Where is Solar Cycle 24?
Did it happen already?
Is there more to come?

Douglas Biesecker
NOAA/SWPC

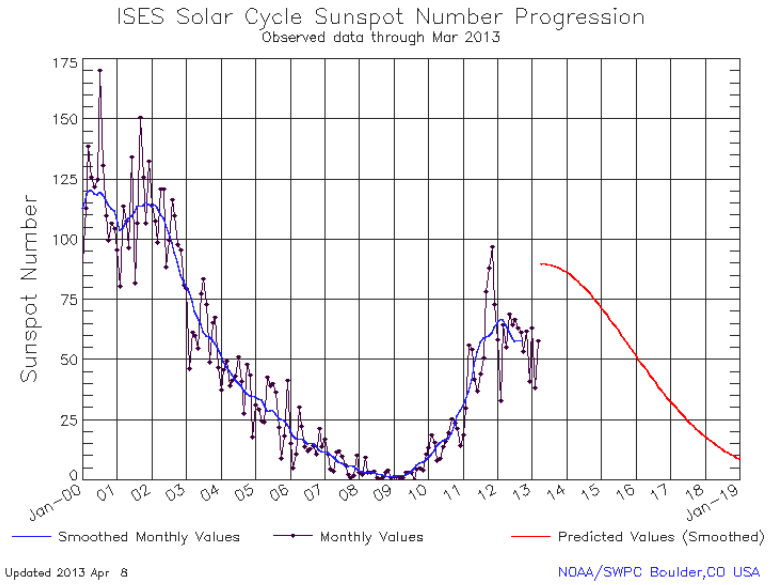
With help from
Chris Balch (NOAA/SWPC) and Scott McIntosh (NCAR/HAO)

Agenda

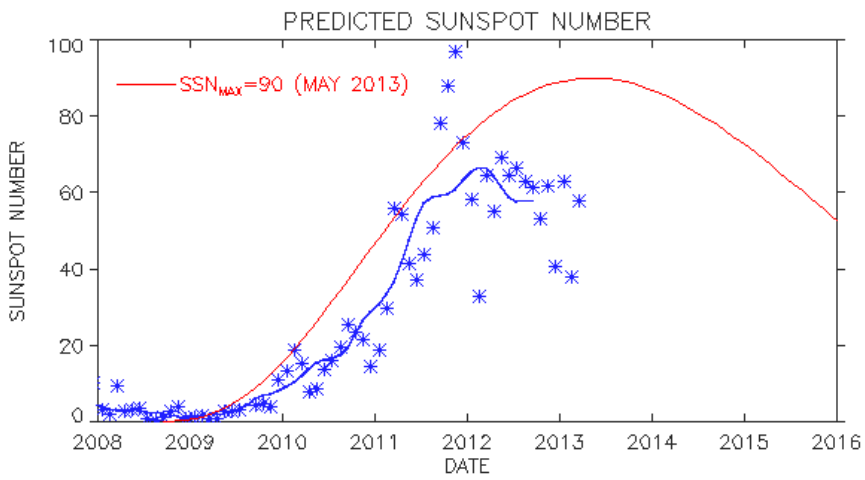
- The panel prediction
  - What was it and where are we?
  - Is it still numerology?
- The bi-modality of the solar cycle
  - North v South
  - We will see a second peak (I think)
- What we really care about is activity
  - How does it compare to recent cycles?

The prediction

- In 2009, the NASA funded, NOAA chaired, international panel said
  - SSN will peak at 90 in May 2013



- Is there any chance we can still salvage some respectability?

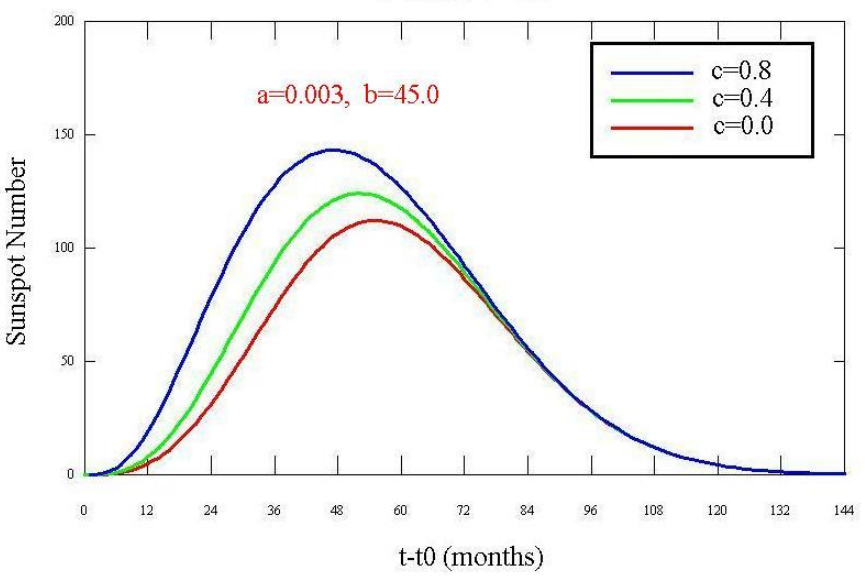


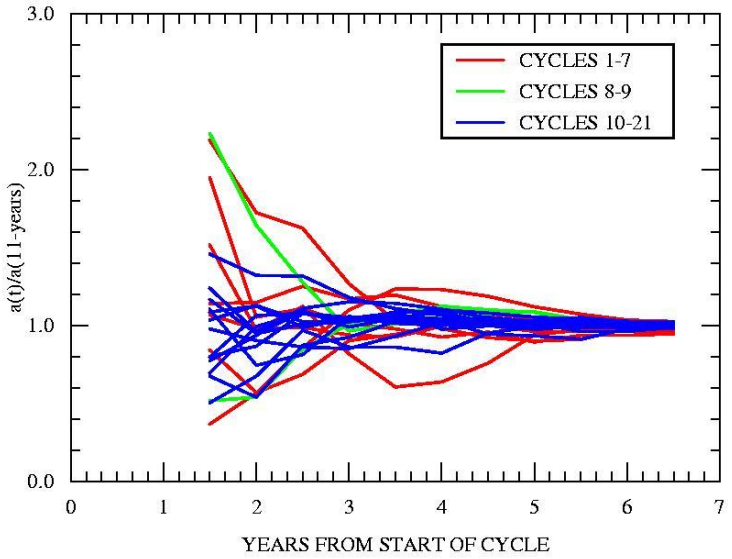
A Functional Form for the Cycle

Fitting the cycle to a functional form with amplitude *a*, starting time t_0, width *b*, and asymmetry *c*, provides a prediction for the current cycle and can account for systematic changes in cycle shape.

$$f(t;a,t_0,b,c)=\frac{a(t-t_0)^3}{\exp\left[(t-t_0)^2/b^2\right]-c}$$

Asymmetry is constant (c=0.71) and width varies with amplitude.

