



Solar Magnetic Field Reversal

V J Pizzo

SHINE Workshop

August 18, 2002



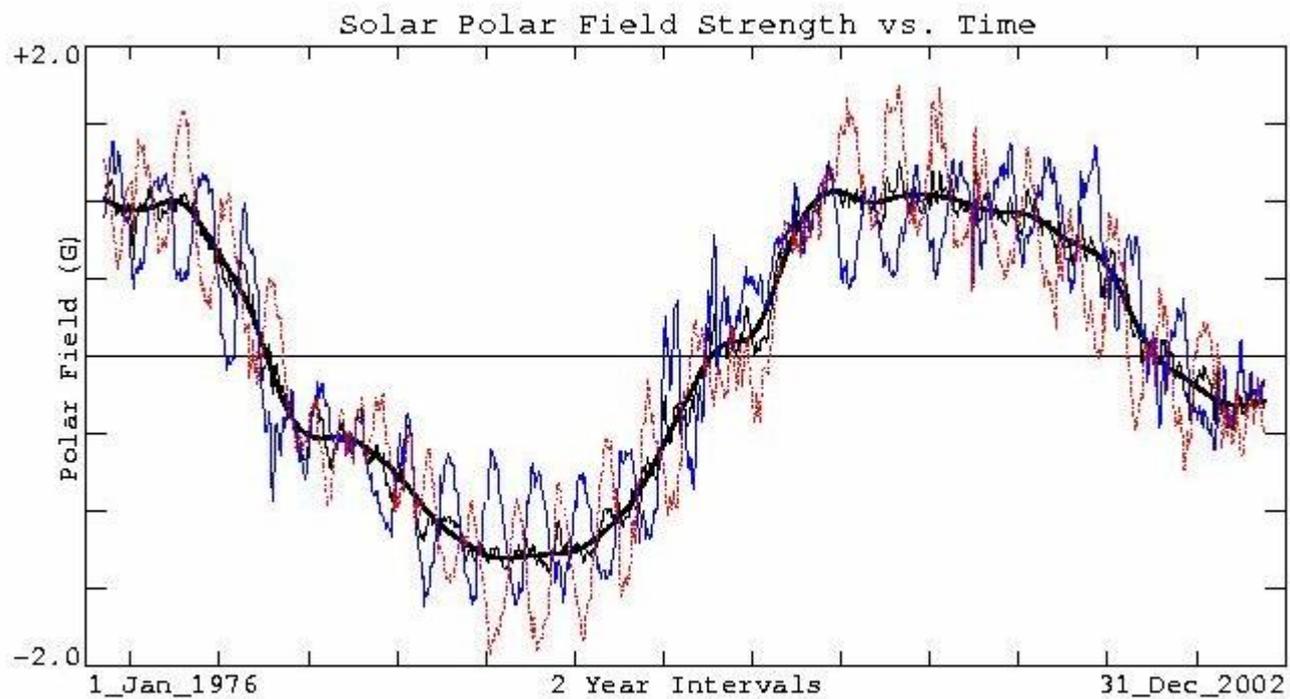
Overview

- Historical Perspective
- Sorting through the Issues
- Challenges and Opportunities



Historical Perspective (1)

- Observational Basis
(Babcock, *ApJ*, **133**, 572, 1961)
 - Sunspot cycle
 - Butterfly diagram (latitudinal progression)
 - Leader/follower asymmetry and polarities
 - BMRs: death by expansion
 - Poleward migration of prominence chain
 - Reversal of global solar magnetic field
 - Differential rotation
 - [Supergranular motions, meridional flows]

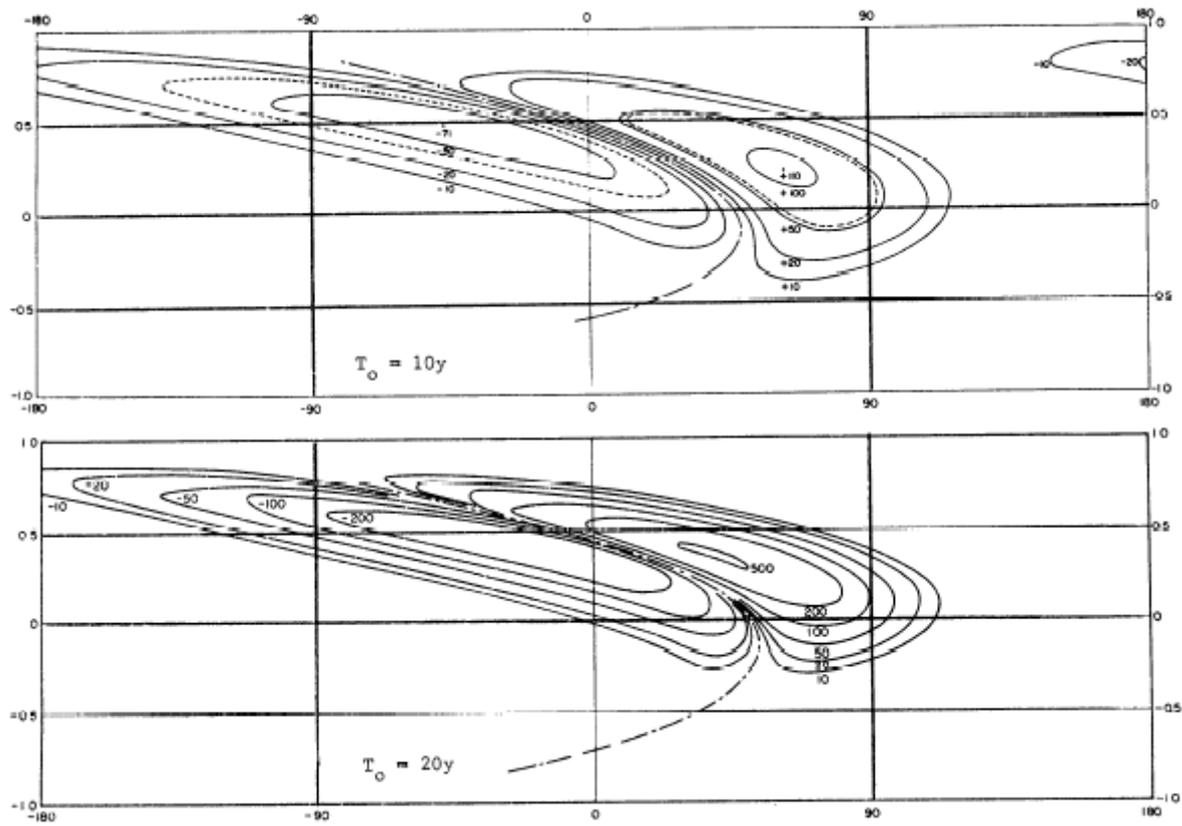


Key: Lt.Solid = North; Dashed = -South; Med.Solid = Average: (N-S)/2; Hvy.Solid = Smoothed Average



Historical Perspective (2)

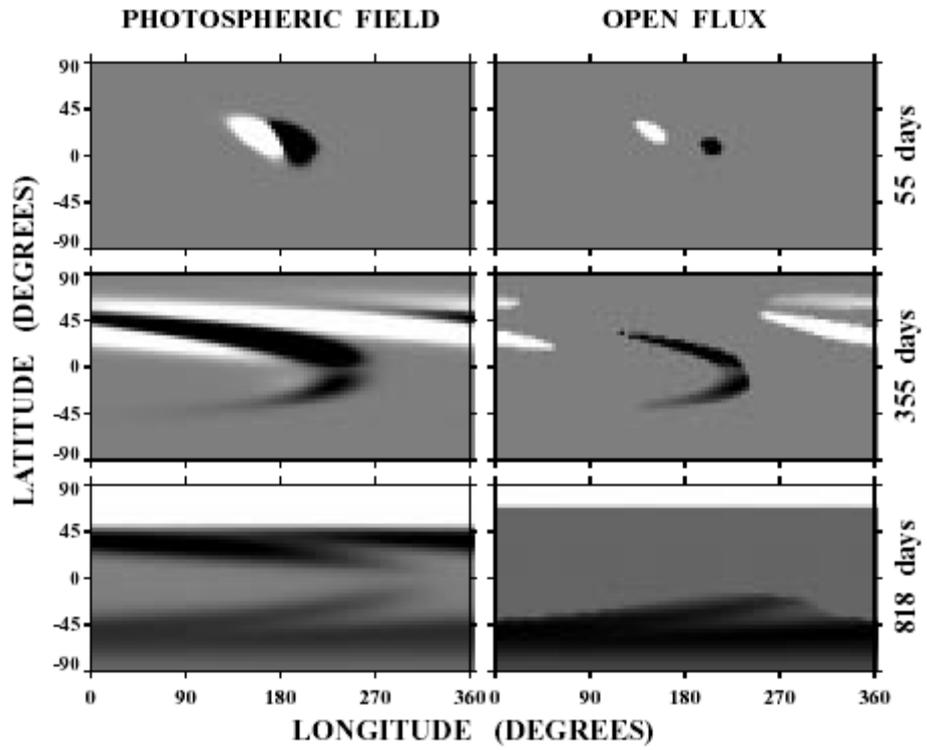
- Leighton model (*ApJ*, **140**, 1547, 1964)
 - Erupted flux disperses via supergranular random walk
 - Differential rotation, but no meridional flow
 - Surface dynamics only, smooth diffusive cancellation of expanding BMR fields
 - **Pre-CME & HCS**
 - Results:
 - Basics “explained”: Polar reversal, leader/follower expansion, poleward prominence migration
 - Shortcomings: Heavily idealized, too slow, smooth +/- transitions, *de facto* dynamo, no corona





