Solar Activity Predictions and a Shallow Solar Dynamo

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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
PESNELL: Our lack of knowledge about the dynamo is summarized by the spread of predictions for Cycle 24.
SOLAR ACTIVITY OBSERVATIONS: PREDICTION DIFFICULT

International/Zurich Sunspot Number vs. Year

Time, Years

International Sunspot Number

0 20 40 60 80 100 120 140 160 180 200

1700 1750 1800 1850 1900 1950 2000

Medieval Minoor Minimum

Spöer Minimum

Maunder Minimum

1100 1200 1300 1400 1500 1600 1700 1800 1900
GEOMAGNETIC PRECURSORS: AN OFFSHOOT SINCE POLAR FIELD AFFECTS INTERPLAN. FIELD & EARTH

Fig. 1

CYCLE 23
$R_z(\text{max})$

EXPECTED
$149 \pm 24$

CORR. = +0.91 (CYCLES 9-22)

OBSERVED
122

$\alpha\alpha$ (min) = 15.7

KANE
Polar Field Precursor Predictions

F10.7 Observations and Predicts

- Observations
- Predicted in Advance

Schatten et al. Predicted in advance
Polar Field Shows Marked Decrease in 2003+, which is why we and Svalgaard predicted small cycle in 2005.
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-field helps percolation to form AR’s; when they break up, they migrate towards the poles.
OVERVIEW

- LARGE FIELDS RESULT WHEN LIKE-SIGN EPRBs 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.
New Region: Like Fields Move Together (White=>White)

Hinode “Trilobite” Movie
SUPERADIABATIC PERCOLATION

A) GROWTH: EPRs TO SPOTS

EPRs → Photosphere

Ionization zone

\[ \text{H} \rightleftharpoons \text{H}^+ + \text{e}^- \]

LARGE-SCALE SUBSURFACE FIELD

Uni-directed Fluid
Flow velocity
Convective cells
Magnetic Field
EPR

B) GROWTH: TO SPOTS/BMRS

EPRs → Photosphere

Ionization zone

\[ \text{H} \rightleftharpoons \text{H}^+ + \text{e}^- \]

LARGE-SCALE SUBSURFACE FIELD

B-L field

C) DECAY: TO FACULAE/PLAGE

EPRs → Photosphere

Ionization zone

\[ \text{H}^+ + e^- = \text{H} + \text{Energy} \]

LARGE-SCALE SUBSURFACE FIELD

B-L field
Lockheed Group-Magnetic Carpet: EPRs
Conv. Collapse of Fibrils: Percolation

Field remains shallow
Flow can go DEEP!
Superadiabatic Percolation, Field Drift, and Normal Percolation into Unipolar Magnetic Regions (UMRs)
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
Large Scale Modeling and Observations (Ulrich and Boyden)

Carrington Rots. #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
CONCLUSIONS-

- 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)}.

- 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
400 & 100 YR MODELING

Polar Fields vs. Time

North Polar Field Data --- South Polar Field Data

Time, Years

Different Longitudes, Both Polar Fields

Magnetic Field, arbitrary units

Time, years
400 & 100 YR MODELING

Polar Fields vs. Time

North Polar Field Data - - - South Polar Field Data

Time, Years
New Region: Like Fields Move Together (White=>White)
Physical basis for solar and geomagnetic precursor techniques

Solar Dynamo

(a) polar fields
(b) rotation
(c) Babcock-Leighton Field
(d) Babcock-Leighton Field
(e) active regions
(f) Solar Max