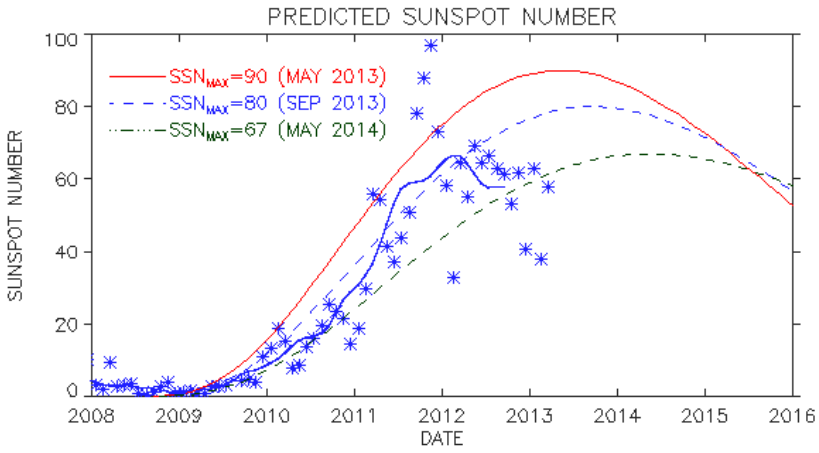




D. Hathaway

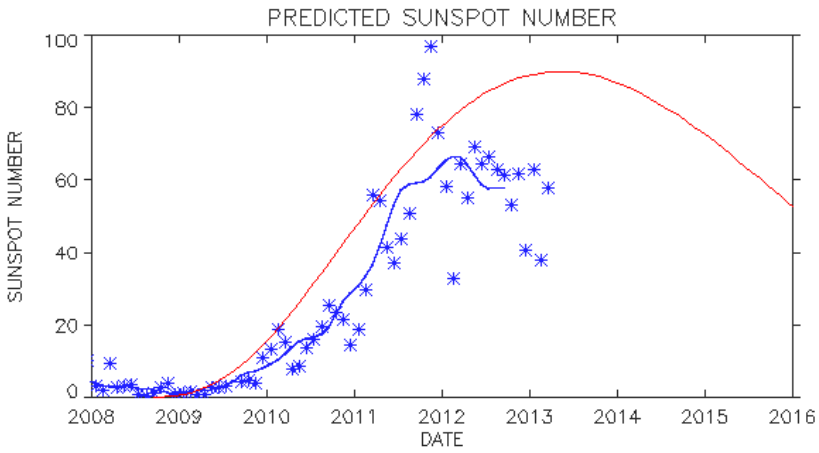
Trying different curves

- Red: Prediction of 90
  - Doesn't look likely
- Blue: Prediction of 80
  - Still seems possible
- Green: Prediction of 67
  - Did it come two years too soon?



Do we have a winner?

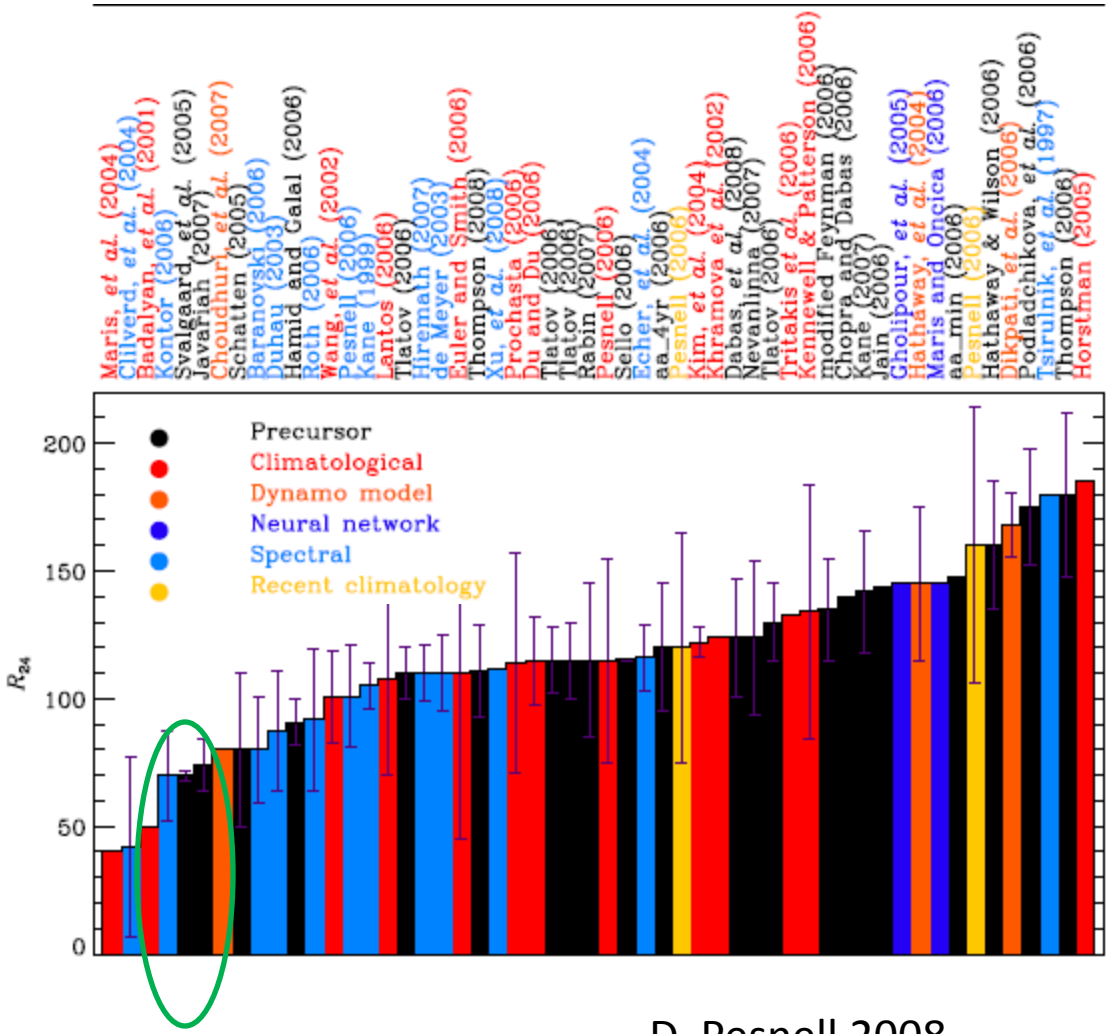
- The cycle has reached a local maximum of R=67 in February, 2012
- Is that all we've got? If so, who was right?



