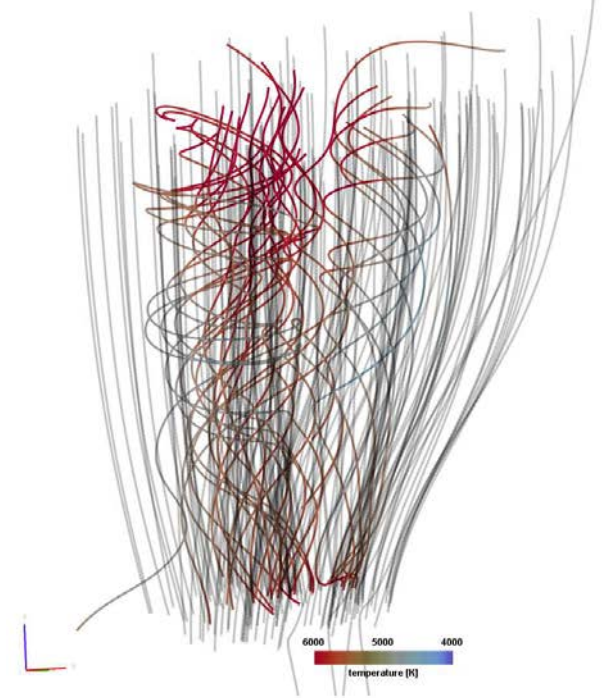
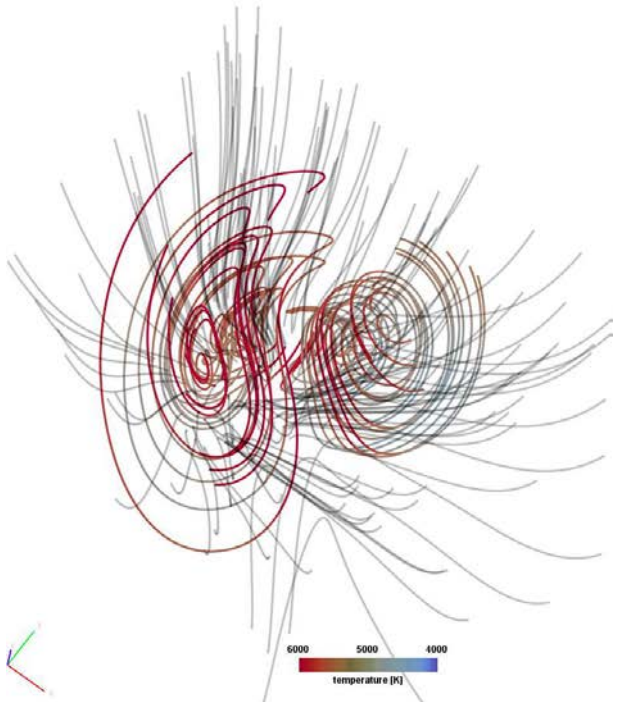
Different models

- Small scale:
  - We resolve the pressure and density scale heights
  - We can resolve (in simulations) the physics near the tau=1 surface which are relevant near the tau=1 surface.

Where we can do better

- Coupling the atmosphere
  - Within individual flux tubes, magnetic fieldlines are tightly couple to the surface turbulence



