

# A Shallow Solar Dynamo and Decadal Forecasting

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Currently though he is recovering from torn rotator cuff

Thanks to colleagues: Mayr, Pesnell, Scherrer, S and UJ  
Sofia, Svalgaard, Wilcox, and others.



# Shallow Dyn, Forecasting, Sol Min

1. **Shallow Solar Dynamo – Novel Ideas about location of Dynamo; Relates to accumulation of EPRs (Ephem. Regions) via “percolation” = strain/filter ; toroidal B like Babcock-Leighton.**
2. **Decadal Forecasting – Uses Polar Field near Minimum to predict size of cycle – small - small**
3. **Recent Solar Minimum -- Weak Polar B, ∴ SLOW RISE of cycle #24, and ∴ extended Min. Polar B is just remnant of cycle #23 detritus – Flotsam and Jetsam.**



# Shallow Solar Dynamo -Percolation

- Introduction and Overview
- Ion Hurricane Mechanism – In- & Down-flows below spots gather neutral H & field below spots. Similar to how water vapor is gathered into clouds in the outer vortex of a terr. hurricane.
- Lockheed Group’s view of Ephemeral Active Regions (EPRs), (X-ray Bright Points) and the Corona
- Percolation –EPRs may gather into spots, under special conditions – high S and large horizontal B.
- The Solar Dynamo & Cellular Automata Modeling



# INTRODUCTION

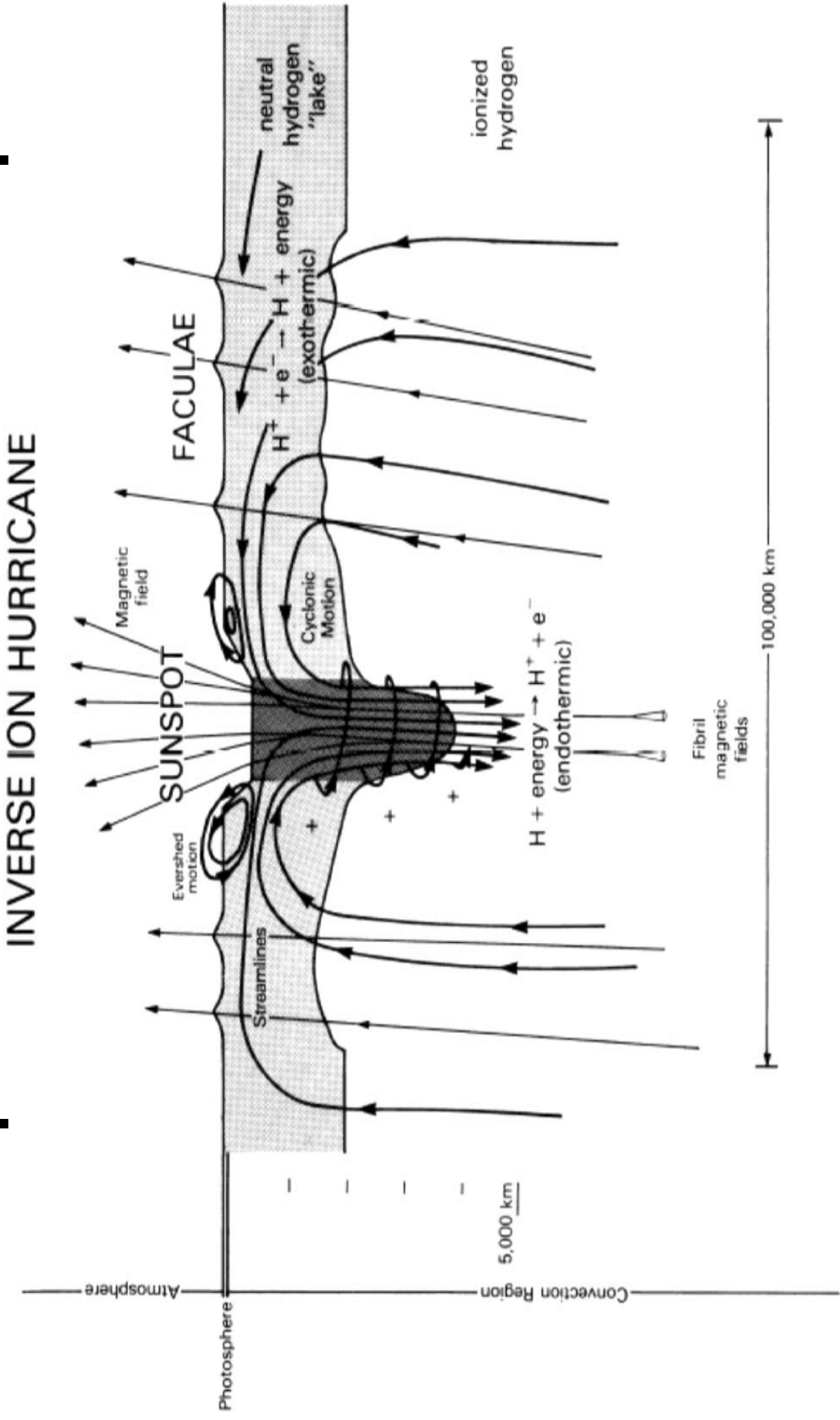
- Percolation comes from Percolare to Filter/Strain may also be called clustering – gathering together.
- Act. Region Percolation began w. Seiden & Wentzel. Ruzmaikin said magnetic field clusters. Brandenburg also considered a shallow solar dynamo.
- Overall, our Model represents a non-linear magnification of small scale fields near the Sun's surface to gather (percolate) to form Active Regions.
- Toroidal (Babcock-Leighton) fields are formed by Differential Rot. of Poloidal field. This subsurface B-L Field helps percolation to form AR's; when they break up, they migrate towards the poles (FLOTSAM AND GETSAM), and opposite polar fields then regenerate.



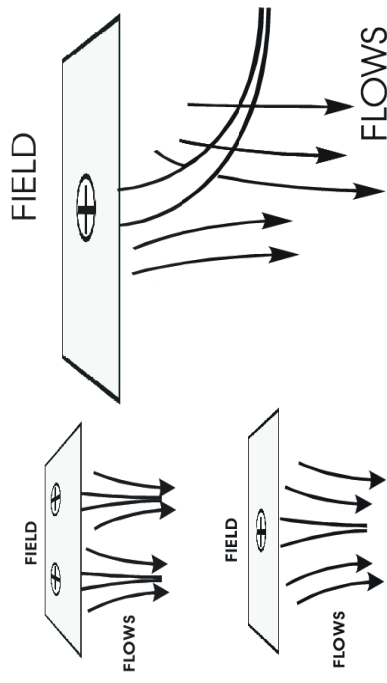
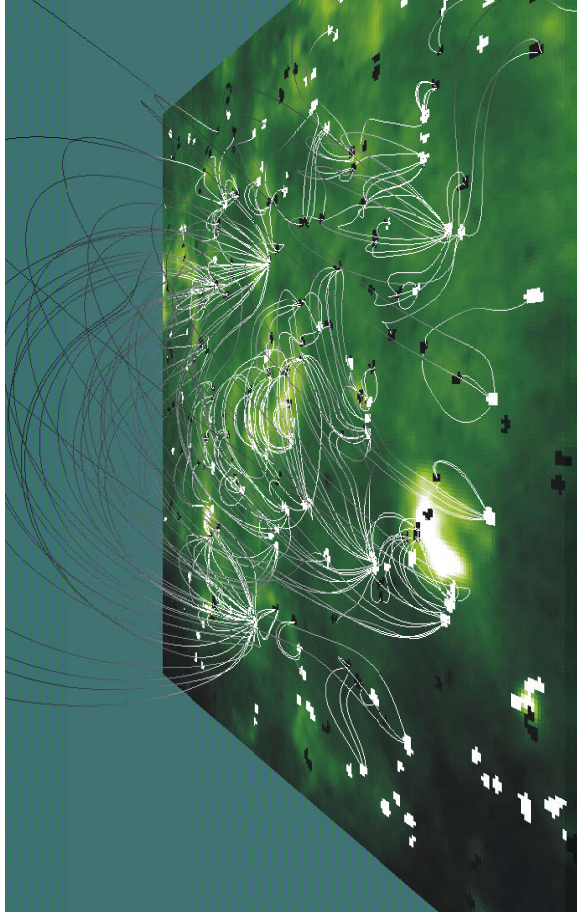
# OVERVIEW

- **LARGE FIELDS RESULT WHEN LIKE-SIGN EPR BS GATHER & DIFFUSE: INVERSE CASCADE**
- **B FIELDS MOVE ON THE SUN'S SURFACE – DRIVEN BY SUBSURFACE MAG. FORCES, MERID. FLOW + D.ROT: NOT SOLELY DIFFUS.**
- **B IS BUOYANT: EVADES ↓ DESCENDING**
- **HOW FIELDS FORM SPOTS AND FACULAE**
- **ROLE OF S TO ACTIVE REGIONS, FIELD, ETC.**
- **MODELING EFFORTS: CELLULAR AUTOMATA**