R	Timing	Author	Technique
74	-	Javariah (2007)	Precursor (sunspot area)
70	-	Svalgaard et al (2005)	Precursor (polar fields)
70	12/2012	Kontor (2006)	Spectral

Here's what we started with

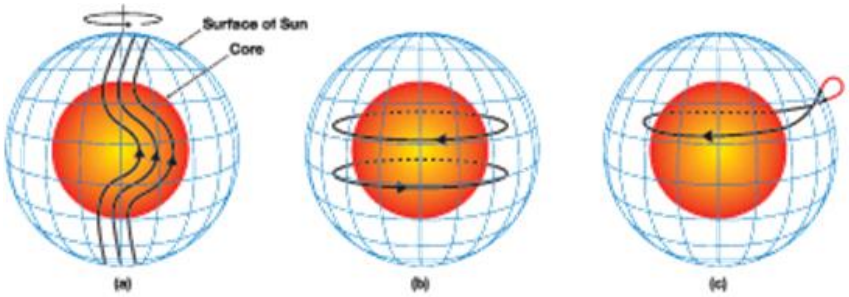
- Spectral (S) techniques include Fourier, Wavelet, and auto-regressive analyses
- Precursor (P) techniques look for leading indicators of solar activity

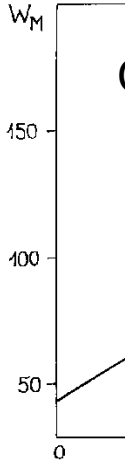


D. Pesnell 2008

Geomagnetic Precursors

- **Utilize information from the declining phase of a cycle or from solar minimum to predict the intensity of the subsequent maximum**
  - Based in dynamo theory, whereby poloidal field of cycle N is converted into toroidal field of cycle N+1
- **Historically, these techniques have provided the best skill at predicting the solar cycle.**





Prediction Method	Cycle 19	Cycle 20	Cycle 21	Cycle 22	Cycle 23	RMS
Mean Cycle	-94.8	-9.1	-53.5	-48.6	-10.1	53.7
Secular Trend	-91.6	8.7	-36.2	-25.3	17.8	46.3
Gleissberg Cycle	-80.4	18.5	-51.6	-51.1	-9.6	49.4
Even-Odd	-59.3		-22.3		61.1	50.8
Amplitude-Period	-74.1	0.3	-61.2	-25.3	9.7	44.7
Maximum-Minimum	-83.9	21.6	-22.9	-15.0	1.8	40.6
Ohl's Method	-55.4	19.1	21.8	4.4	22.2	29.7
Feynmann's Method	-42.8	9.6	26.9	3.6	41.1	29.5
Thompson's Method	-17.8	8.7	-26.5	-13.6	40.1	24.1

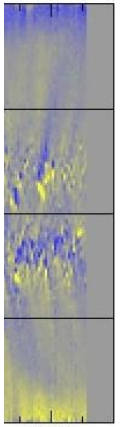
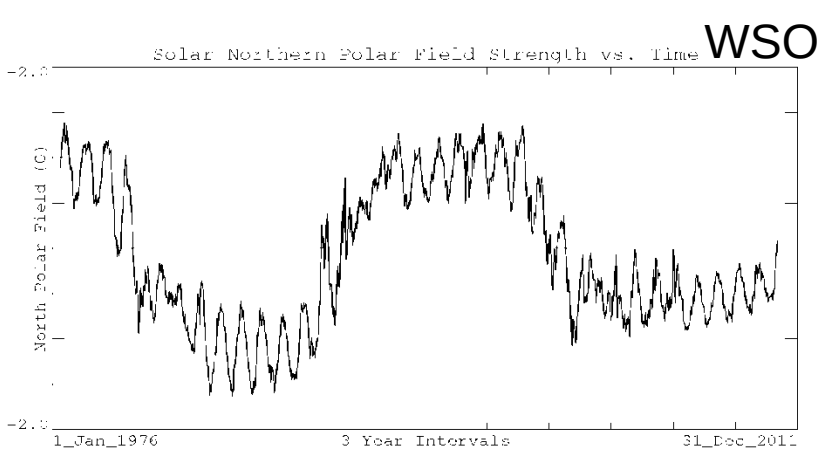


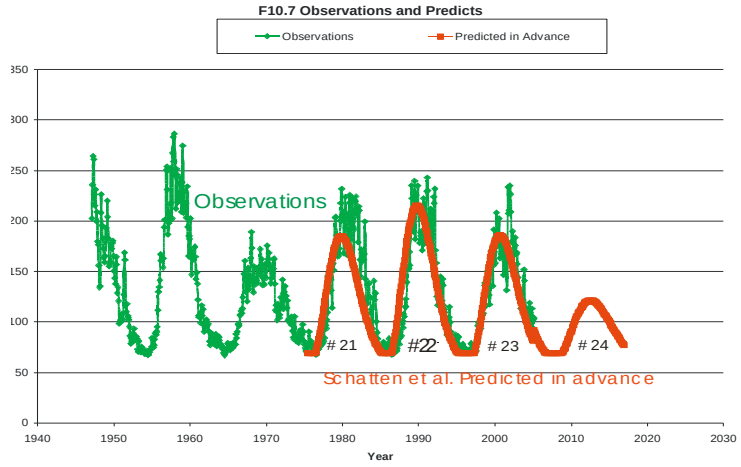
Figure 1 ... in the maximum of the next 11-year cycle.

Courtesy D. Hathaway

Polar Field Precursor Methods

- A model calling for a small cycle – short recycle time
  - Skip the 'proxy' (geomagnetic disturbances)



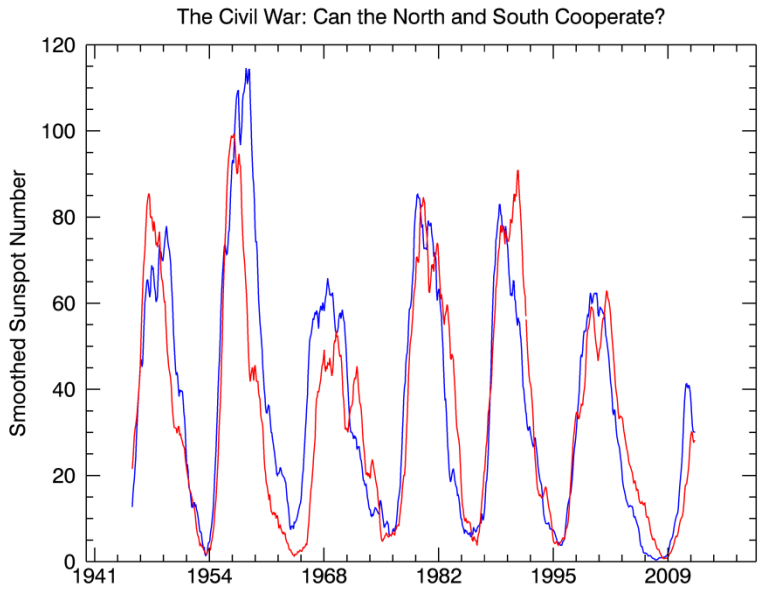


$$\mathrm{SODA} = 60 + 146\left[\left(\frac{B_{pol}}{1.28}\right)^2 + \left(\frac{\mathrm{F10.7} - 60}{146}\right)^2\right]^{1/2}$$