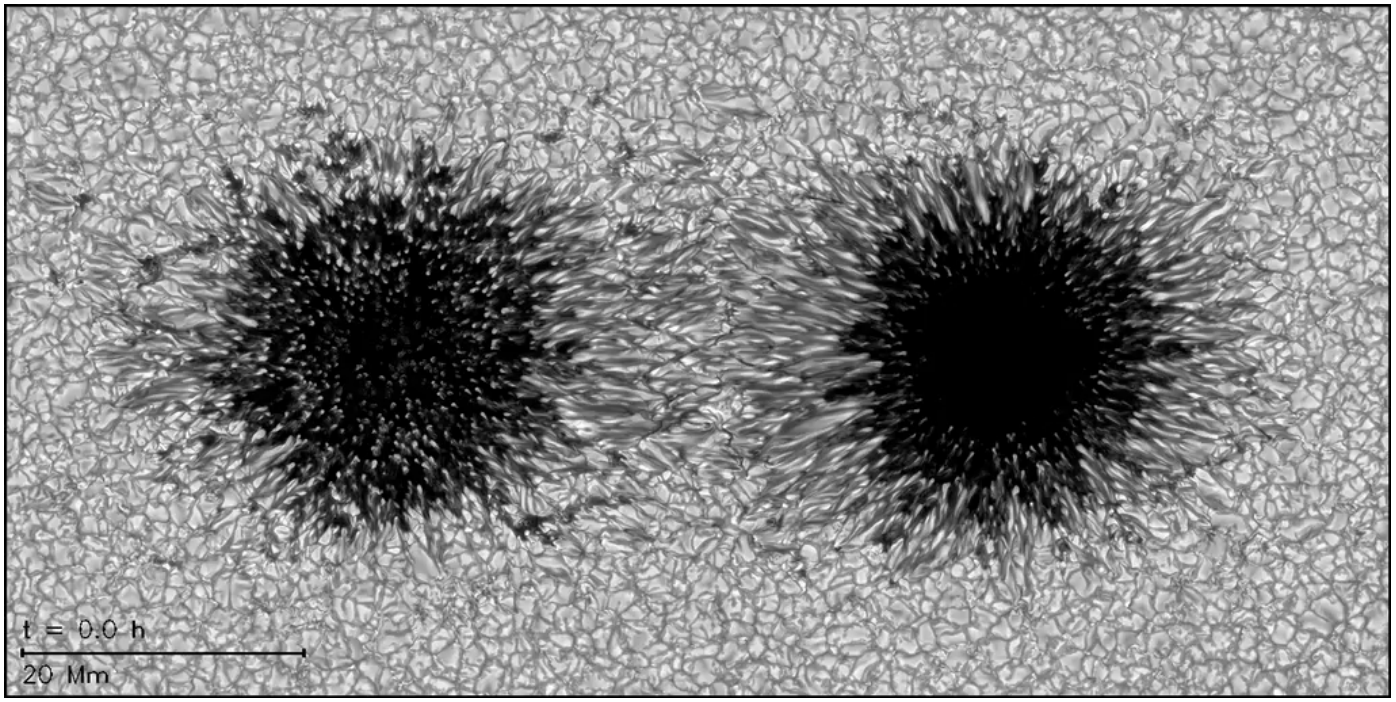


One flux tube can be highly structured internally,with different bundles of field lines being associated with different turbulent eddies in the lower photosphere – not ciritcal for the surface appearance of the tube, but potentially very important for transporting motions and turbulence into the chromosphere and corona.

Moll et al 2012

Coupling the atmosphere

- What can we learn from about the deep structure of spots and flux emergence from their surface appearance?