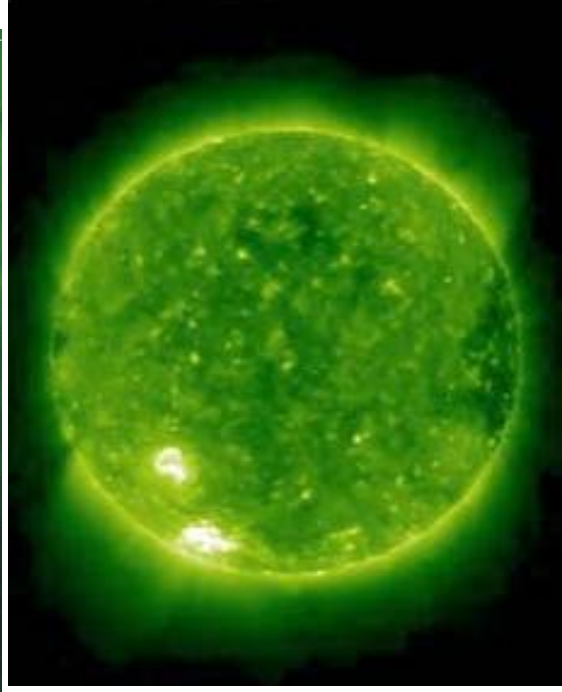
**Schatten&Mayr: Shallow Surface Layers:  
 S large; latent energy (H to H<sup>+</sup>) available;  
 convective collapse (Zwaan,Parker)  
 occurs/process allows field to form spots.**



# Lockheed Group-Magnetic Carpet: EPRs Conv. Collapse of Fibrils: Percolation



**Flow can go DEEP!**



12/2008  
EIT/SOHO  
EXTREME  
UV  
IMAGING

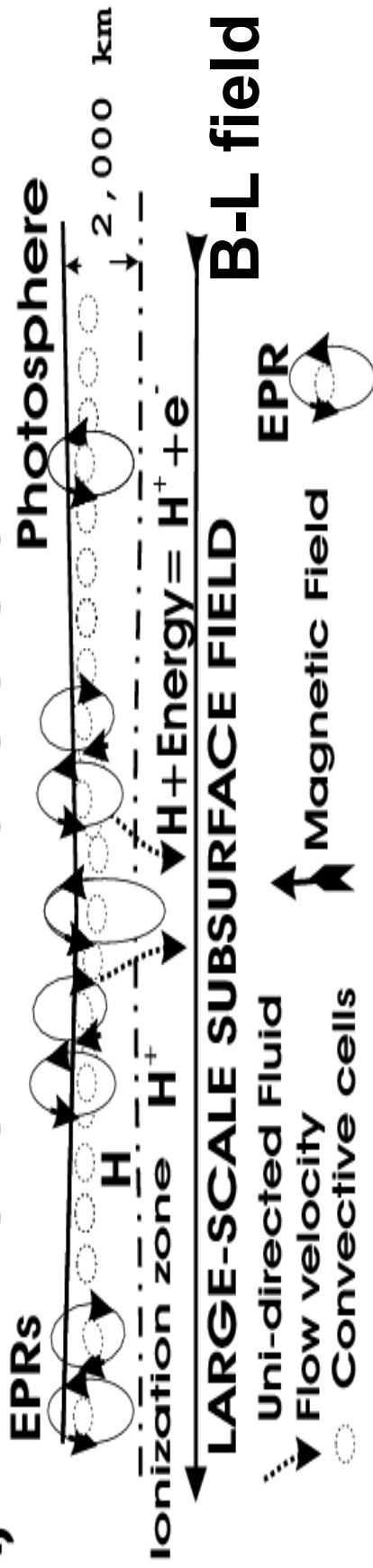


a.i. solutions

# SUPERADIABATIC PERCOLATION

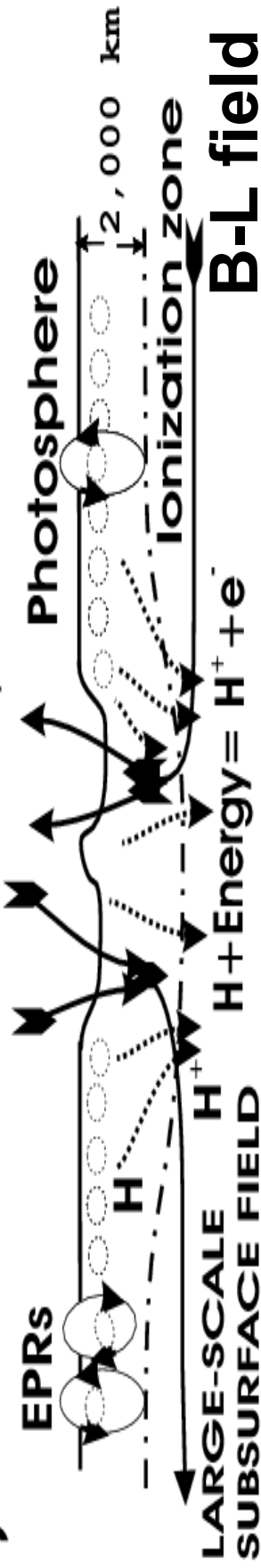
A)

GROWTH: EPRs TO SPOTS



B)

GROWTH: TO SPOTS/BMRS



C)