Schatten and Pesnell (1993)

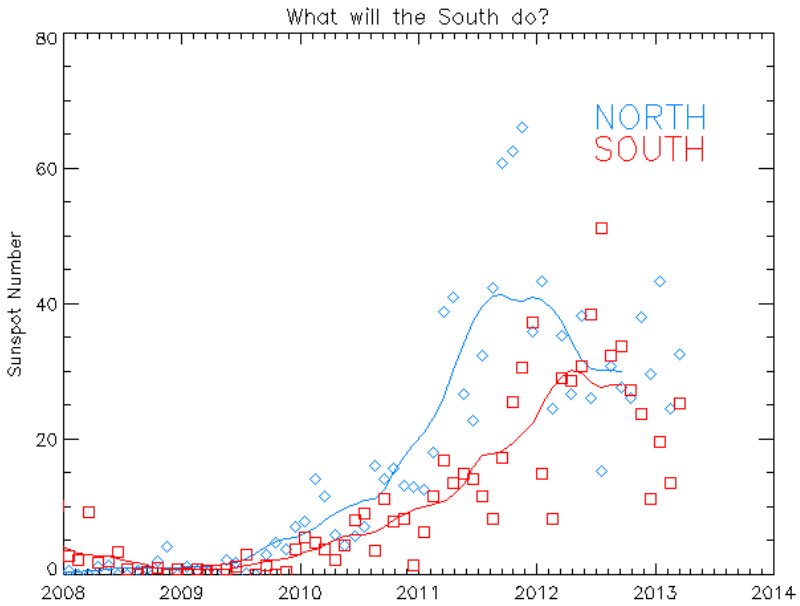
The North/South Divide

- The two hemispheres generally peak at different times
  - Cycle 24 is no different
- Does this help us figure out where this cycle is headed?



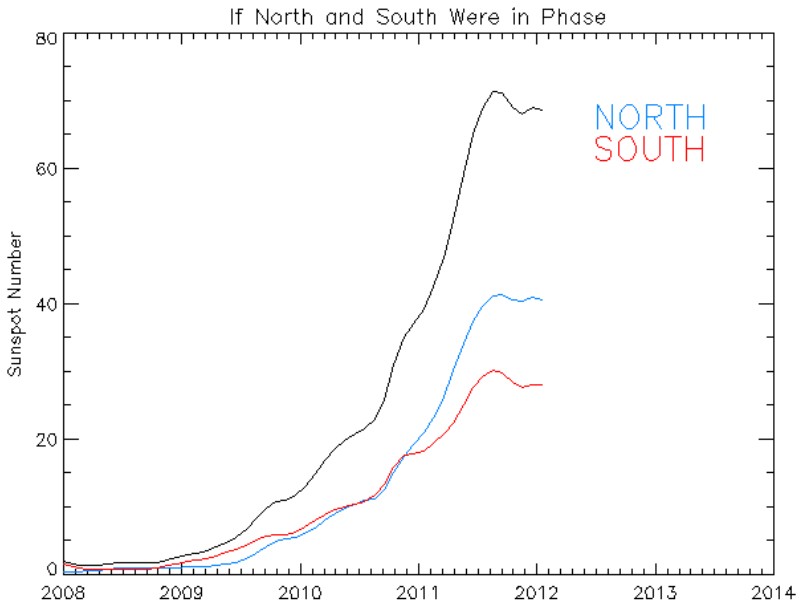
The Divide of Cycle 24

- It seems likely the North peaked at R=41 in 2011
- The South lags the North by about 8 months
  - Did it peak in early 2012 at R=30?
  - If so, this cycle is pretty much done
- But, I can't predict the future…



What if they had been in phase?

- If the two hemispheres were in phase, we wouldn't even be having this conversation
- The Prediction Panel did discuss the need to consider the hemispheres independently
  - But, there was almost nothing in the literature
  - Everyone considers the Sun as a whole
    - Need to consider it as a game of two halves



Enough of those spots, what about the activity?

The Telegraph

ACE NEWS

Launch | Contracts | Civil | Military | Satellite Telecom | Earth Observat

ASBAA
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14 June 2010
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04/30/10 05:34 PM ET

Galaxy 15, Still Adrift, Poses Threat to Its Orbital Neighbors

By Peter B. de Selding

PARIS — An Intelsat satellite that stopped communicating with its ground controllers April 5 remains out of control and has begun moving eastward along the geostationary arc, raising the threat of interference with other satellites in its path, Intelsat and other industry officials said.

In what industry officials said is an unprecedented event, Intelsat's Galaxy 15 satellite has remained fully "on," with its C-band telecommunications payload still functioning left its assigned orbital slot of 133 degrees west longitu

Robert Bednar
of SES World S
News photo by

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The Christian Science Monitor

Solar flares: Be glad you're on Earth, not Mars (+video)

The recent solar flares provide a dramatic backdrop for a study that shows Mars gets far more of its atmosphere stripped away by solar storms than does Earth. Thank you, magnetosphere.

Sun Erupts With Major Solar Flare

SPACE.com Staff
Date: 05 March 2012 Time: 10:04 AM ET

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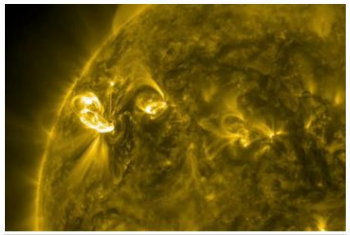

This story was updated at 11:42 a.m. EST.

A major solar flare erupted from the sun late last night (March 4) sending an explosion of plasma and charged particles hurtling toward Earth.

The flare was an X1.1-class solar flare and exploded from the surface of the sun at 11:13 p.m. EST (0413

ABC Science

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4 comments Share Print

Can solar storms unleash communications chaos?

Today, we humans are a very long way from our pre-electronic ancestors. We are attached to the electronic toys that we enjoy and use: the GPS unit that finds a street in an unfamiliar city, the smart phone that is a camera as well as a dictionary as well as giving access to the internet, and even the accurate watch you wear on your wrist.

But what if they were all to suddenly die?

Welcome to the superstorm, when the Sun decides to have a hissy fit! Welcome to the Carrington Event!

About one-and-a-half centuries ago, an independently wealthy English astronomer, Richard C. Carrington, was following his normal daily habit of observing the Sun. He had already discovered that the Sun rotated faster at the equator than at the poles.