Historical Perspective (3)

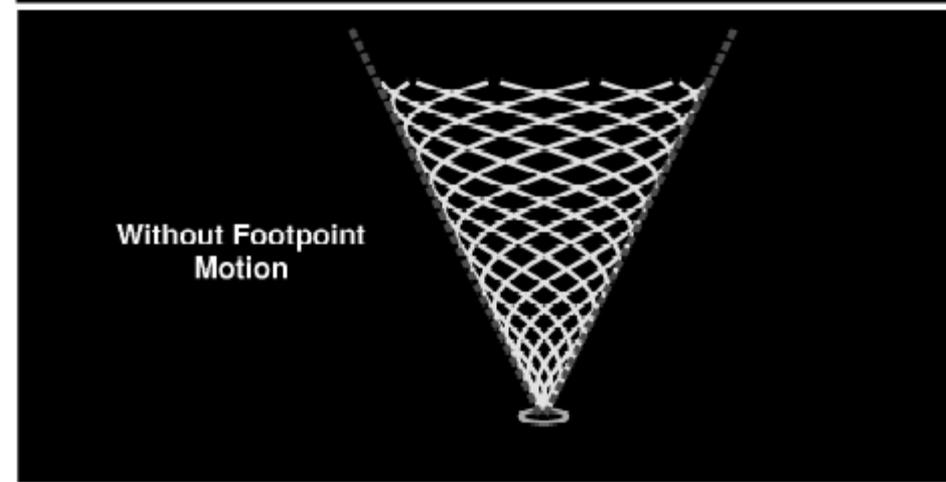
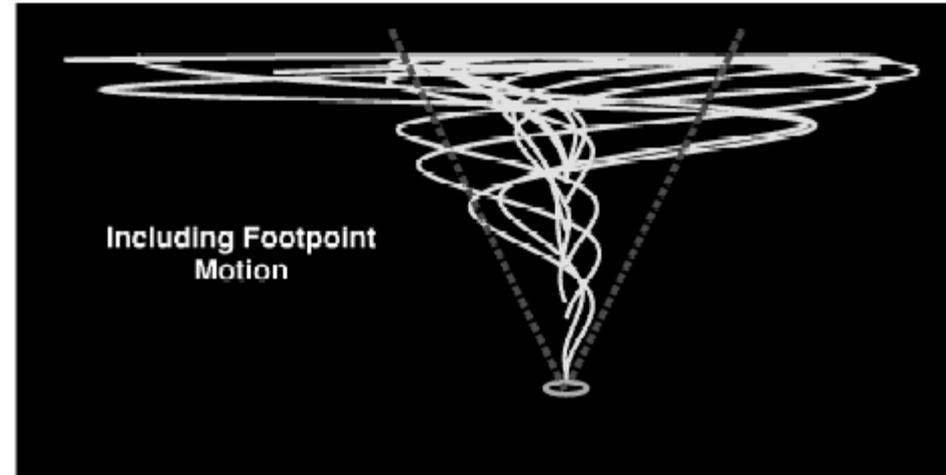
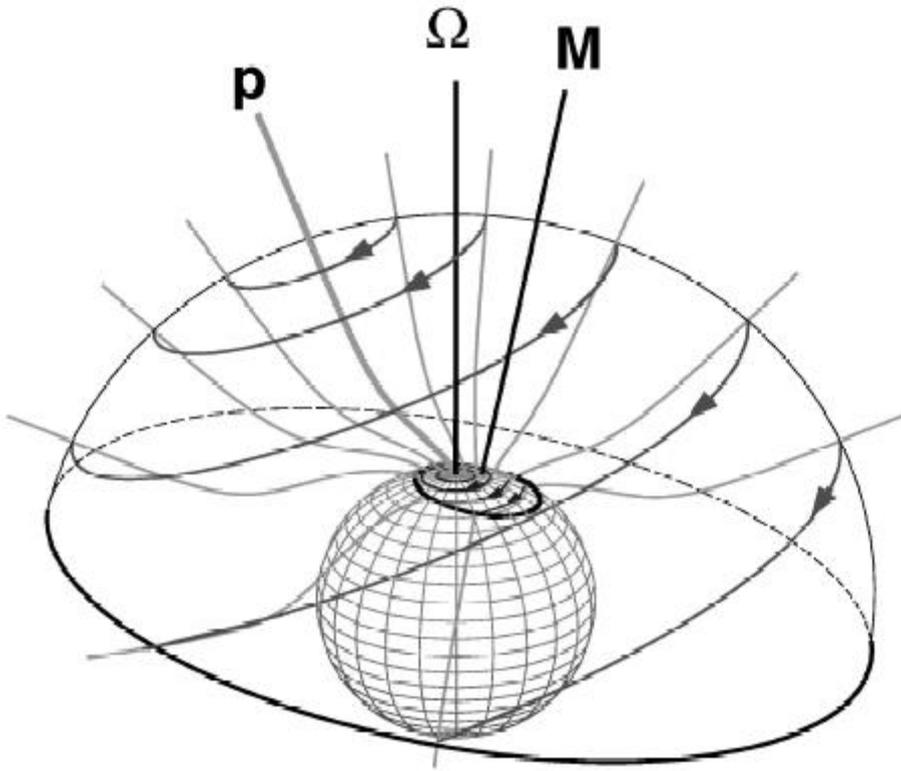
- Wang, Sheeley, & Lean
(*GRL*, **27**, 621, 2000; + *previous publ.*)
 - Include systematic meridional flows
(e.g., Komm *et al.*, *Sol. Phys.*, **147**, 207, 1993)
 - More realistic inputs
 - Main results:
 - Meridional flows speed latitudinal dispersal of flux
 - Evolution of **open flux**, relation to total flux
 - Emerging BMRs can be source of new open flux
 - Effects of nonuniform distribution of erupted flux

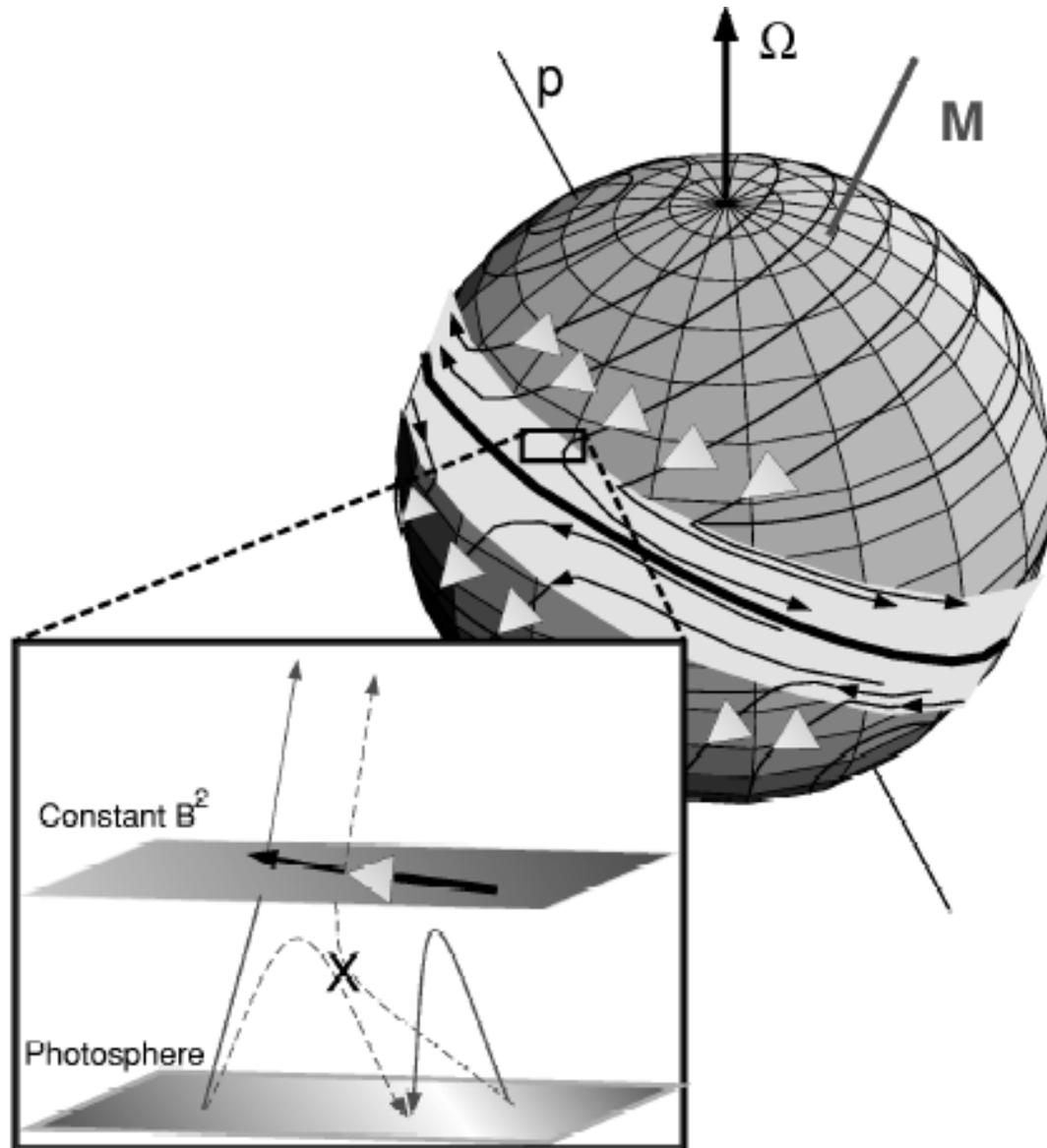




Fisk Mechanism (heliospheric)