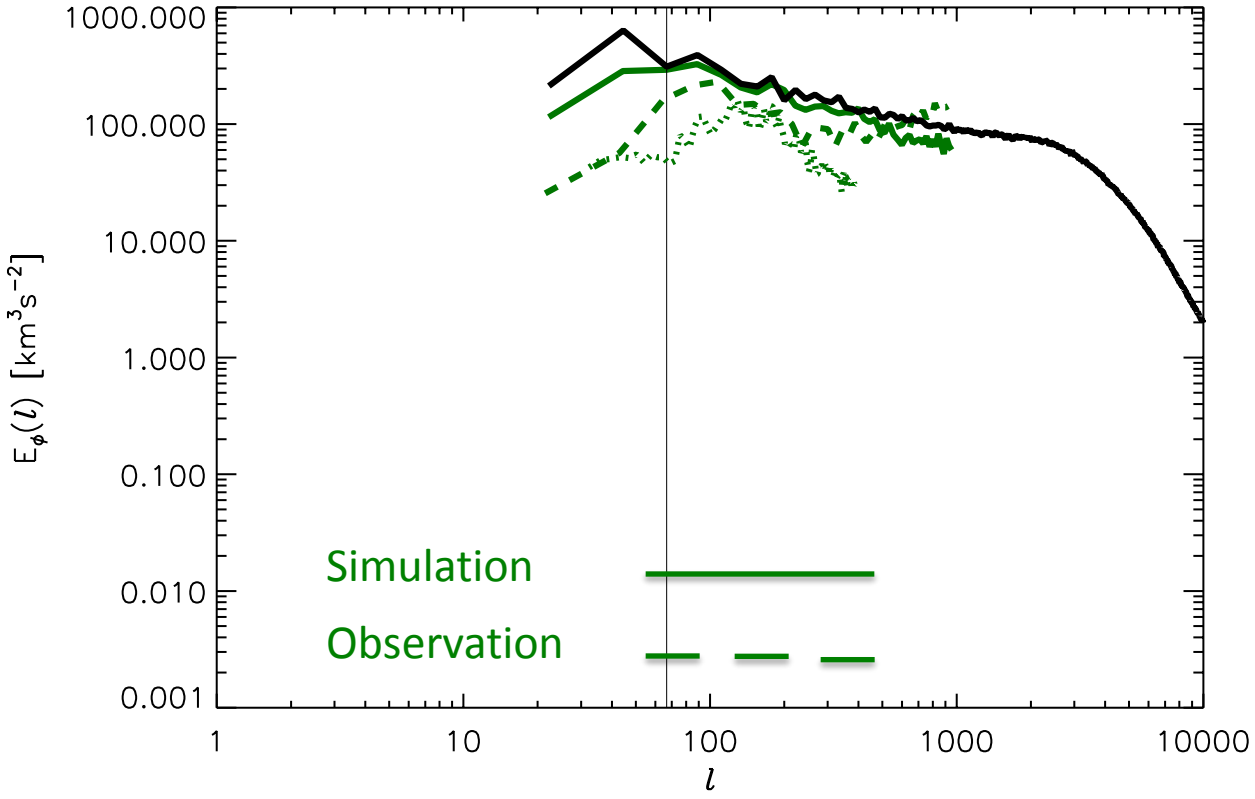


Rempel et al 2009

Where are we doing poorly

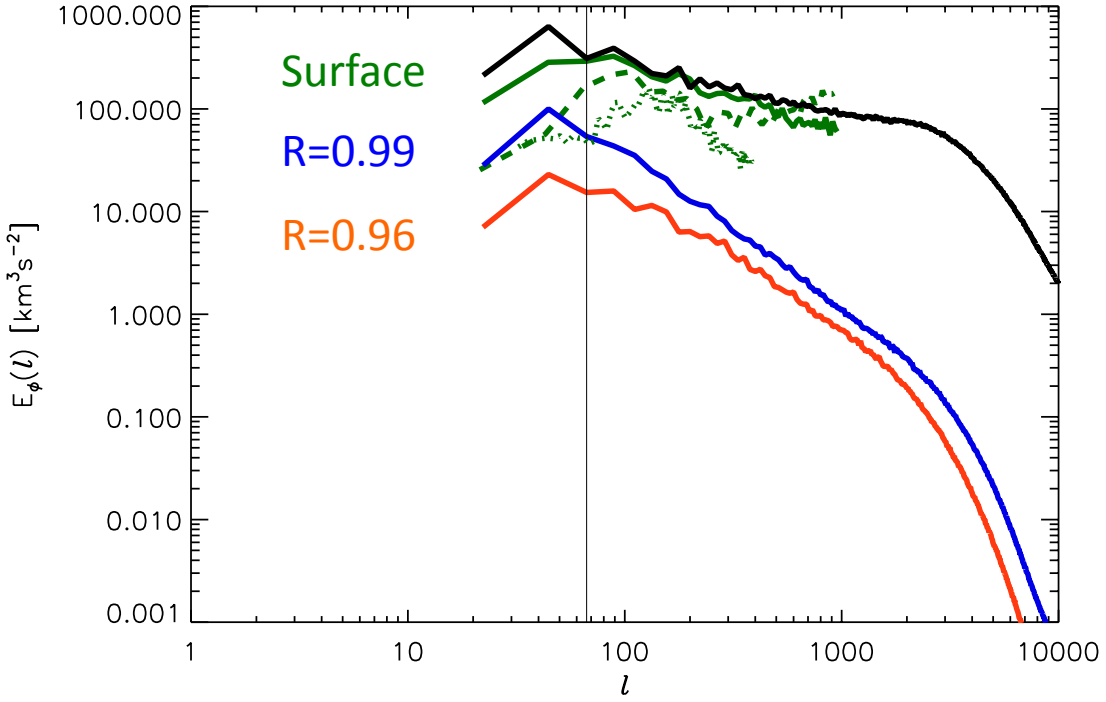
- Coupling the scales
  - How does the small-scale fields and flows interact with the large-scale flows and fields
    - Supergranulation
    - Why does the SFT model work
    - Flows around active regions