On August 26, 1859, the Sun had thrown a few billion tonnes of super-hot gas directly at the Earth. The impact with the Earth's magnetic field and the upper atmosphere

The Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI), launched in 2002, explores the explosive energy released in solar flares. (Source: NASA)

s | Spa

support for Hughes

ike you, as well as the Hughes team.

/ Updates

Sea

Solar Flares Knock Out LightSquared Satellite

As Run of Bad Fortune Continues

by Karl Bode 7 hours ago tags: satellite · business · wireless · alternatives · bandwidth · trouble · wireless

Tipped by viperadamr

Earlier this week we noted that recent solar flares managed to knock HughesNet's Spaceway 3 satellite offline for a significant part of Tuesday. User viperadamr writes in to note that the flares also took out LightSquared's Skyterra 1 satellite, which has been out of service since the original solar flare on March 7. The last update from the company was on March 9 insisting they'd have the satellite operational again by last

Help get this topic noticed by sharing it on Twitter, Facebook, or email.

EMPLOYEE

katie (Official Rep) 3 days ago

SPACEWAY NETWORK OUTAGE NOTICE

HughesNet SPACEWAY HN9000 service is currently unavailable. We have engineering teams working to restore service to these customers as quickly as possible. We apologize for the inconvenience. Please check back for updates.

Non-SPACEWAY customers are not affected. Your system modem model number on the front of your unit will tell you if you are an HN9000 customer.

follow

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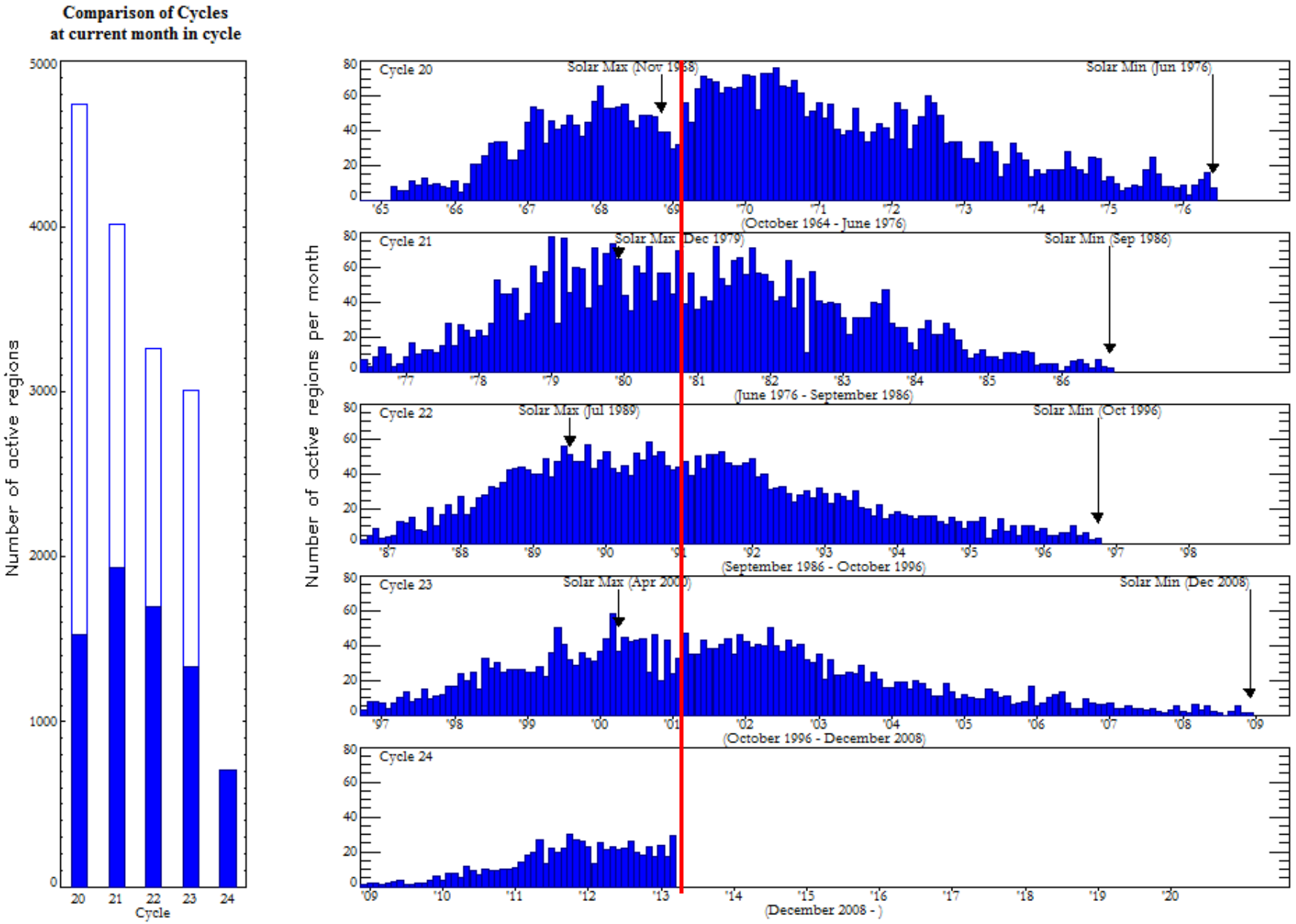
Storm

paralysed by a solar flare or a nuclear attack, Liam Fox will warn next week.