- Fisk, Schwadron, & Zurbuchen
 - Reconcile observations of rigid rotation in corona with surface differential rotation
 - Follow consequences of magnetic fieldline footpoint motion due to differential rotation
 - (long-lived footpoints)
 - Restricted to high-latitude field
 - Produce non-Parker field topology (N/S particle transport)

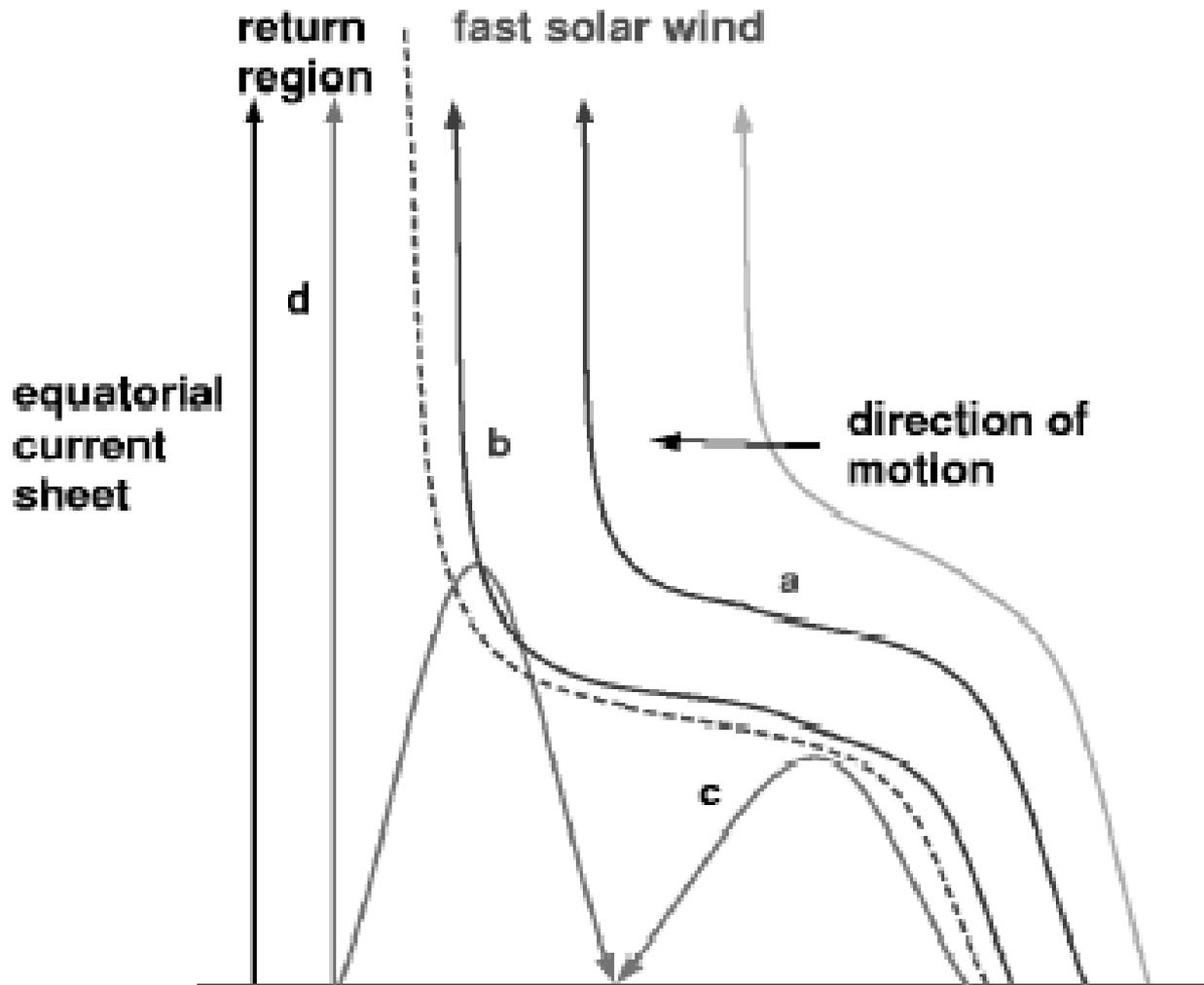


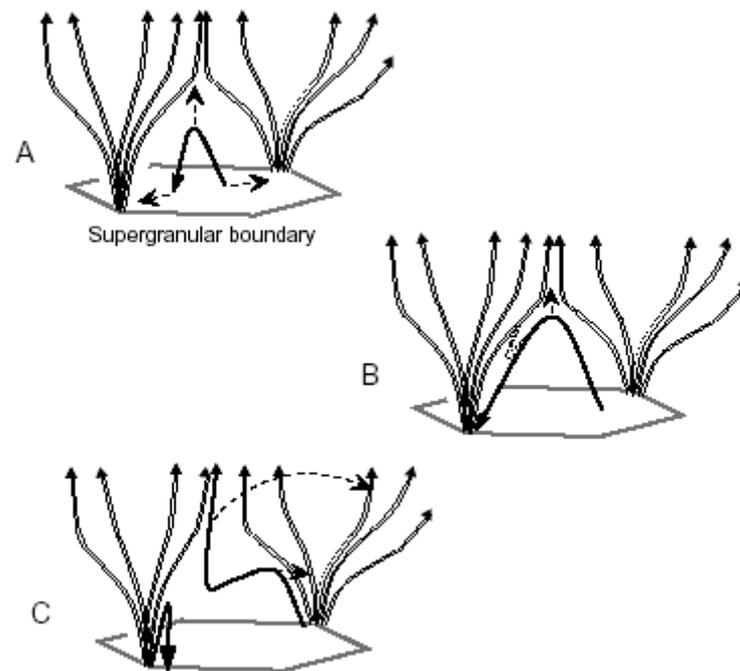
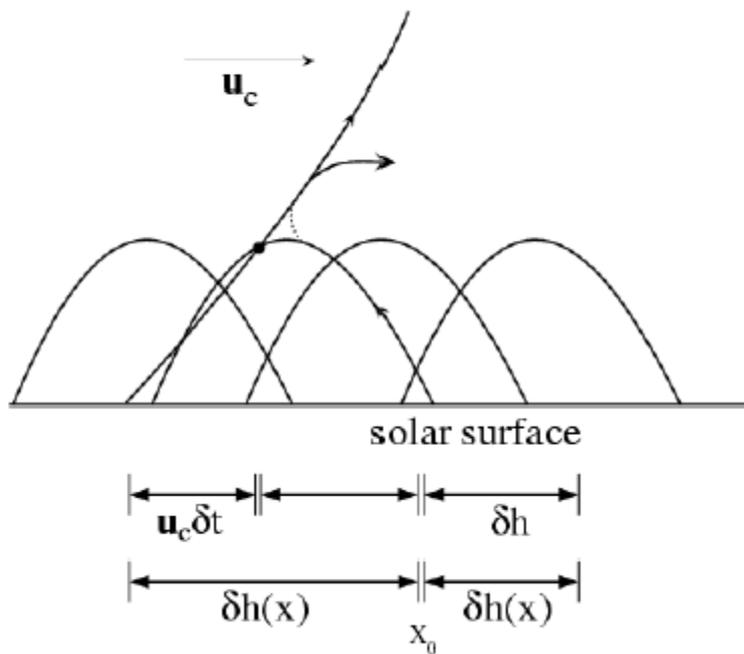




Fisk Mechanism (Corona)

- Account for interaction of differential rotation with HCS & streamers
- Consider “interchange” reconnection (driven by differential rotation) in open and closed regions
- Model for field reversal
 - “constancy” of open flux
 - rotation of HCS







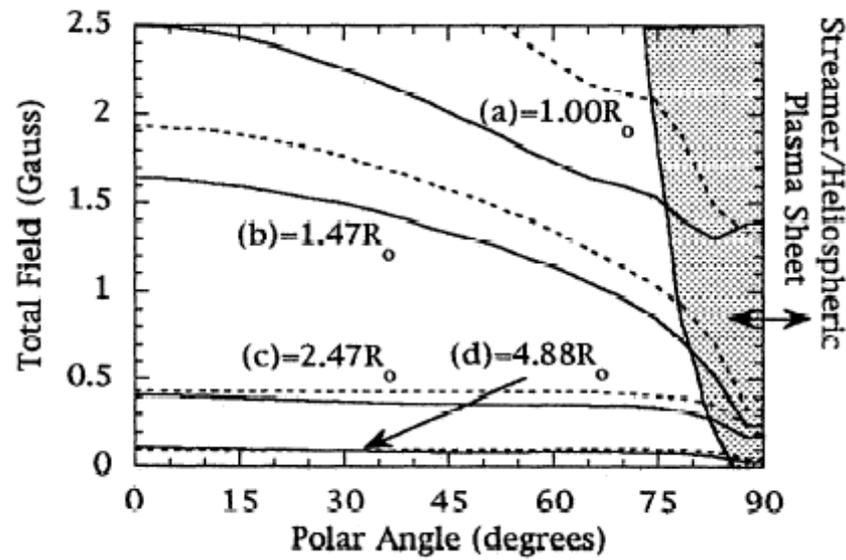
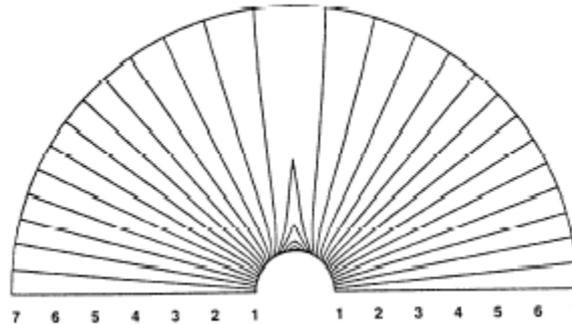
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Open flux as the key