Comprehensive MURaM simulations have strong giant cells

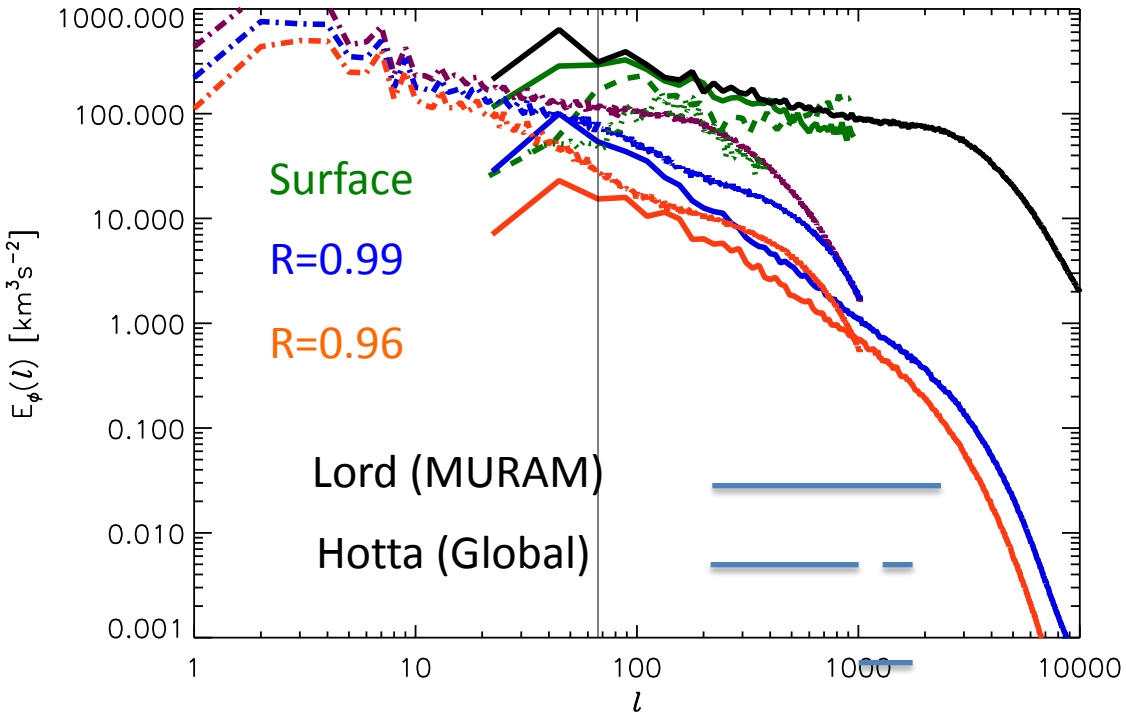


(After Gizon and Birch)