Active Regions

March 2013

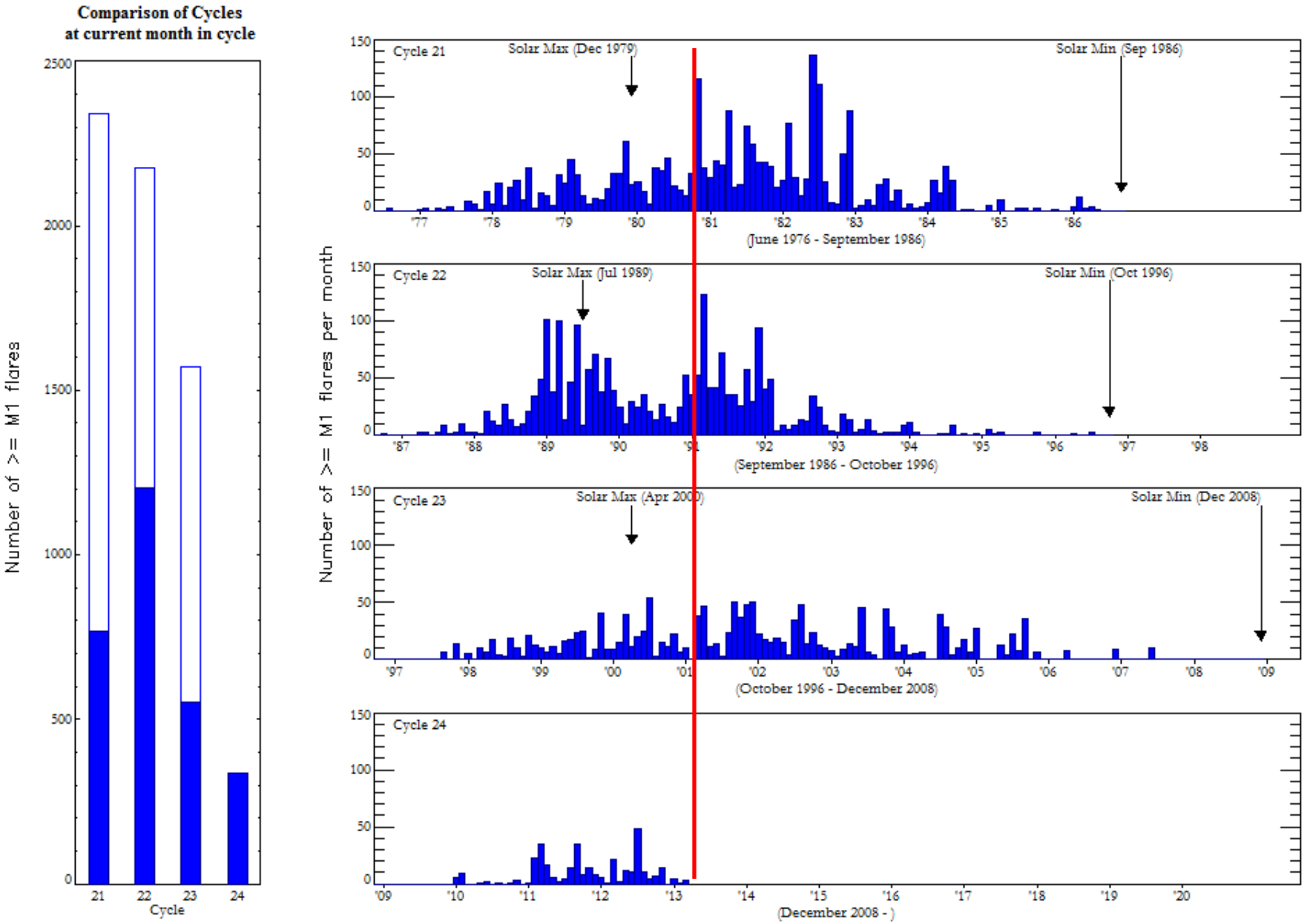
(Month 52)



X-ray flares >= M1 (R1)

March 2013

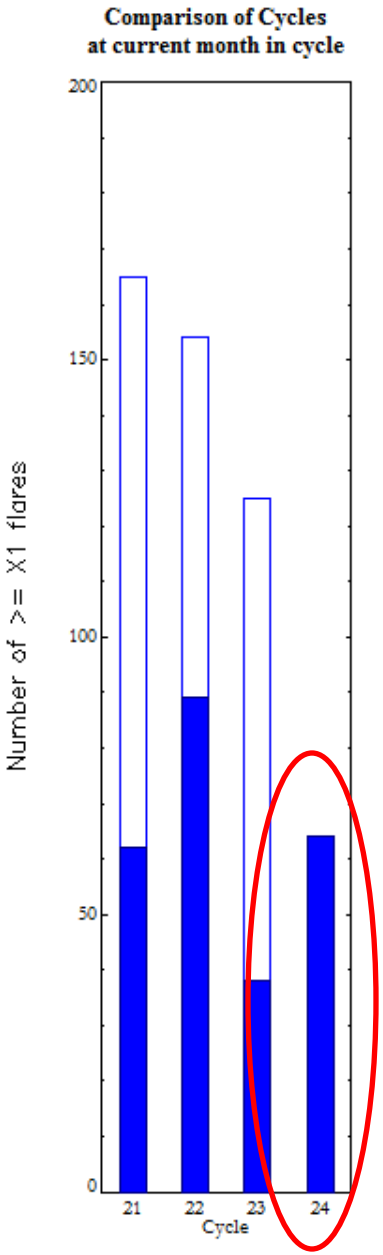
(Month 52)