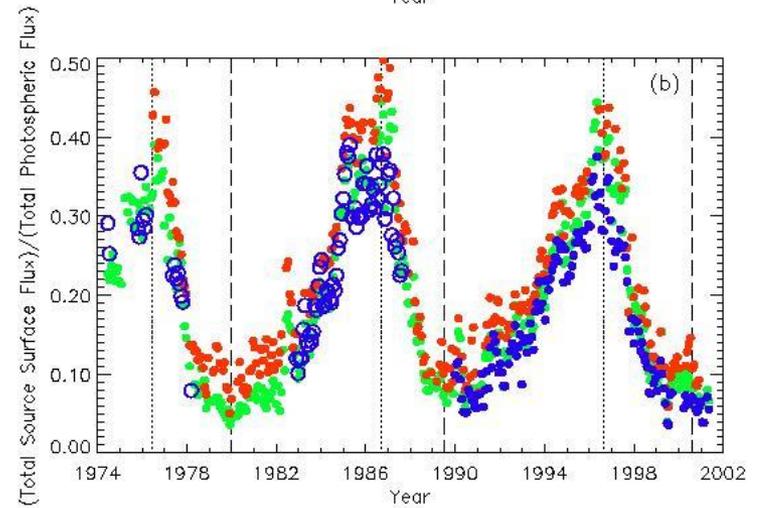
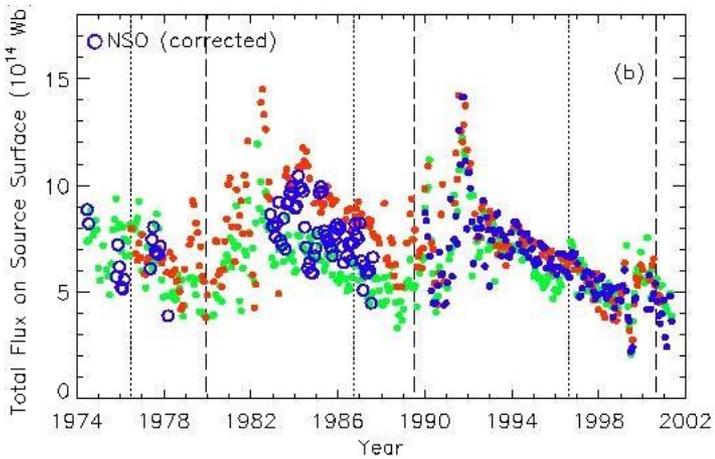
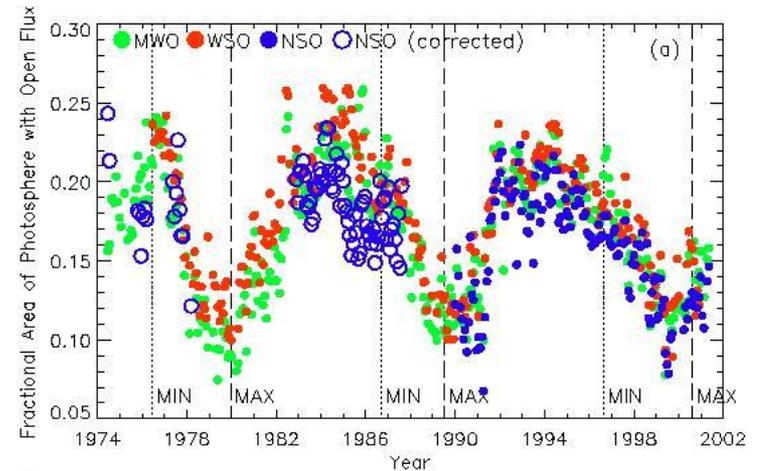
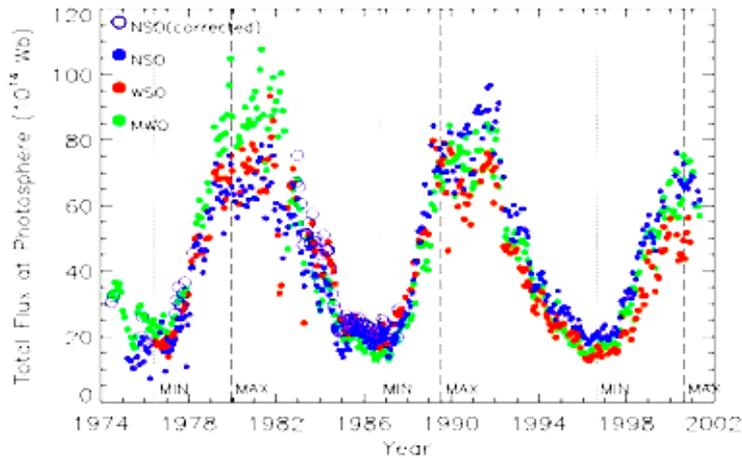
Suess *et al*

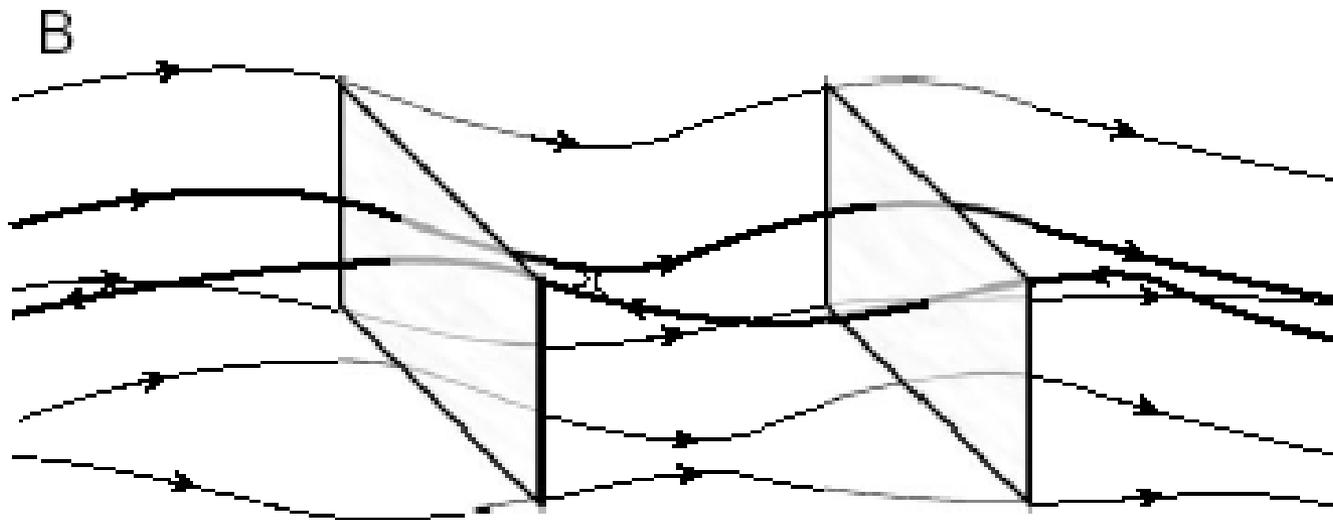
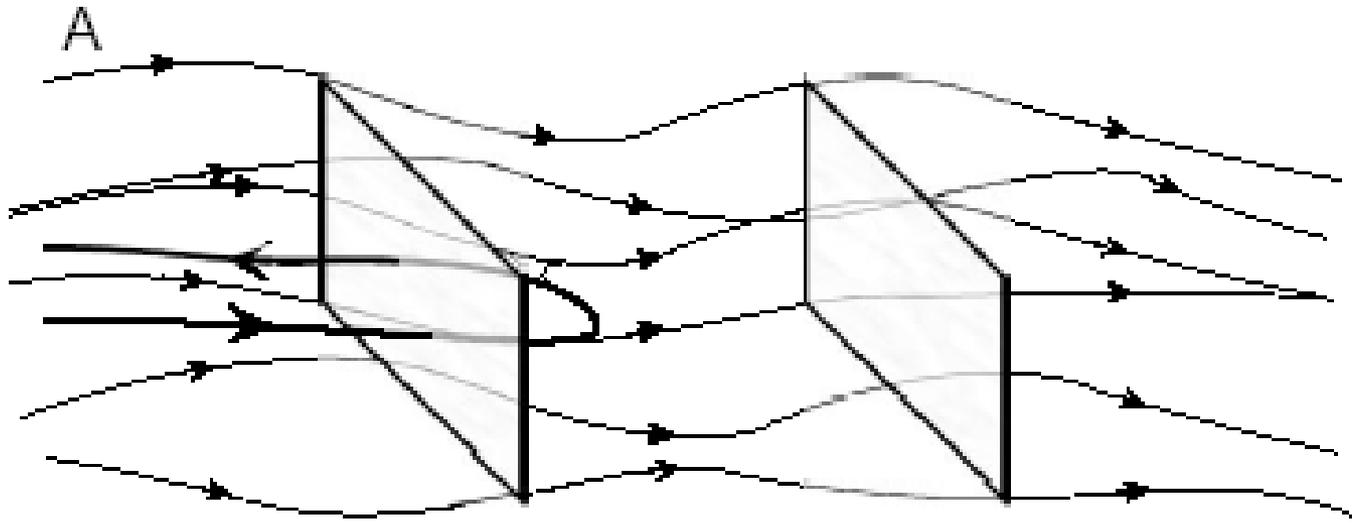
Magnetic Field Lines