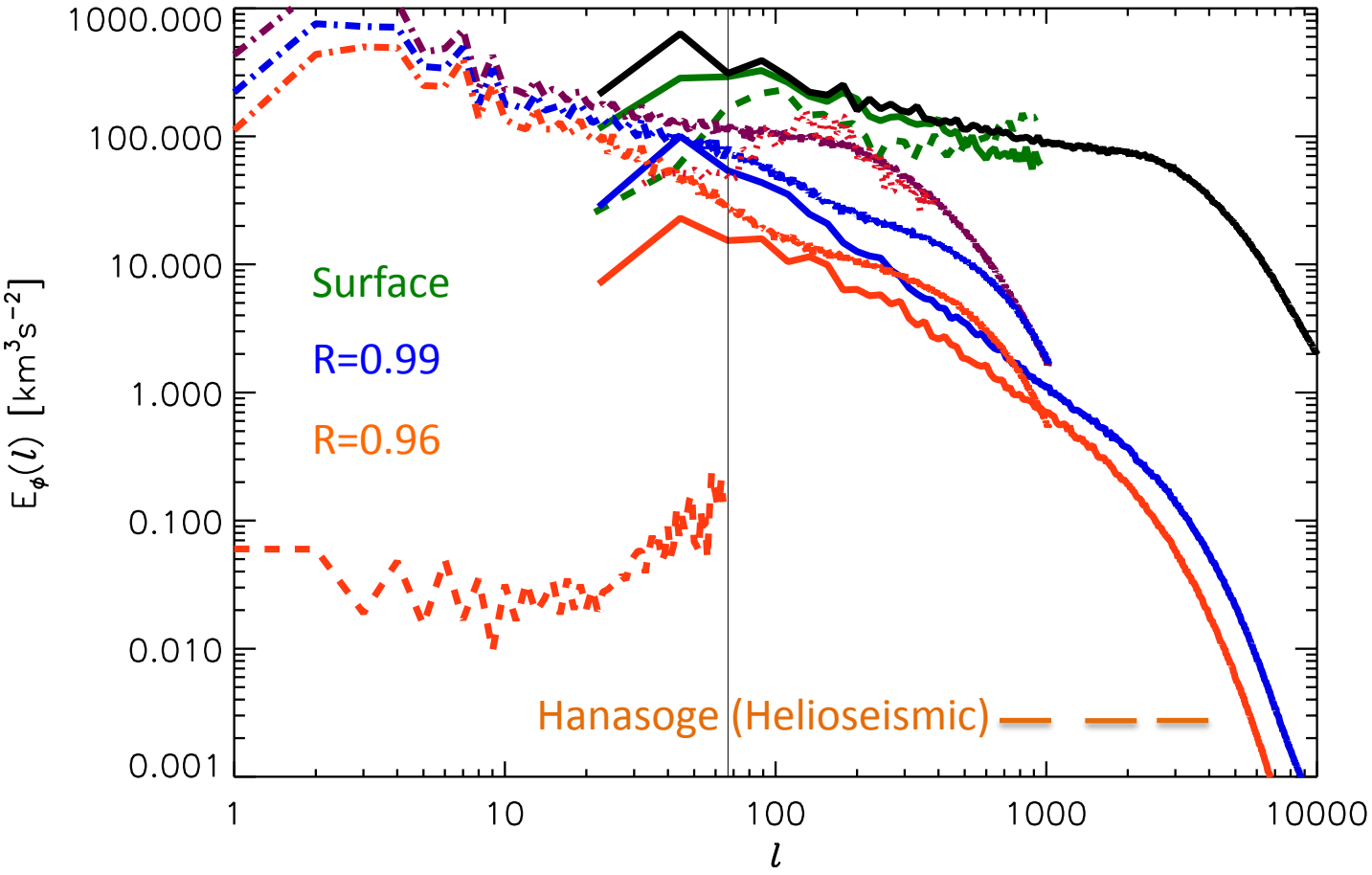
Different depths



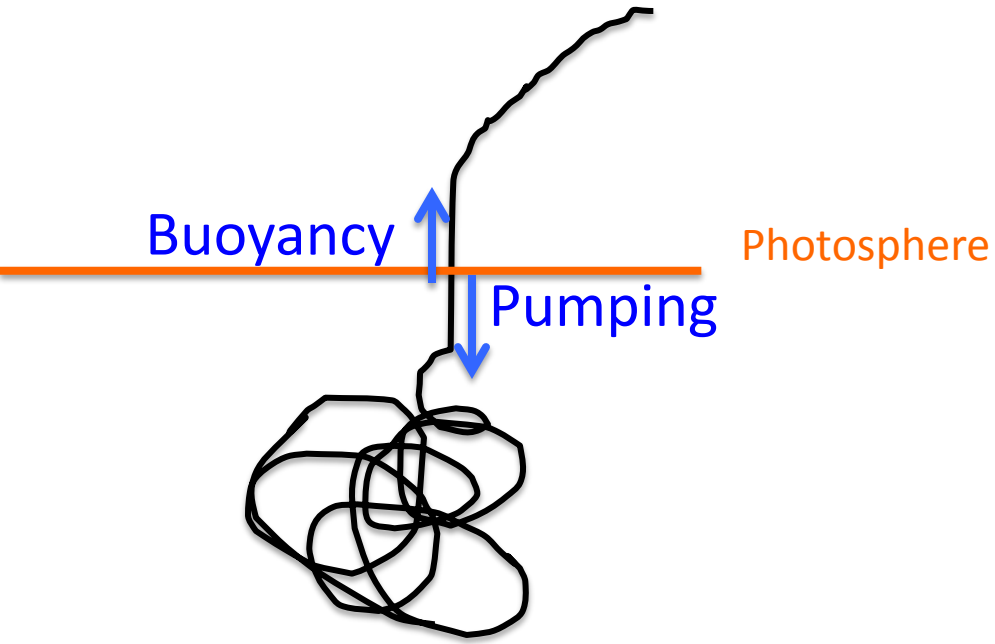
Comparison with global simulations



Giant cells


1000.000
100.000
10.000
1.000
0.100
0.010
0.001
$E_\phi(l)$ [km^3s^{-2}]
Surface
R=0.99
R=0.96
Hanasoge (Helioseismic)
1
10
100
1000
10000
l