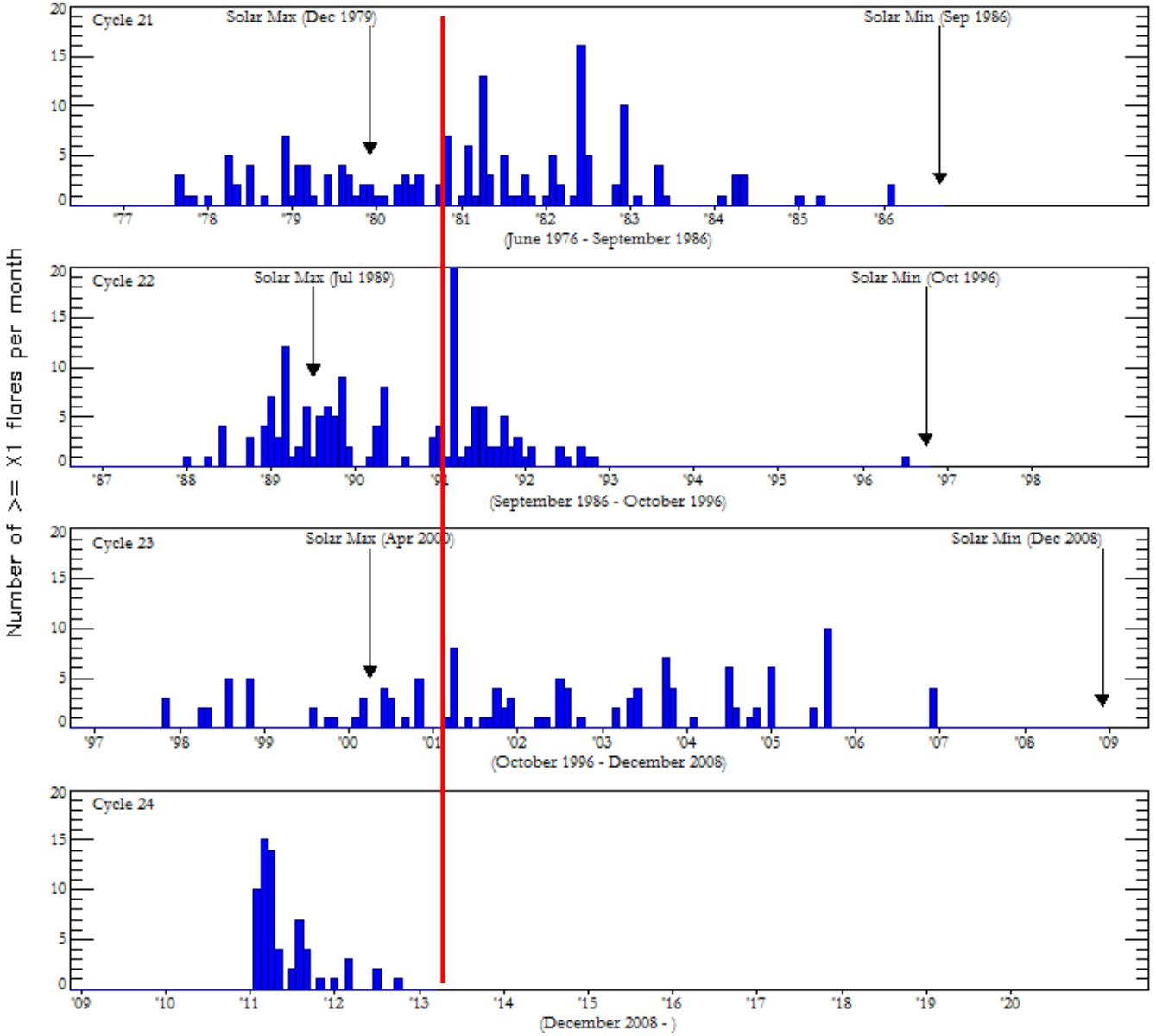


X-ray flares >= X1 (R3)

March 2013

(Month 52)

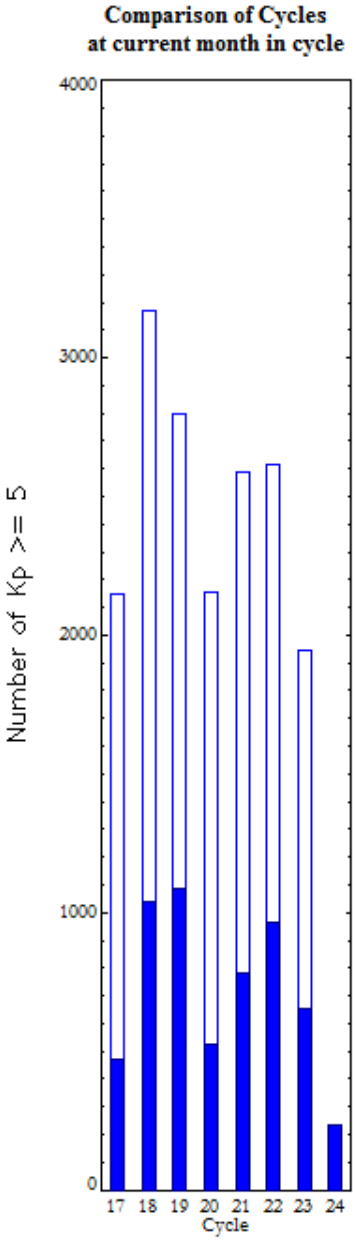


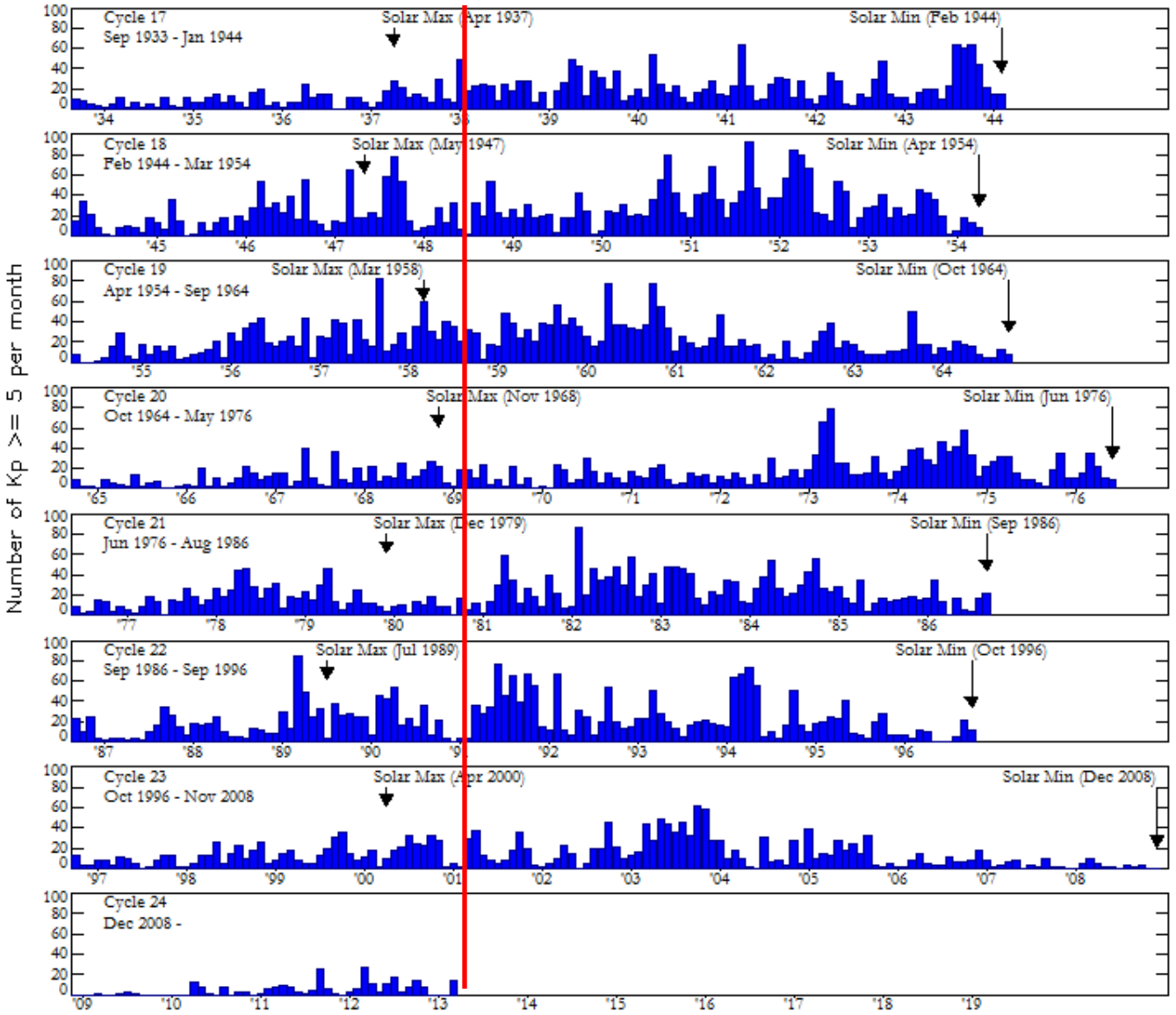


Periods with Kp >= 5

March 2013

(Month 52)