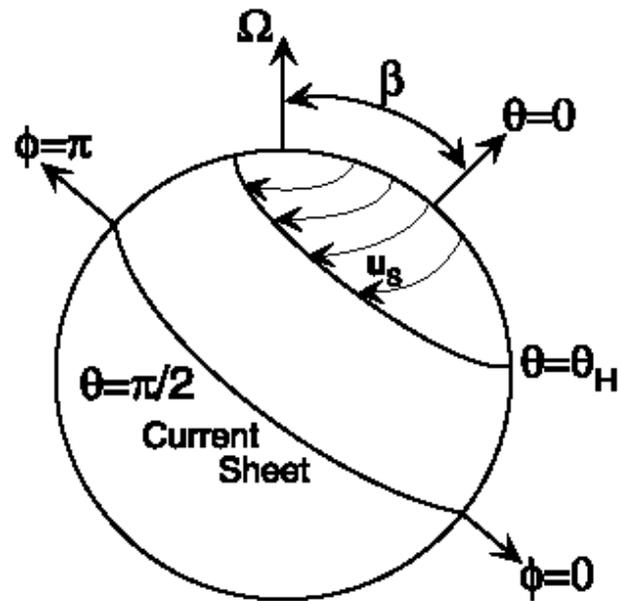




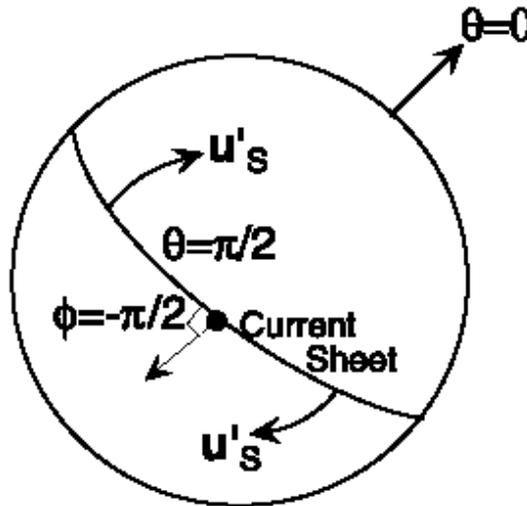
Arge et al., *JGR* (in press)







Solar Minimum



Solar Maximum



Northern Hemisphere Coronal Hole Evolution Preceding the Polar Reversal May 1989 - July 1990