DECAY: TO FACULAE/PLAGE

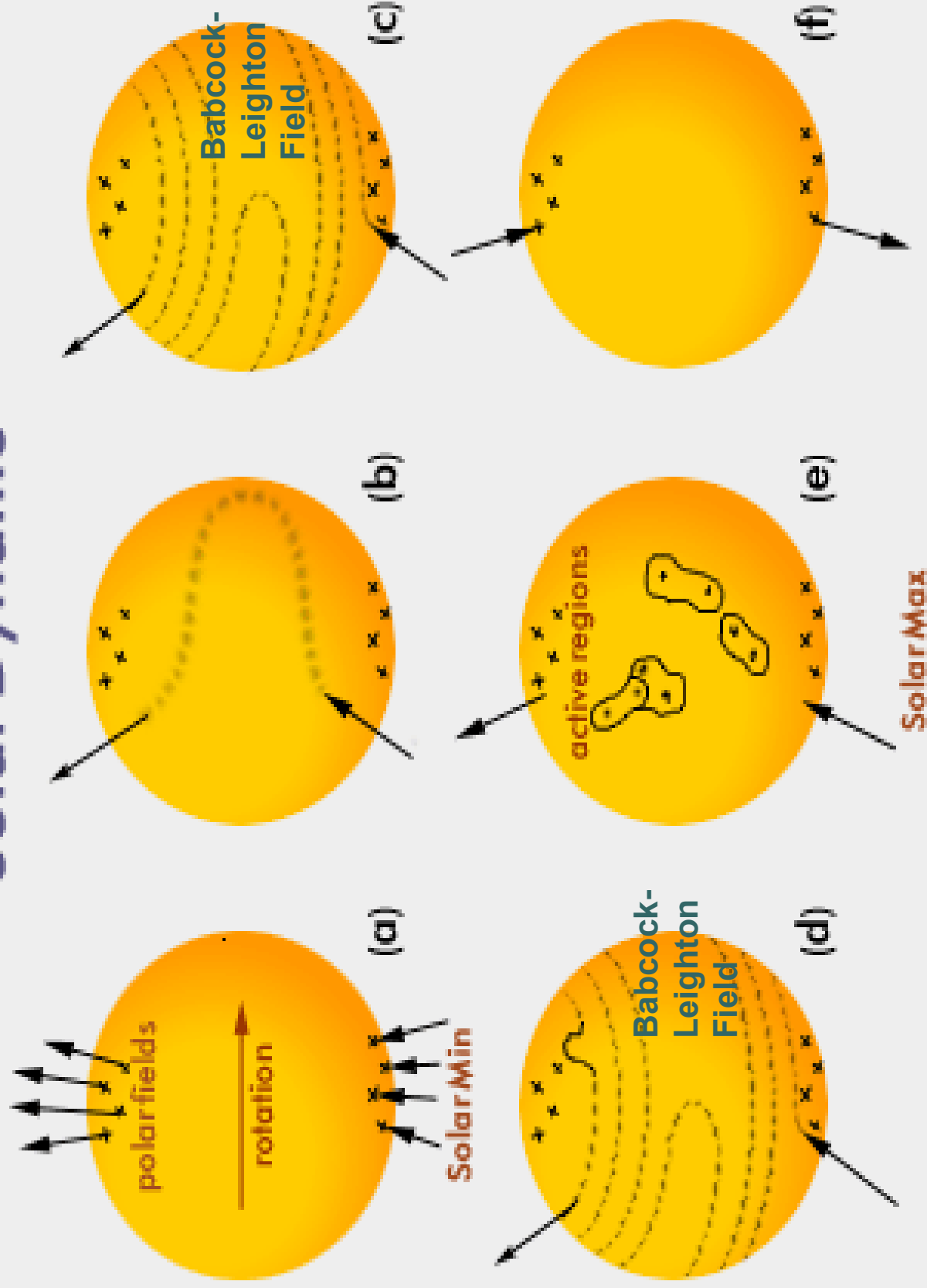


B-L field

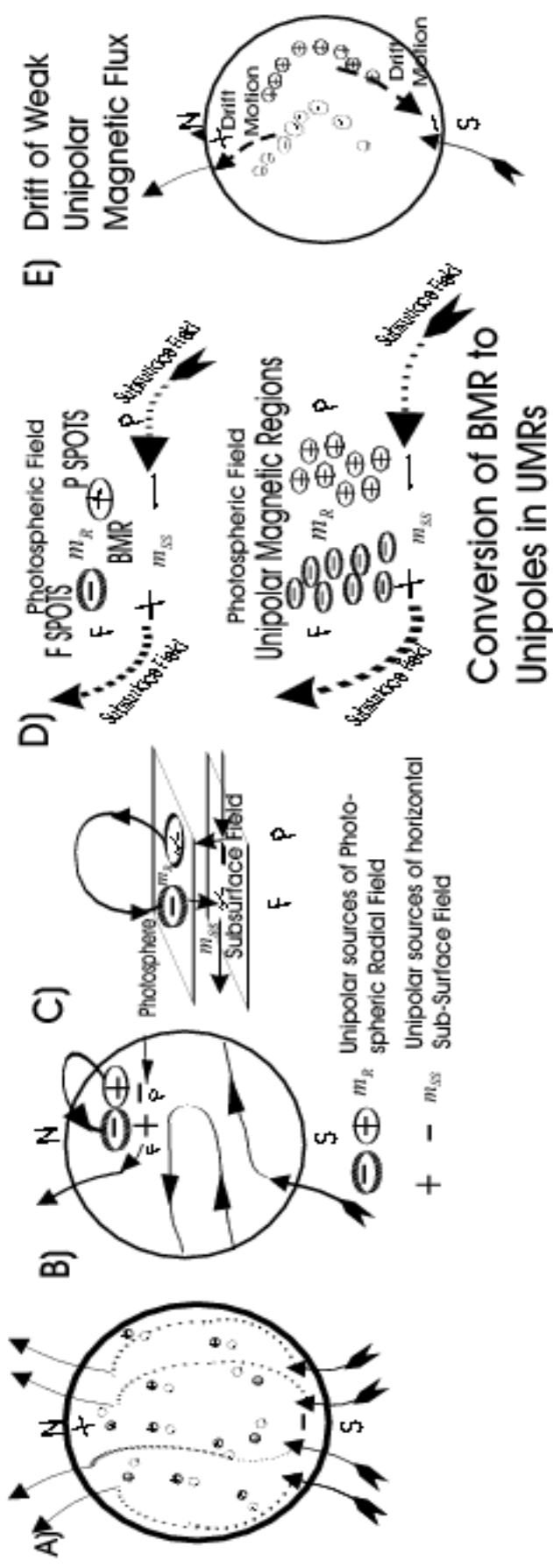


# Physical basis for solar and geomagnetic precursor techniques

## Solar Dynamo



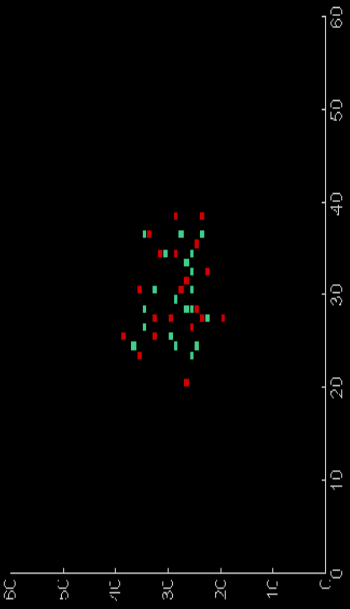
# 3D VIEW: Shallow Dynamo-B moves by B TENSION (=mB), not diffusion



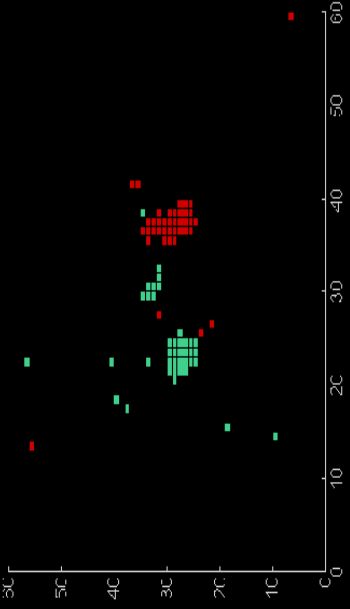
Development of Fields During an Odd # Cycle:

NH Following Flux => NH pole; NH Preceding Flux => SH pole  
 Vice Versa for SH Fluxes, and Even # Cycles

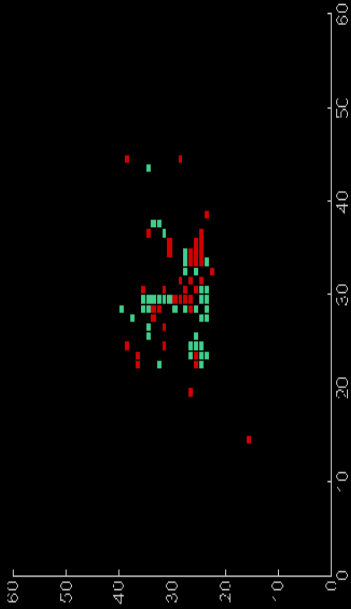
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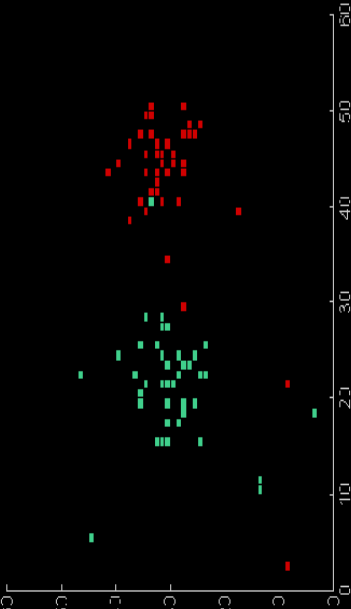
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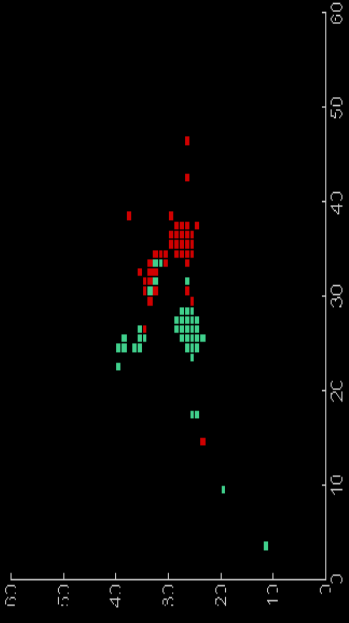
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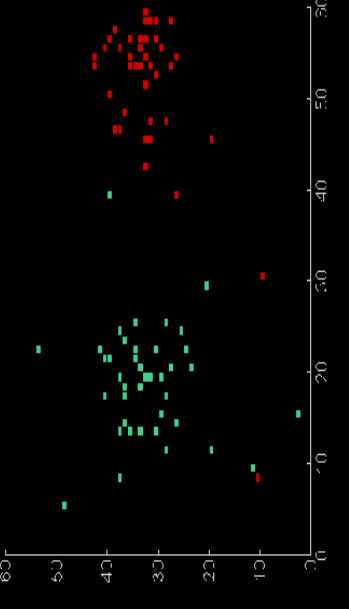
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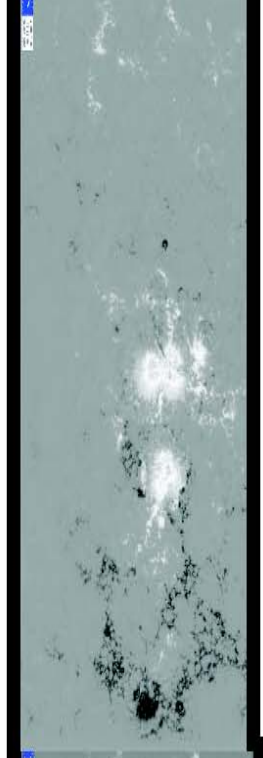


# Superadiabatic Percolation, Field Drift, and Normal Percolation into Unipolar Magnetic Regions (UMRs)

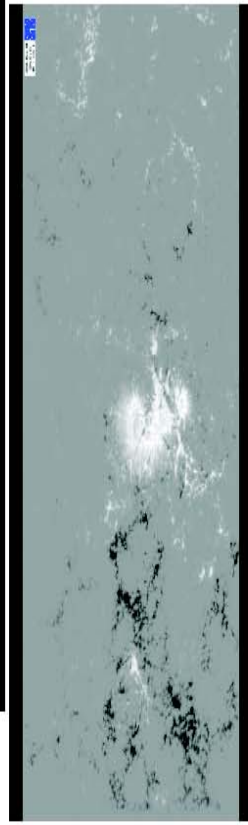
New Region: Like Fields Move Together (White=>White)