Surface dynamics are governed by surface flows. Why? (Why does the SFT model work)

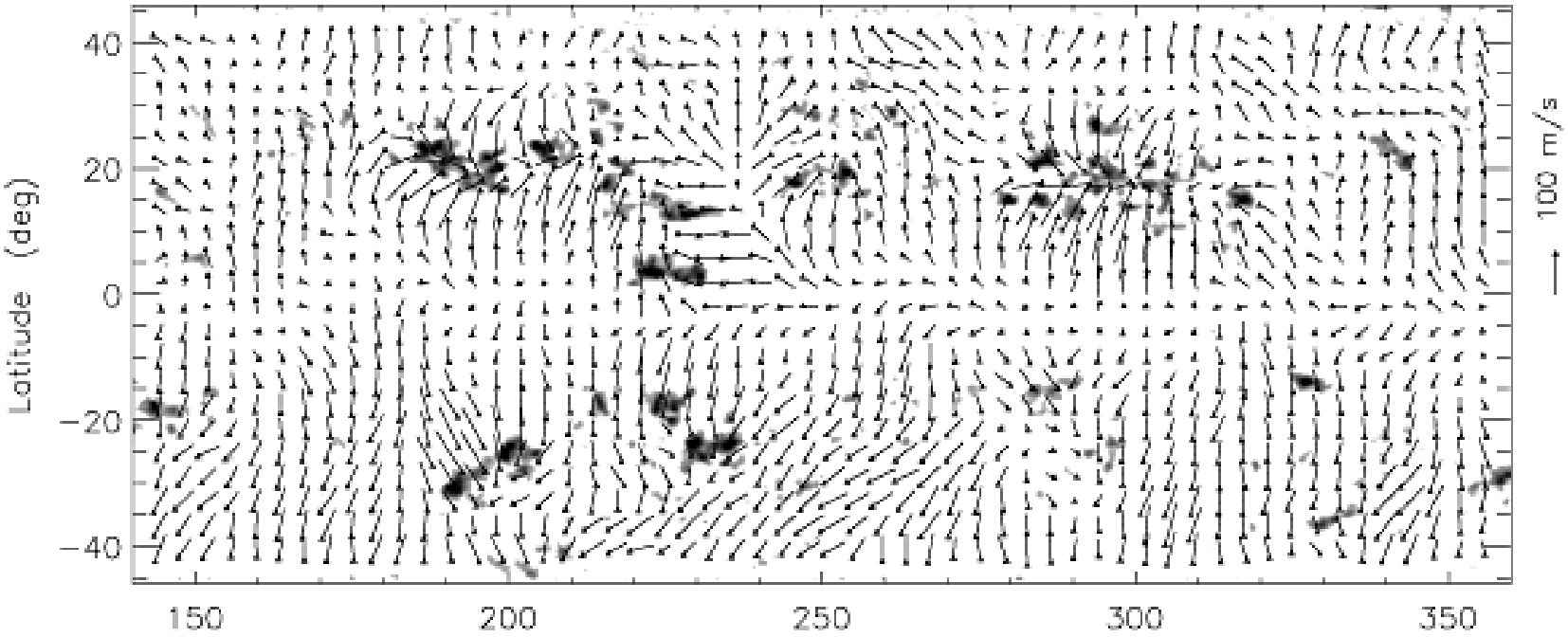


One possble explanation.

See Cameron, Schmitt, Jiang and Isik 2012

Inflows into active regions.