Fox,
McIntosh,
& Wilson

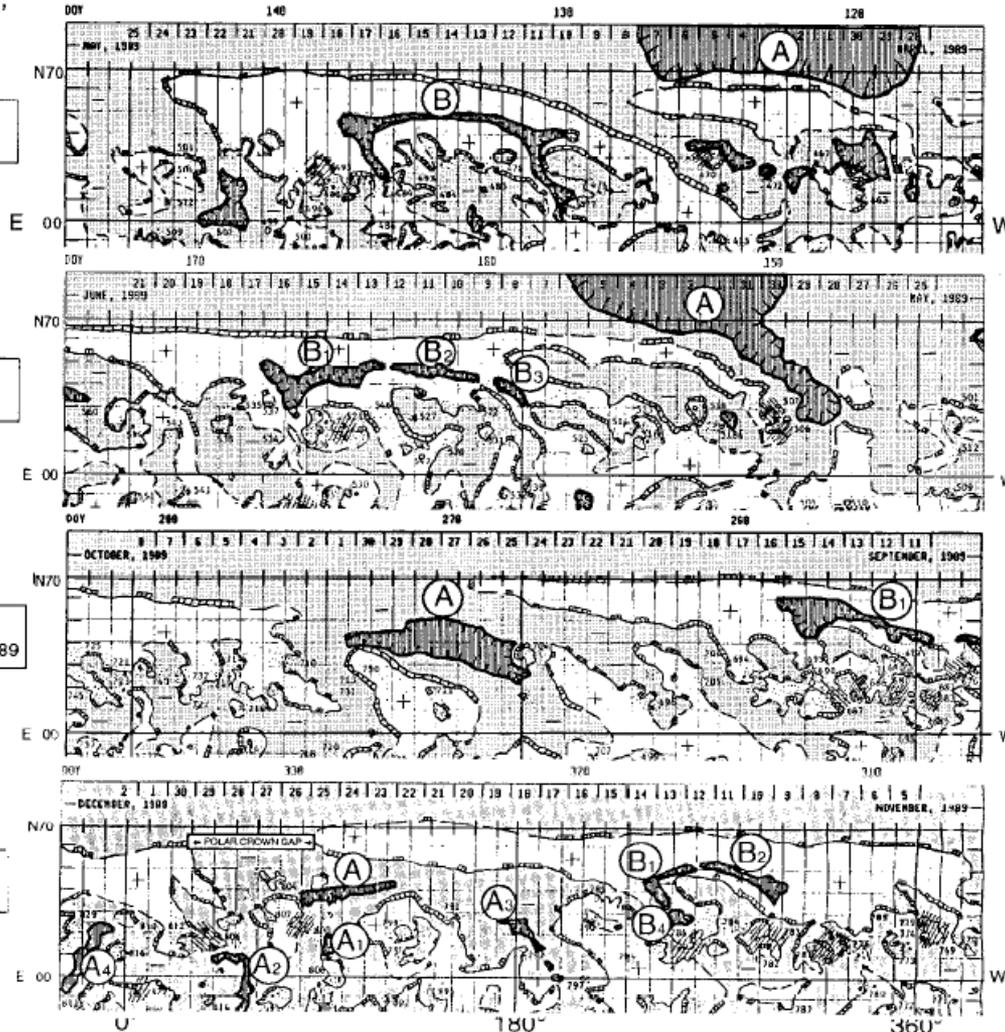
Carrington
Rotation,
Month

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May 1989

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June 1989

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Sept - Oct 1989

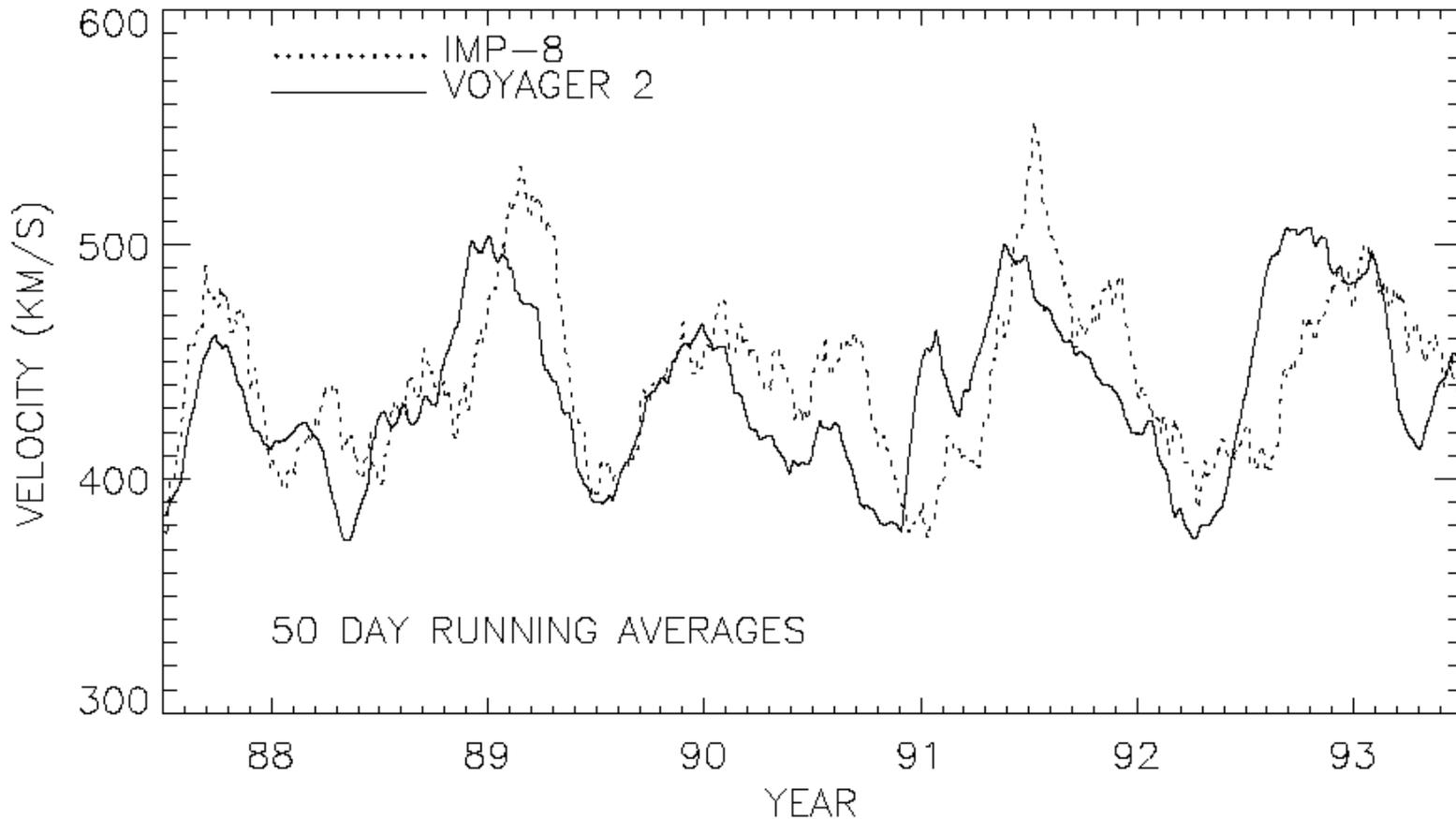
1822
Nov 1989



HELIOGRAPHIC LONGITUDE



Richardson *et al.*, *GRL*, **21**, 1559-1560, 1994

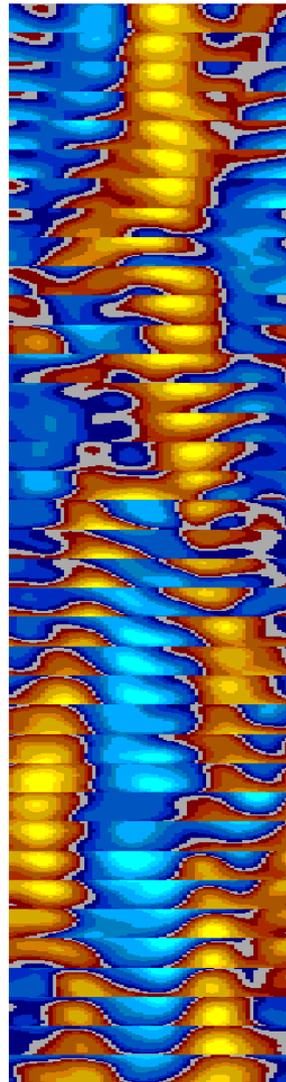
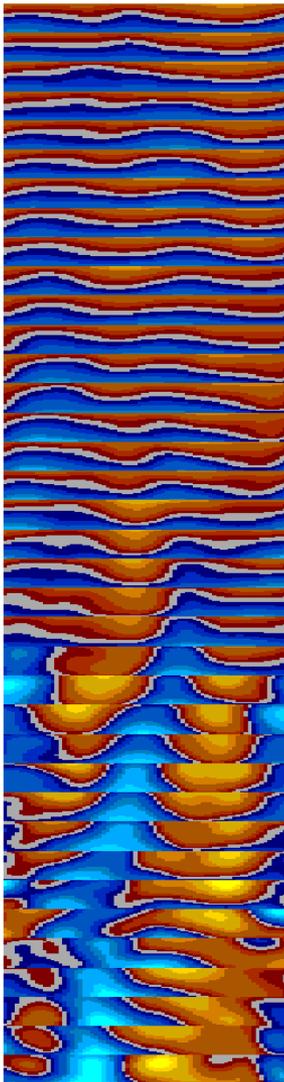




WSO Classic Source Surface Field

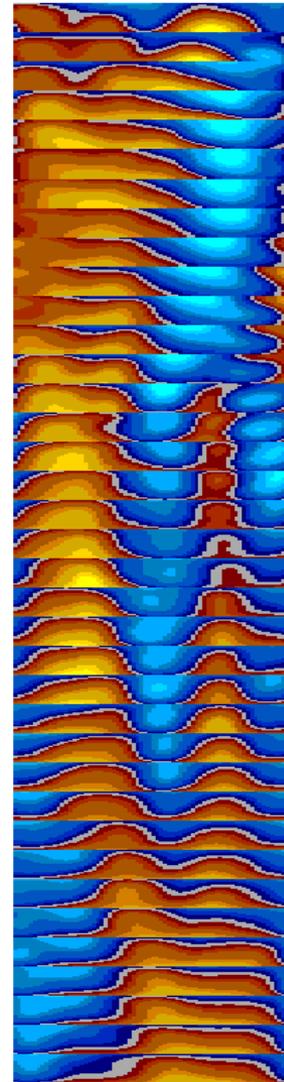


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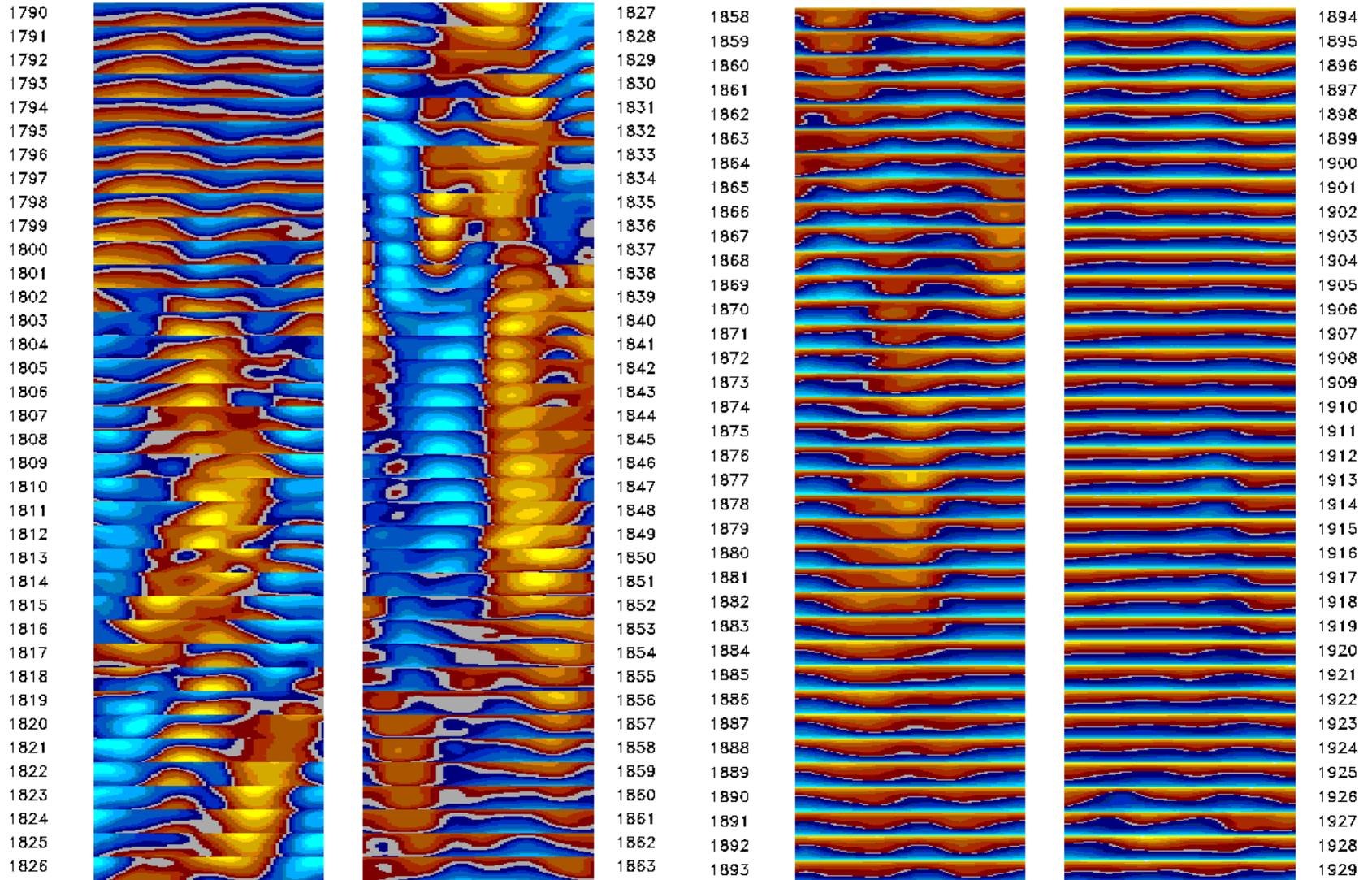
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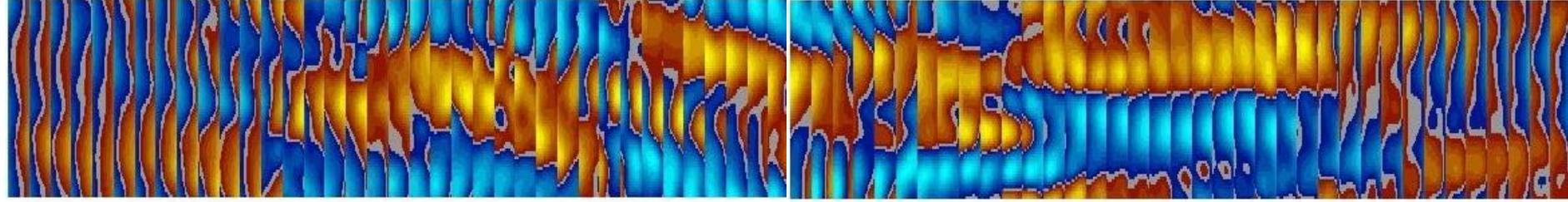
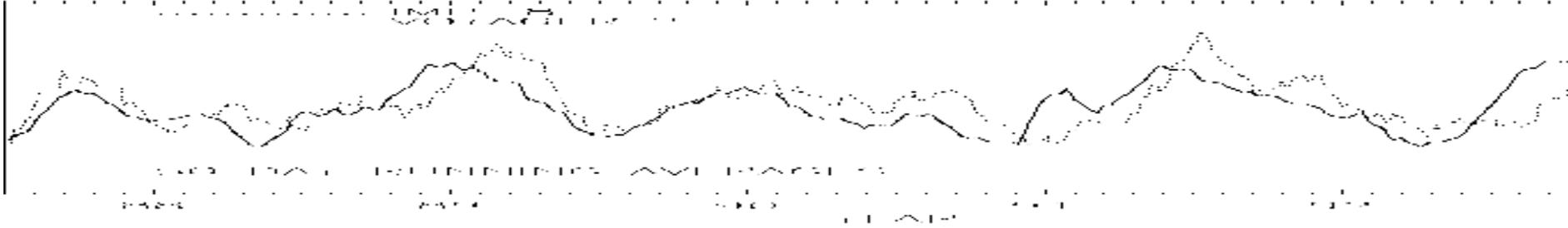