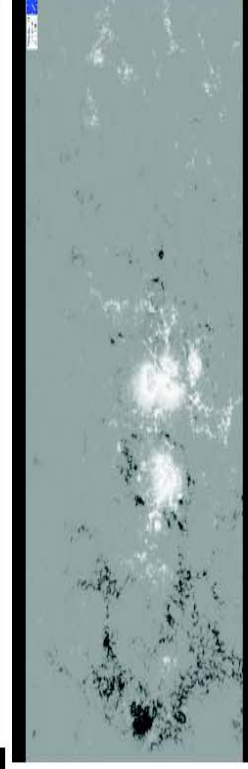
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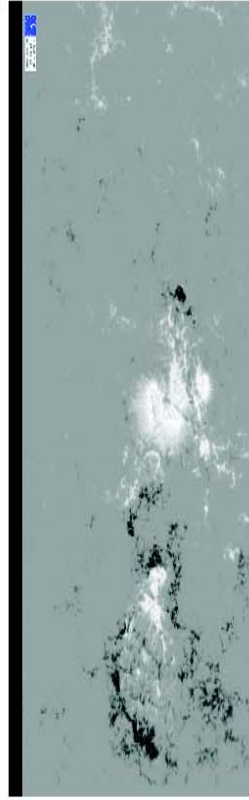
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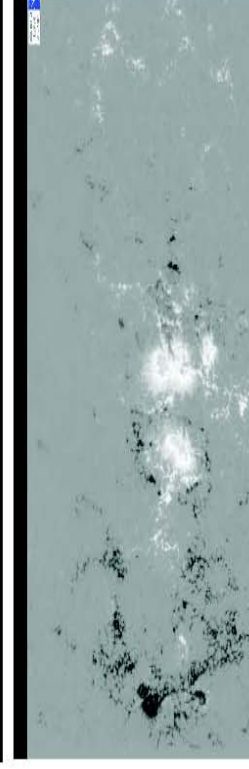
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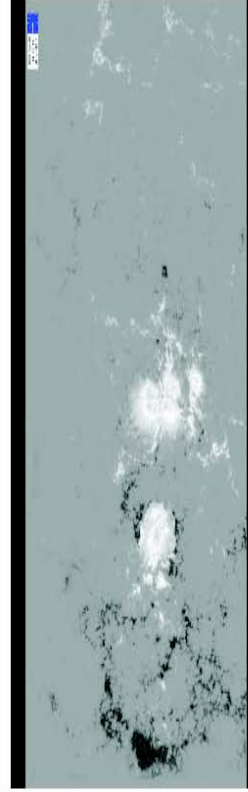
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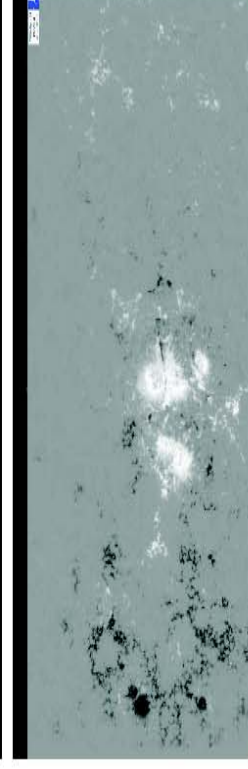
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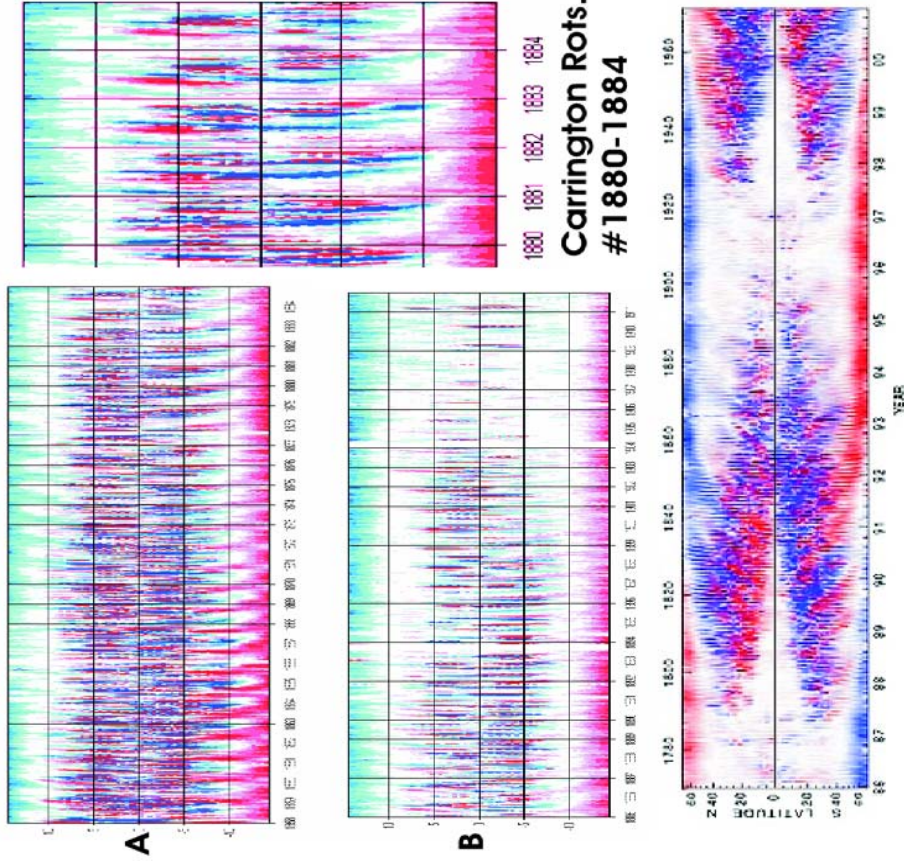


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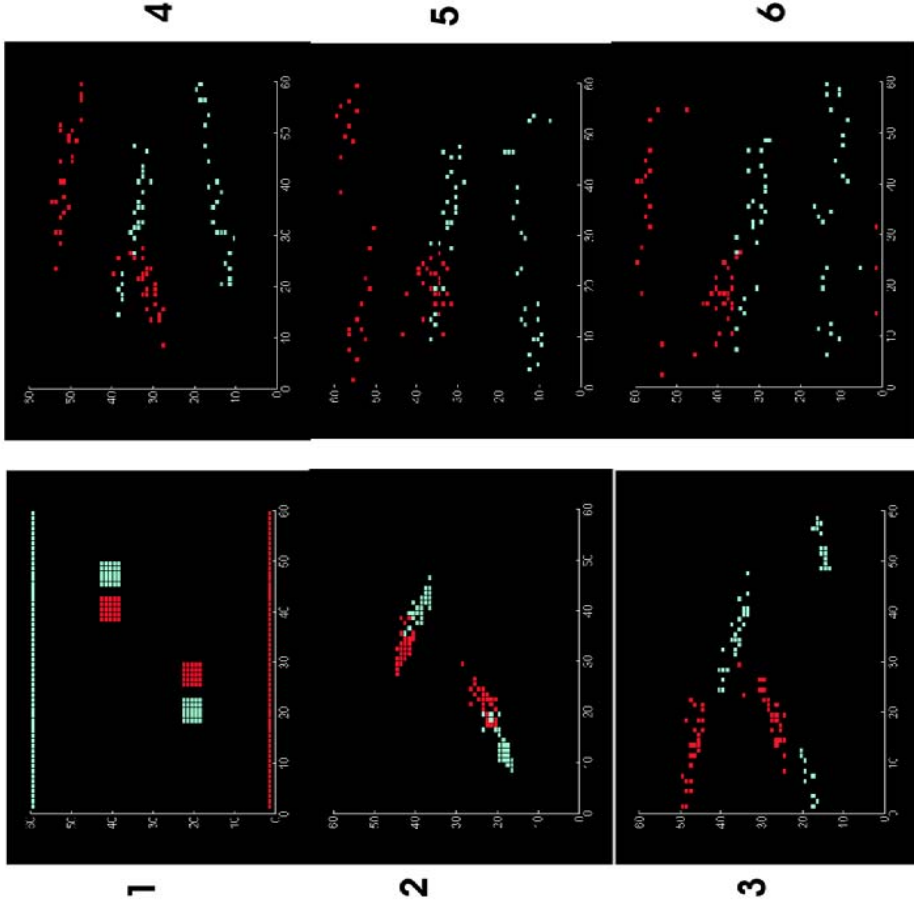


