A Shallow Solar Dynamo and Decadal Forecasting

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Currently though he is recovering from torn rotator cuff

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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

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 JETSAM), 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⁺) available; convective collapse (Zwaan, Parker) occurs/process allows field to form spots.

**INVERSE ION HURRICANE**

- Atmosphere
- Photosphere
- Convection Region
- 5,000 km
- 100,000 km

**Diagram Details:**
- SUNSPOT
- FACULAE
- Neutral hydrogen "lake"
- Ionized hydrogen
- Magnetic field
- Streamlines
- Evershed motion
- Cyclonic motion
- Fibril magnetic fields
- H + energy → H⁺ + e⁻ (endothermic)
- H⁺ + e⁻ → H + energy (exothermic)
Lockheed Group-Magnetic Carpet: EPRs
Conv. Collapse of Fibrils: Percolation

Field remains shallow
Flow can go DEEP!

12/2008 EIT/SOHO EXTREME UV IMAGING
a.i. solutions
SUPERADIABATIC PERCOLATION

A) GROWTH: EPRs TO SPOTS

- EPRs
- Photosphere
- Ionization zone
- \( H^+ \)
- \( H + \text{Energy} = H^+ + e^- \)
- Uni-directed Fluid
- Flow velocity
- Convective cells
- Magnetic Field

B) GROWTH: TO SPOTS/BMRS

- EPRs
- Photosphere
- Ionization zone
- \( H^+ \)
- \( H + \text{Energy} = H^+ + e^- \)

C) DECAY: TO FACULAE/PLAGE

- EPRs
- Photosphere
- Ionization zone
- \( H^+ + e^- = H + \text{Energy} \)
- Magnetic Field
Physical basis for solar and geomagnetic precursor techniques

Solar Dynamo

(a) polar fields rotate

(b) Babcock-Leighton Field

(c) Babcock-Leighton Field

(d) Babcock-Leighton Field

(e) active regions

(f) Solar Max
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
Superadiabatic Percolation, Field Drift, and Normal Percolation into Unipolar Magnetic Regions (UMRs)
New Region: Like Fields Move Together (White=>White)

Hinode “Trilobite” Movie
Large Scale Modeling and Observations (Ulrich and Boyden)

A

B

Carrington Rot.
#1880-1884

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

Time, Years

Different Longitudes, Both Polar Fields

Series1 --- Series2 --- Series3 --- Series4
Series5 --- Series6 --- Series7 --- Series8

Magnetic Field, arbitrary units
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

KANE

CYCLE 23
Rz (MAX)
EXPECTED
149 ± 24
CORR. = + 0.91 (CYCLES 9-22)
OBSERVED
122

Rz (max)

150
100
50

aa (min)

0
5
10
15
20

Fig. 1
Polar Field Precursor Predictions

F10.7 Observations and Predictions

- Observations
- Predicted in Advance

Schatten et al. Predicted in advance

Year

Radio Flux, F10.7

#21 #22 #23 #24

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

- Observed Radio Flux
- ALL predictions in advance
- Updated timing: 2/2010


Flux, F10.7: 0, 50, 100, 150, 200, 250, 300

Predictions:
- #21
- #22
- #23
- #24

Timing Uncertainty

All data points are connected by lines to show the trend and fluctuations over time.
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)}. 