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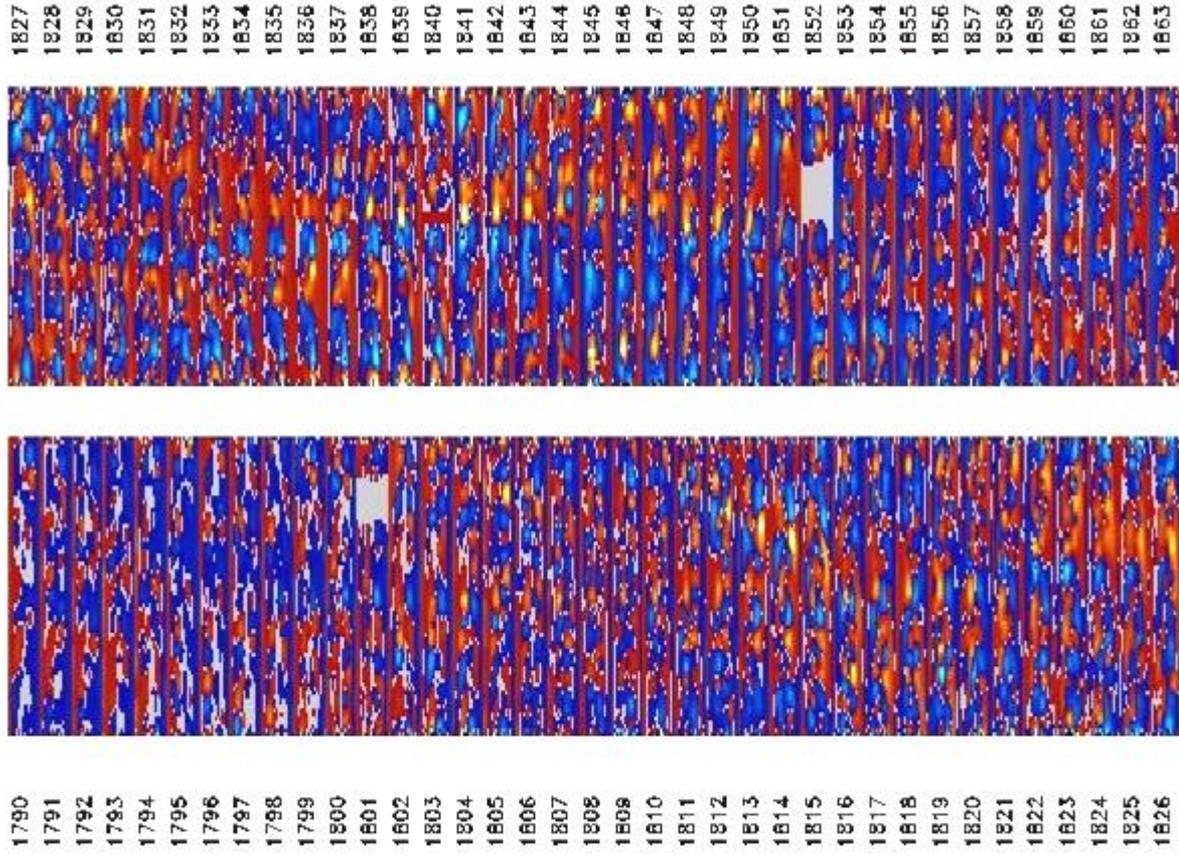


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MWO Photospheric Field



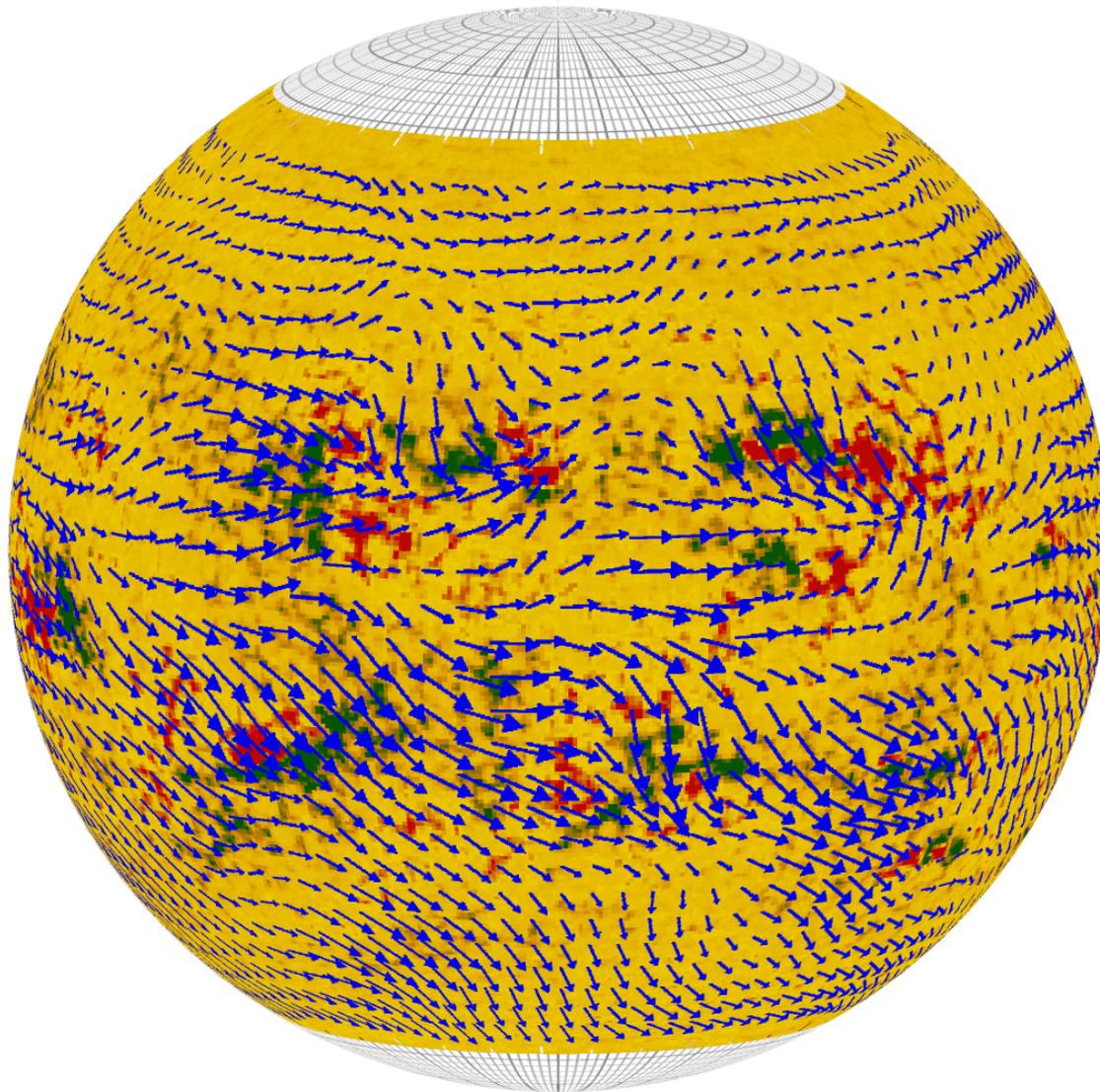


Sub-surface Driver?

- Torsional Oscillation
- Solar weather via helioseismology
 - Role of systematic subsurface motions
 - “Gulf stream” analogy?

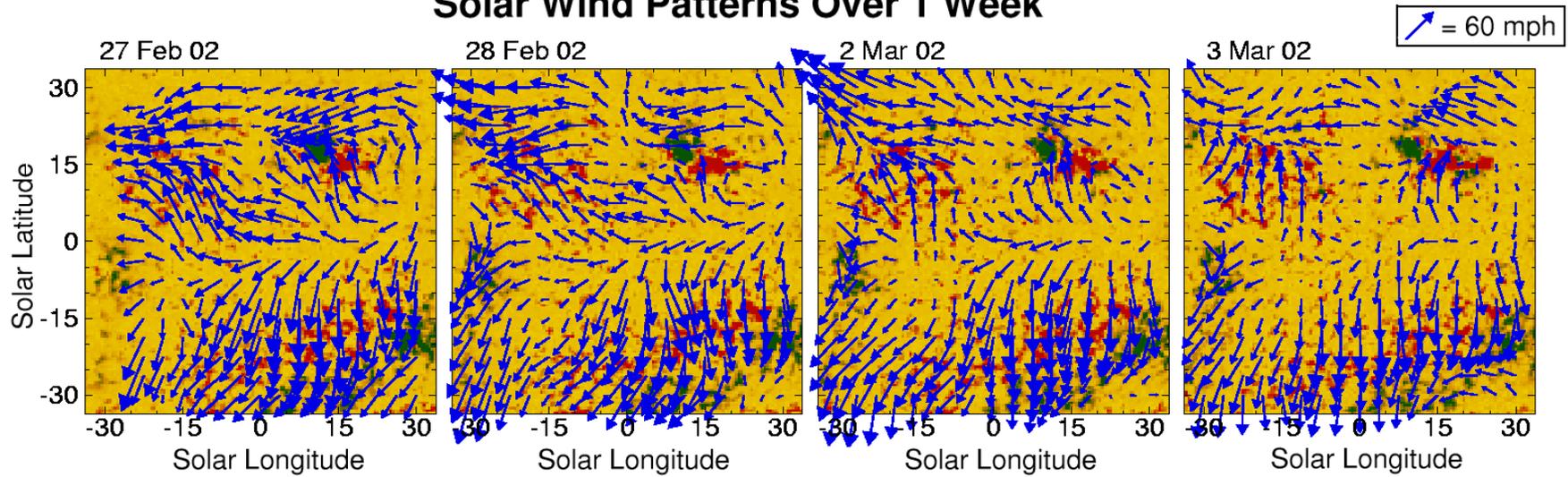


Haber et al.