Hinode "Trilobite" Movie

# Large Scale Modeling and Observations (Ulrich and Boyden)



**D** SUPERSYNOPTIC & SYNOPTIC MAPS OF THE SUN'S MAGNETIC FIELDS : SOLAR CYCLE #22

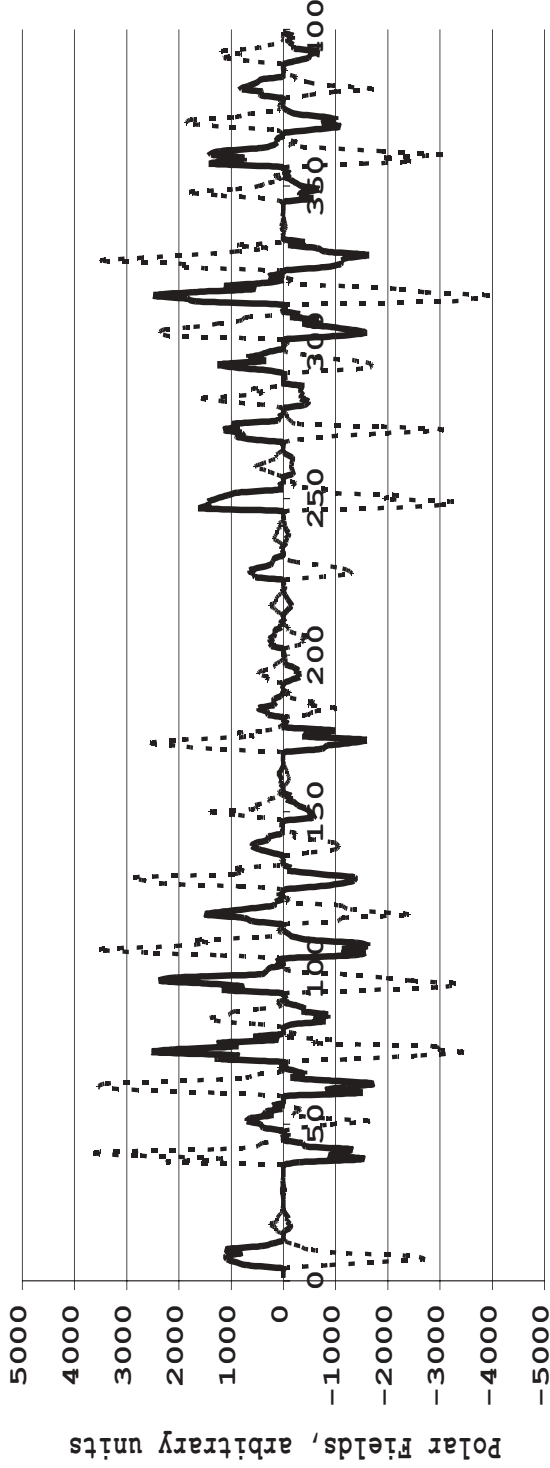


MODELED BIPOLAR MAGNETIC REGIONS (BMRs): PERCOLATION WITH SUBADIABATIC GRADIENT + DRIFT FROM DIPOLE FIELD + DIFFERENTIAL ROTATION

# 400 & 100 YR MODELING

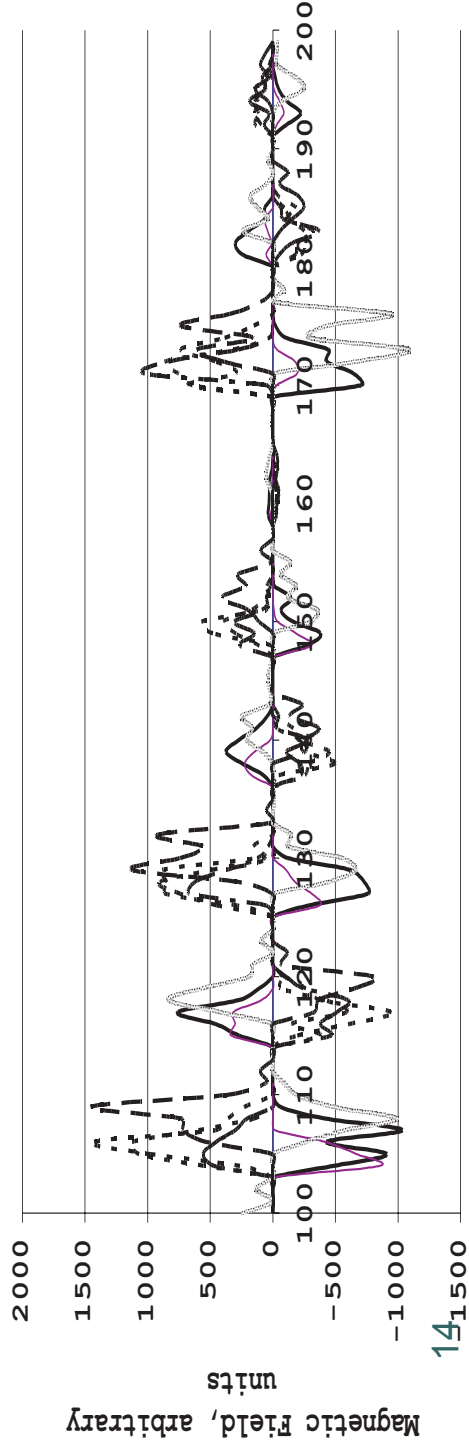
## Polar Fields vs. Time

— North Polar Field Data - - - South Polar Field Data



Different Longitudes, Both Polar Fields

Series1 Series2 Series3 Series4  
Series5 Series6 Series7 Series8

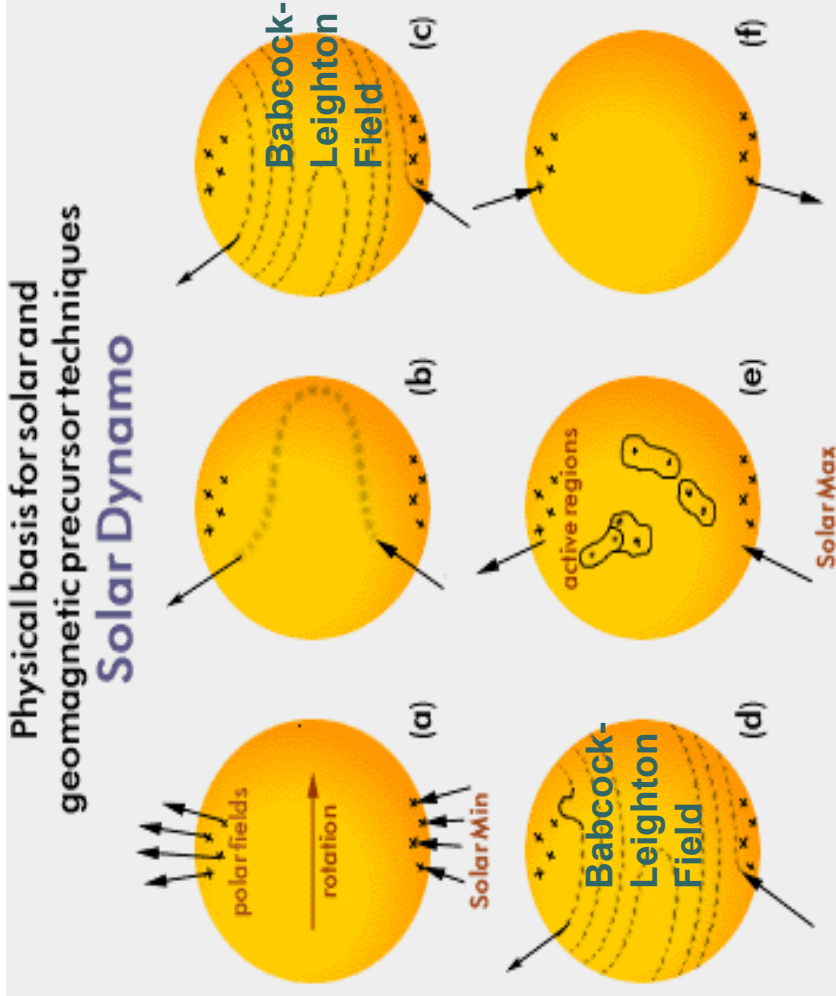
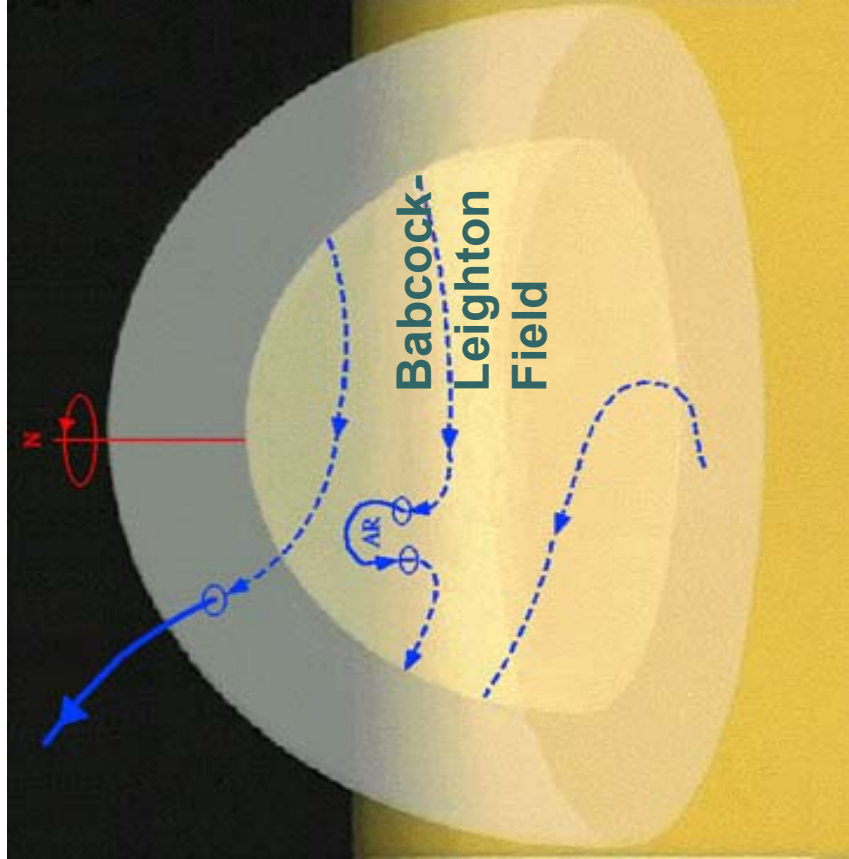