Active regions inflows



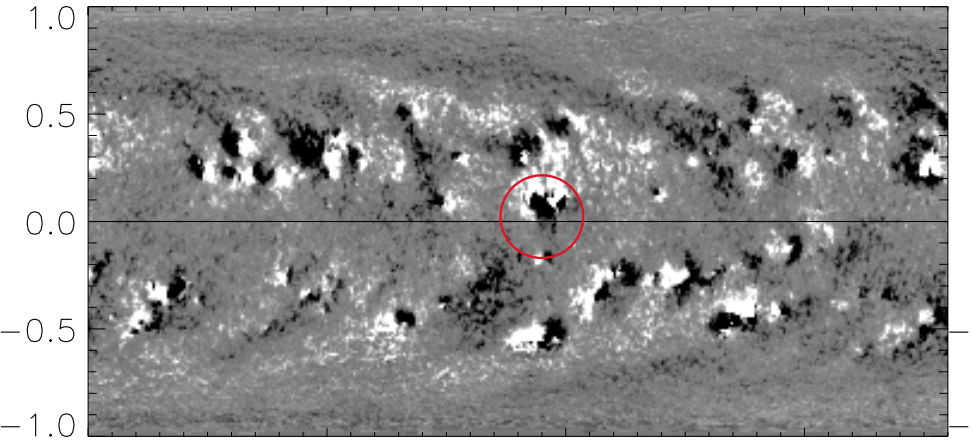
Gizon et al 2001

Is the explanation that these flows are due to cooling associated with the excess radiance from plage (Spruit 2003) correct? Can we get the total radiance changes associated with plage correct (cf Thaler & Spruit, 2014)?

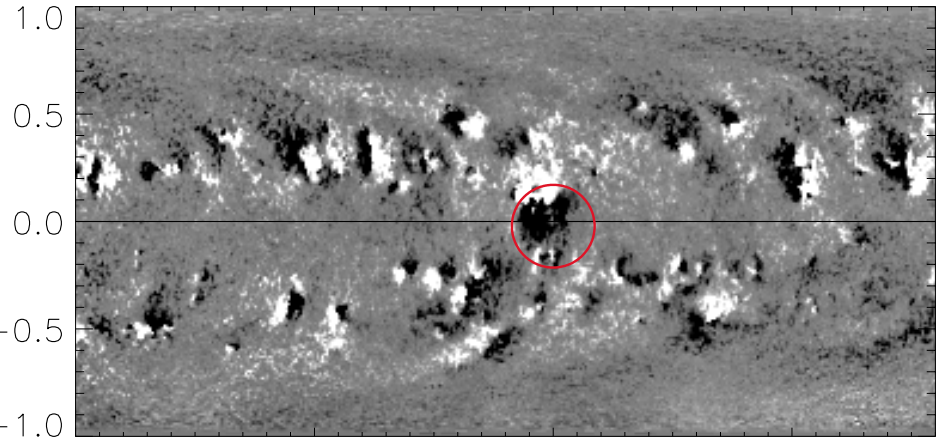
What causes the scatter in the tilt angle of ARs?

Cameron, Dasi-Espuig, Jiang, Isik, Schmitt & Schüssler (2013)

CR 1685

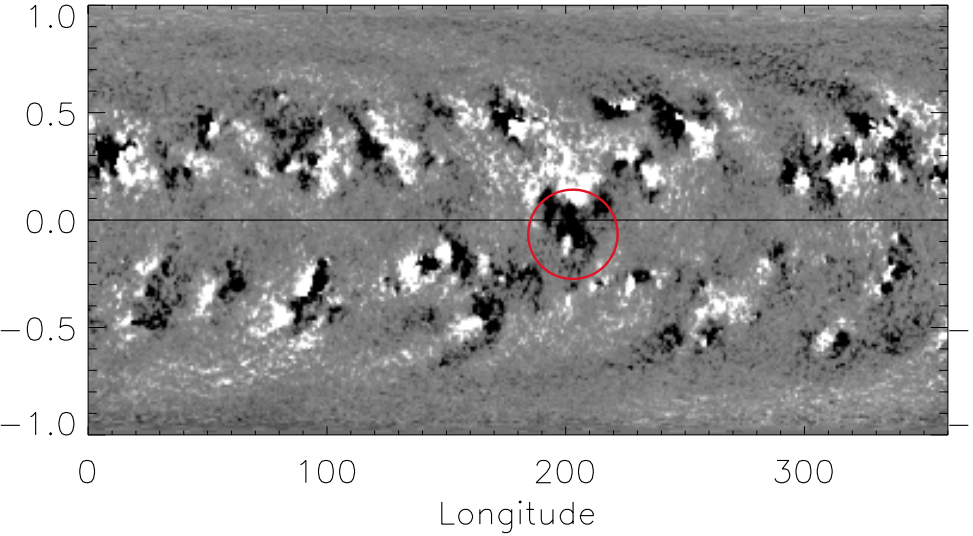


CR 1686



Physical causes of solar cycle randomness: emergence of large, highly tilted sunspot groups near the equator

CR 1687



CR 1688