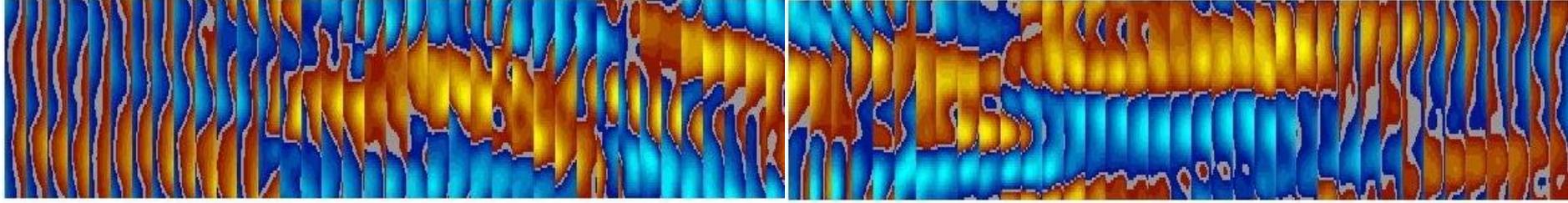
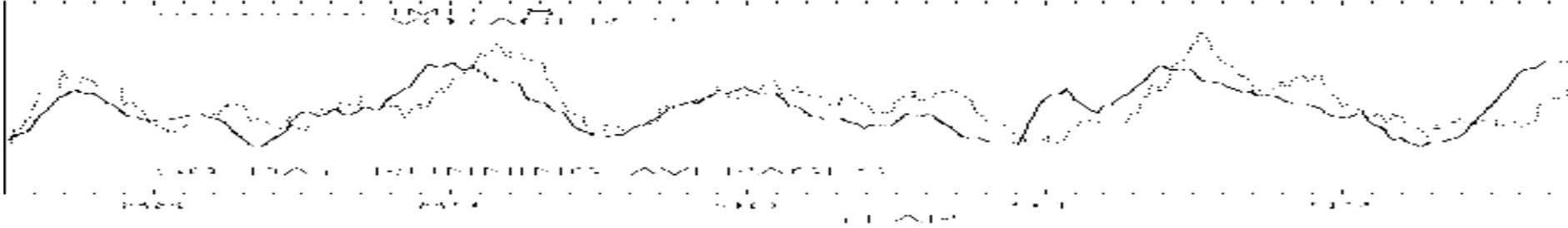
Solar Wind Patterns Over 1 Week





1.3 year Coronal “Cycle”

- Heliospheric identification
- driven by dynamo (photospheric field)?
- relation to torsional oscillation?
- relation to polar field reversal?
- relation to Fisk mechanism?
- heliospheric manifestation?



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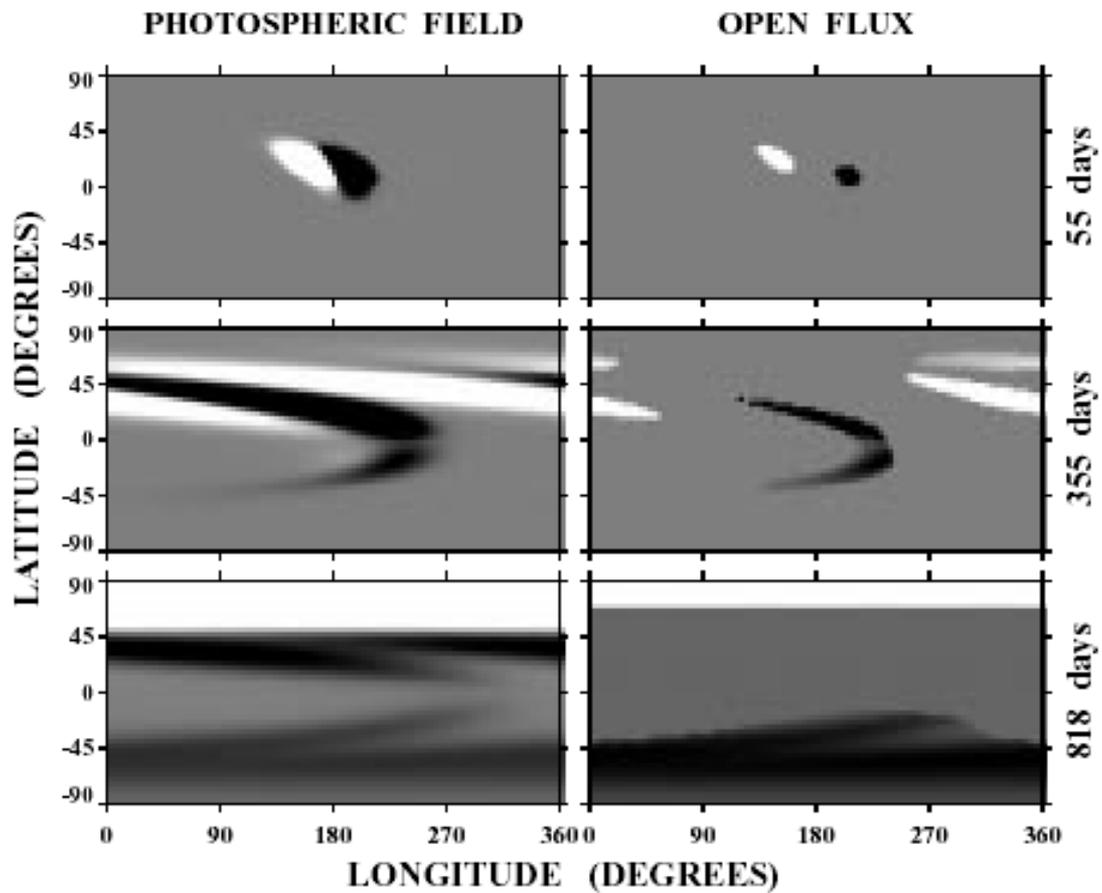
Role of CMEs

- Why are they there? ([Earthquake analogy](#))
- Remove flux? (flux catastrophe: how well can we identify detached field *in situ*?)
- Remove helicity?
- Driver or agent of exchange reconnection?
- Relation to large scale coronal topological evolution
 - Location (streamer belt, switch-backs, delta config.)
 - Frequency (temporal clustering?)
 - Type (complex, fast vs slow, polar crown, etc.)
- Coronal source of GMIRs?



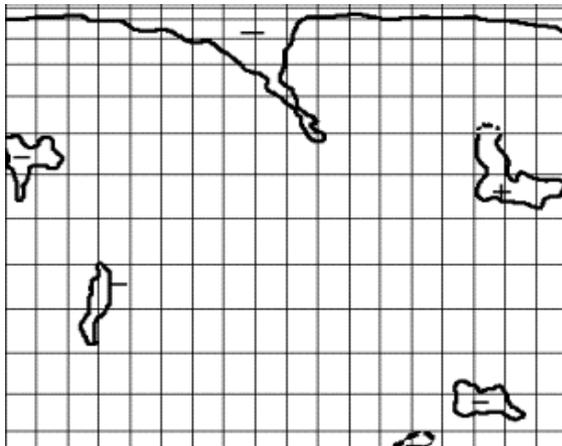
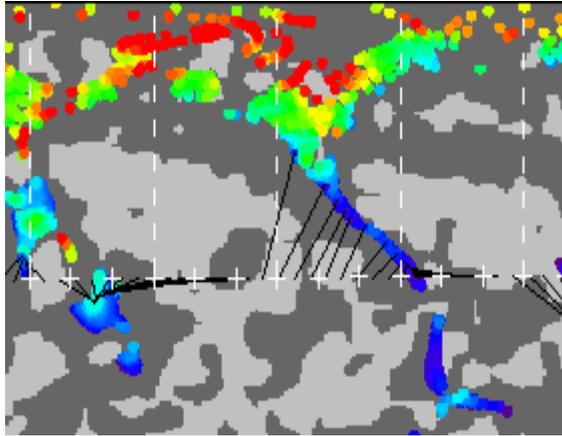
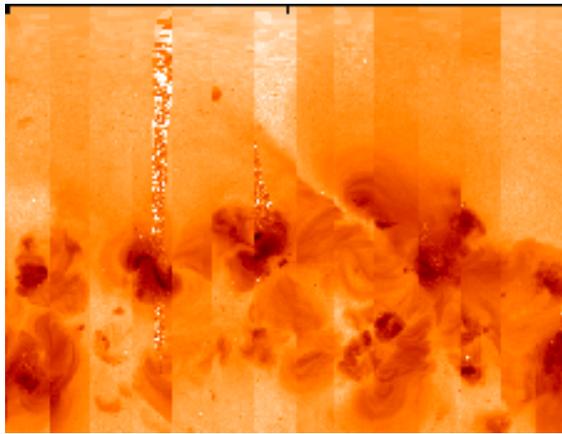
Challenges and Opportunities

- Timescale and pattern of coronal topological changes
- Frequency and distribution of CMEs relative to coronal topological changes
- Open flux → hole vs open region
- STEREO target: location of CMEs
 - surface activity poor indicator of longitude
- HCS and heliospheric structure during major episode of change





Arge,
K Harvey,
Hudson,
& Kahler





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