# Solar Activity Prediction Methods

- METHOD: SOLAR- PRECURSOR METHOD  
USES SUN'S POLAR FIELD TO PREDICT  
FUTURE SOLAR ACTIVITY
- OTHER
  - “CLIMATOLOGY” (AVERAGE SOLAR ACTIVITY)  
RECENT CLIMATOLOGY (RECENT AVERAGE)  
GEO-MAGNETIC PRECURSOR  
(GEO FIELD VARS.: PROXY OF SOLAR FIELD)  
DYNAMO MODELS (MEAN FIELD, MODEL  
DEPENDENT)
  - NEURAL NETWORK (NUMERICAL)  
SPECTRAL (NUMERICAL, UNPHYSICAL)

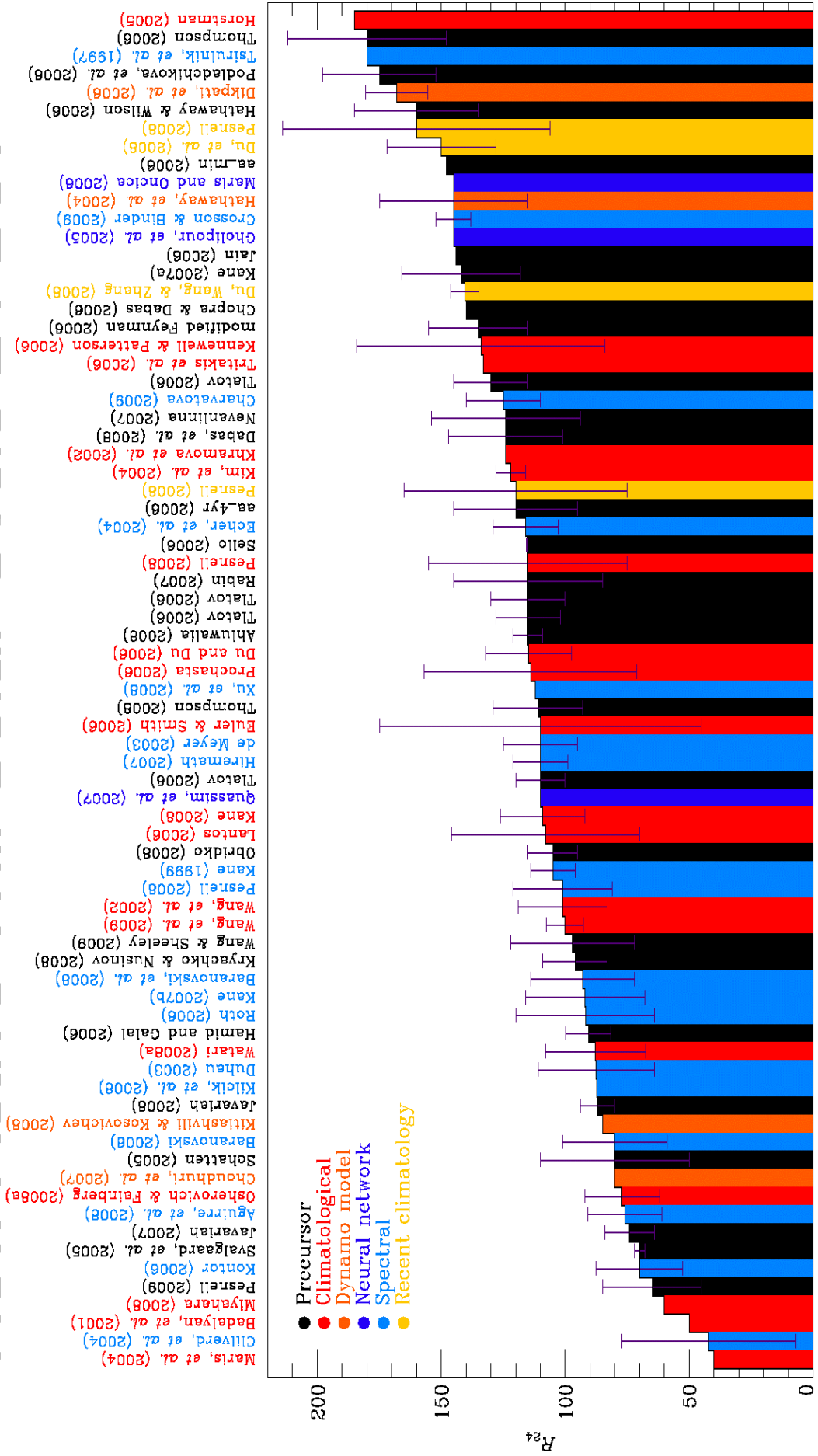
# POLAR FIELD PRECURSOR METHOD

- DOES NOT DEPEND ON SHALLOW VS DEEP SOURCE OF DYNAMO.
- BABCOCK-LEIGHTON ORIGINAL VIEW WAS SHALLOW
- DYNAMO MOVED TO BOTTOM CZ
- BOTH: POLAR B =>TOROIDAL B and TOROIDAL B => POLAR B





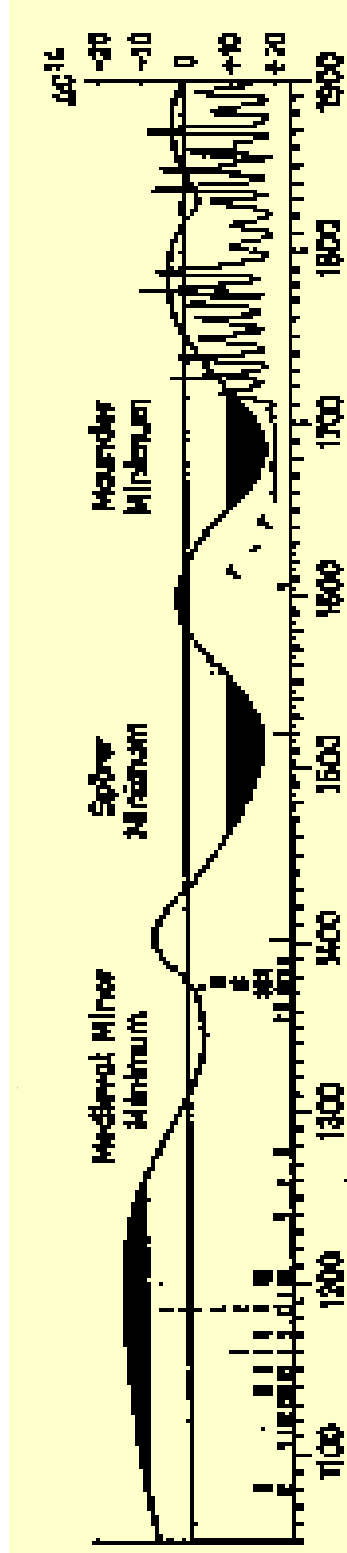
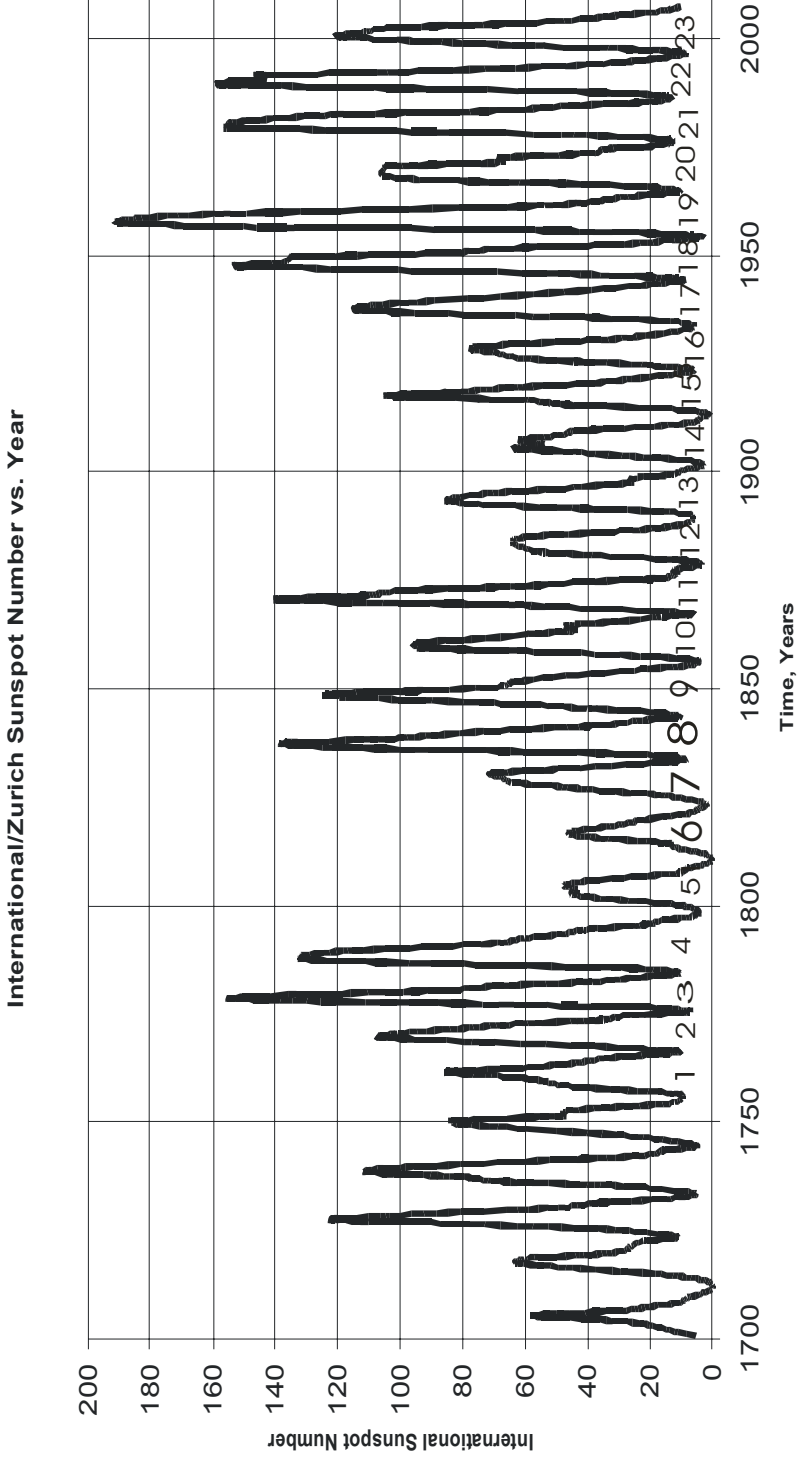
# How Active Will Solar Cycle 24 Be?



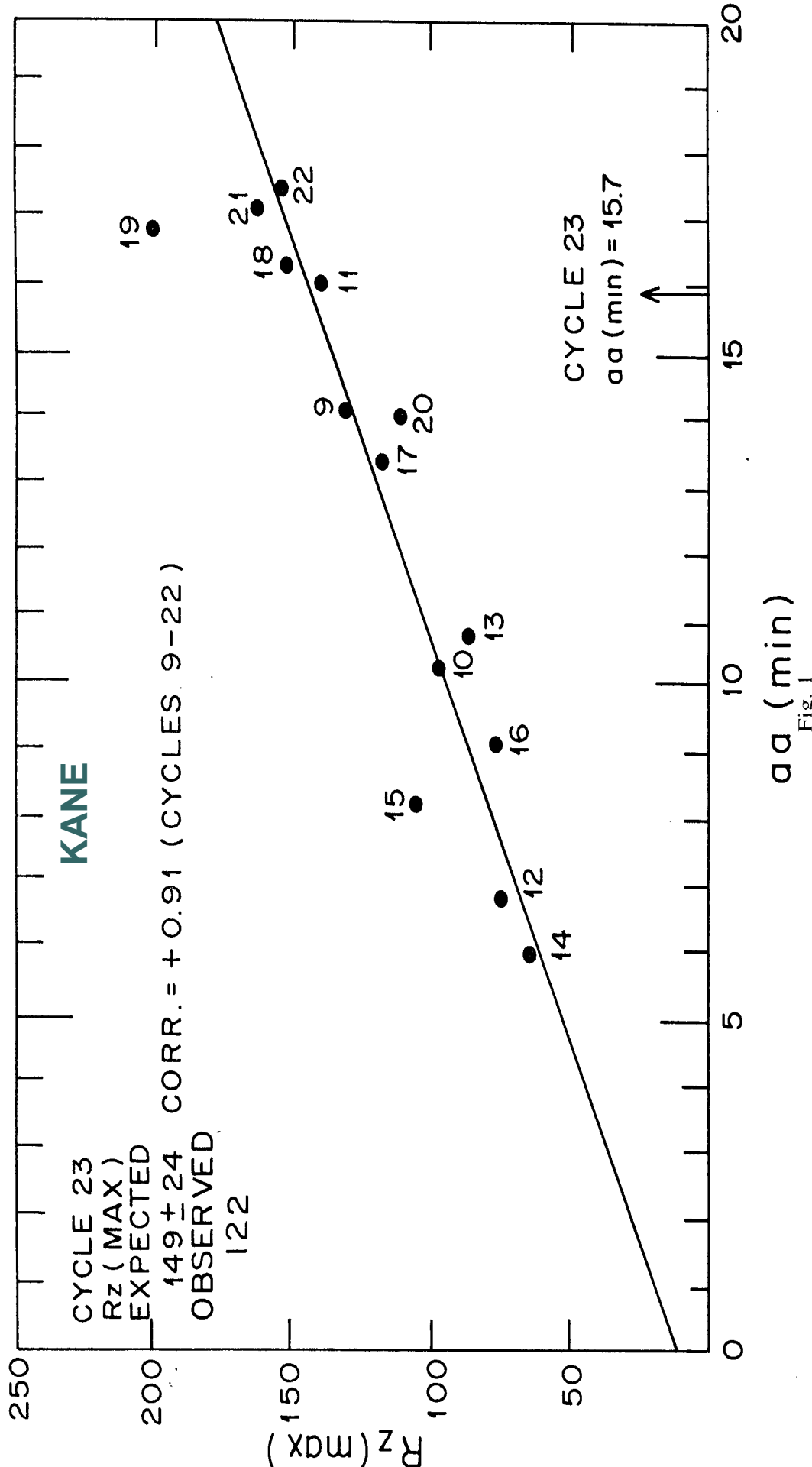
**PESNELL : Our lack of knowledge about the dynamo is summarized by the spread of predictions for Cycle 24**



# SOLAR ACTIVITY OBSERVATIONS: PREDICTION DIFFICULT

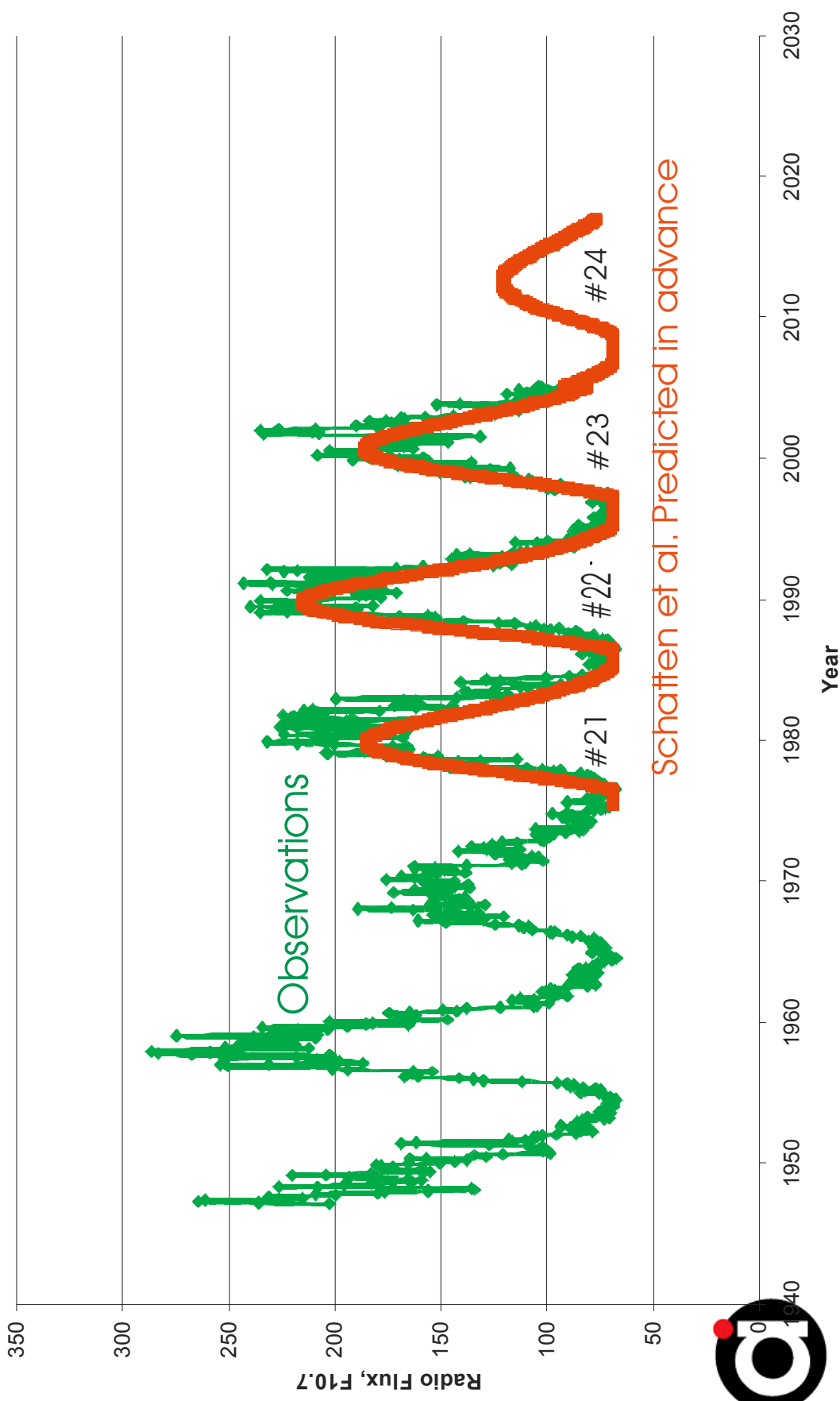


# GEOMAGNETIC PRECURSORS: AN OFFSHOOT SINCE POLAR FIELD AFFECTS INTERPLAN. FIELD & EARTH



# Polar Field Precursor Predictions

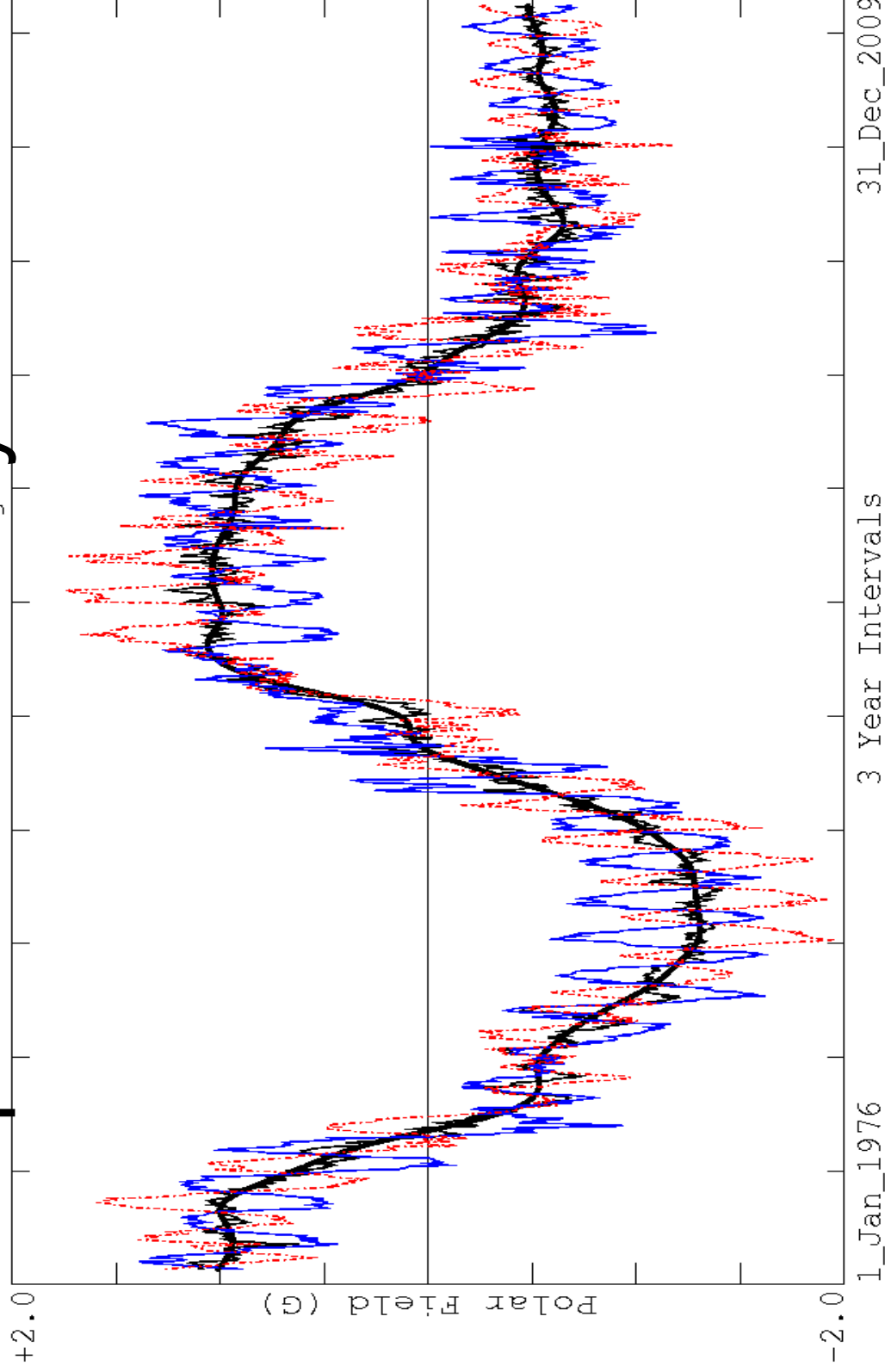
F10.7 Observations and Predicts



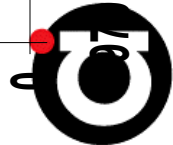
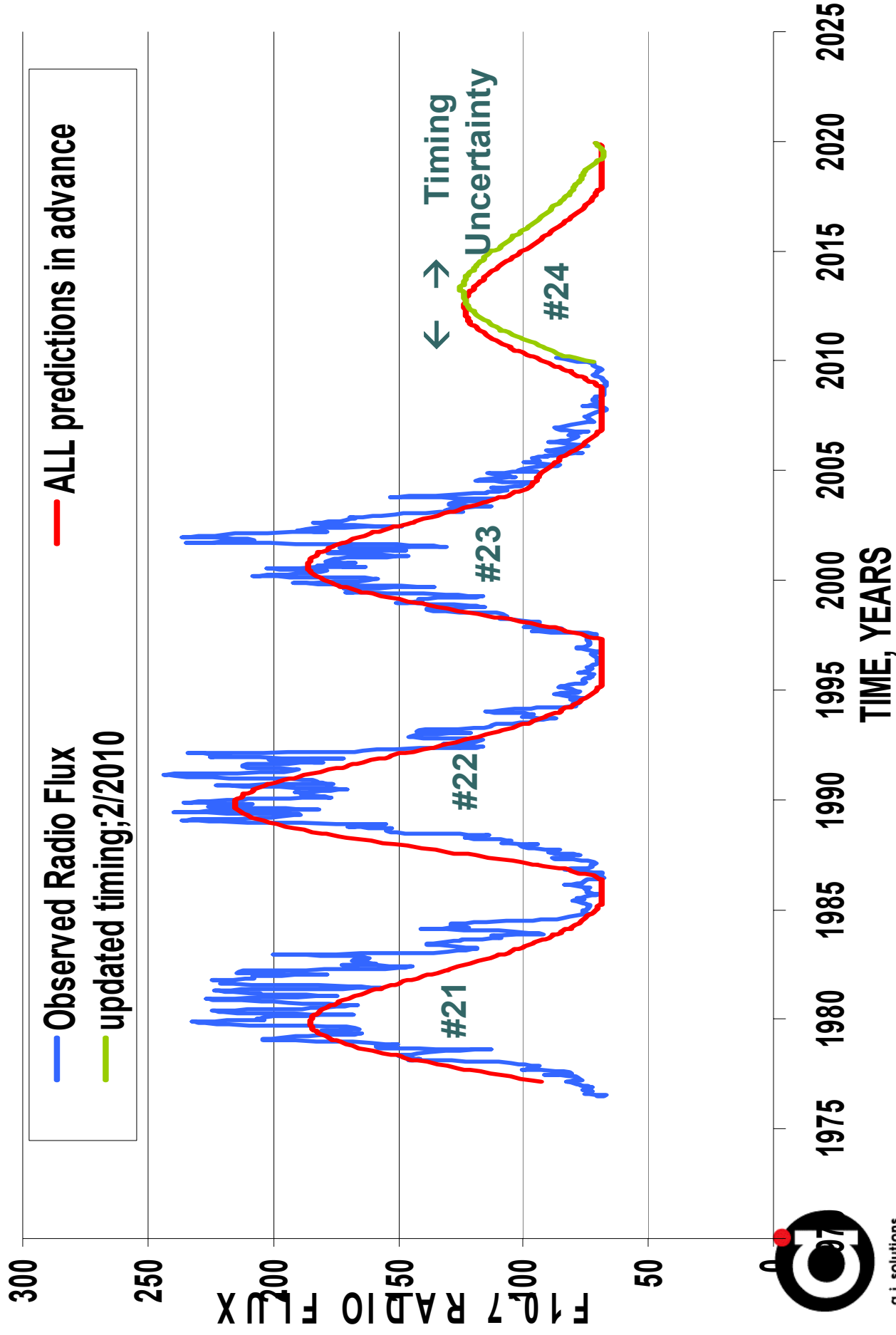
Schatten et al. Predicted in advance



# Polar Field Shows Marked Decrease in 2003+, which is why we and Svalgaard predicted small cycle in 2005



# Observed and Predicted Radio Flux, F10.7



## CONCLUSIONS-

- SHALLOW DYNAMO MAY BE POSSIBLE VIA PERCOLATION OR CLUSTERING; IN THE HIGHLY SUPERADIABATIC REGIONS OF THE OUTER SOLAR CZ, LIKE-SIGN FIELD ARE ATTRACTED BY NONLINEAR PROCESSES DRIVEN BY S. , ETC.
  - {Sol. Phys., 255:3-38,2009}
- CELLULAR AUTOMATA ABLE TO MIMIC FEATURES OF SOLAR DYNAMO
- SOLAR PREDICTIONS BASED ON POLAR FIELDS – Have Predicted a SMALL CYCLE ~125 in F10.7 or ~75 RZ, PEAK ~ Early 2013. {GRL- 32, L21106 (2005)}.