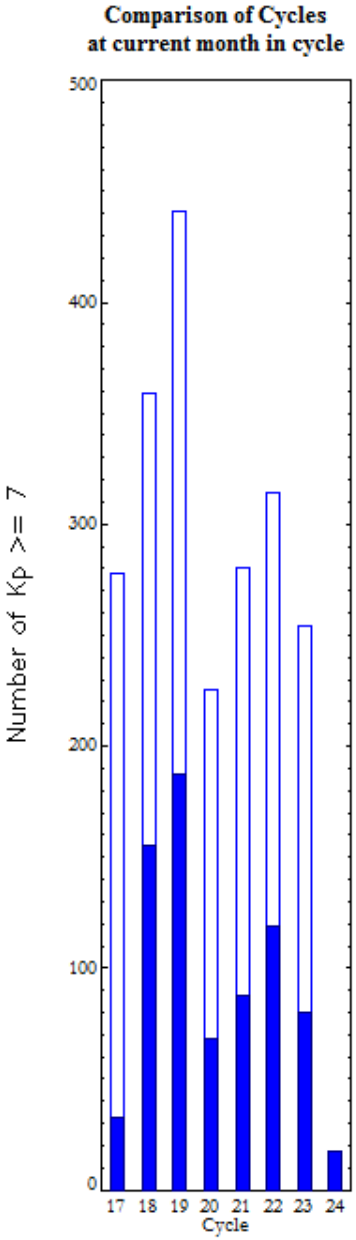


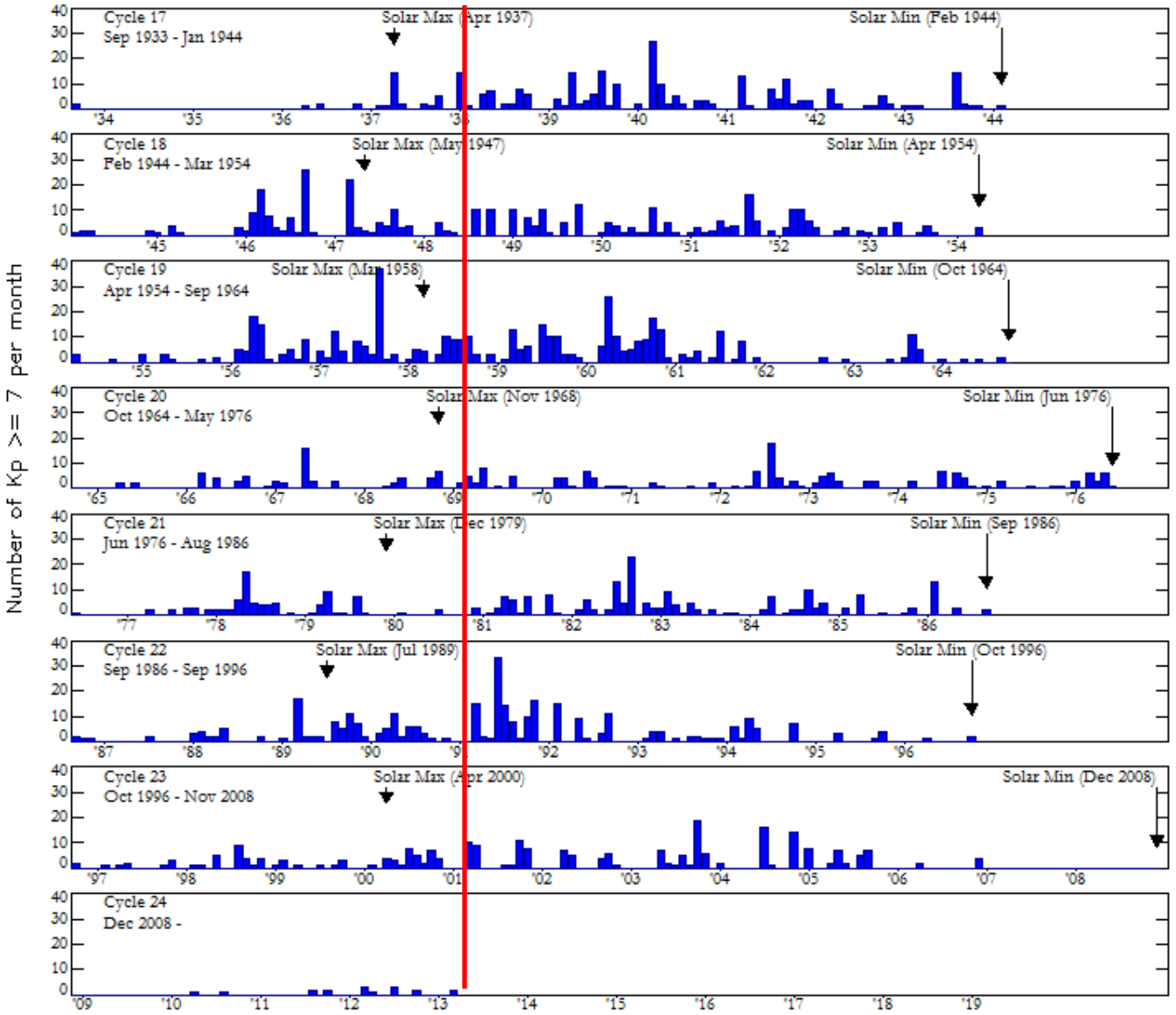


Periods with Kp >= 7

March 2013

(Month 52)

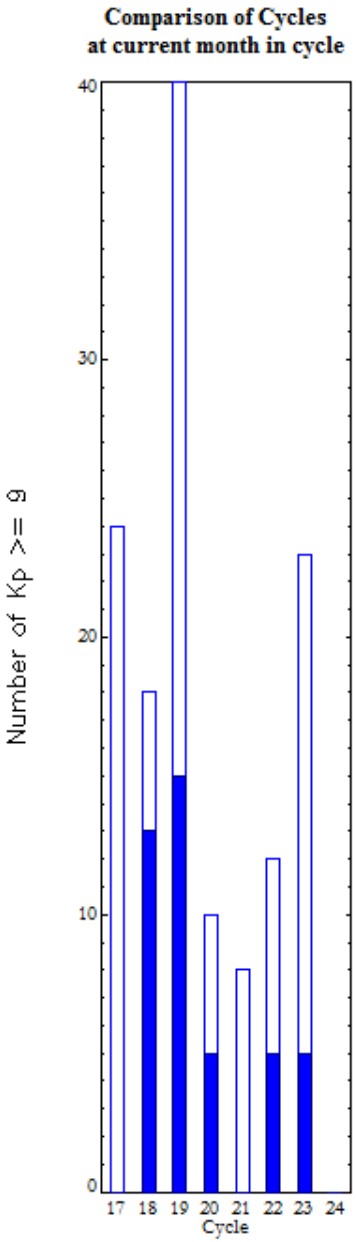


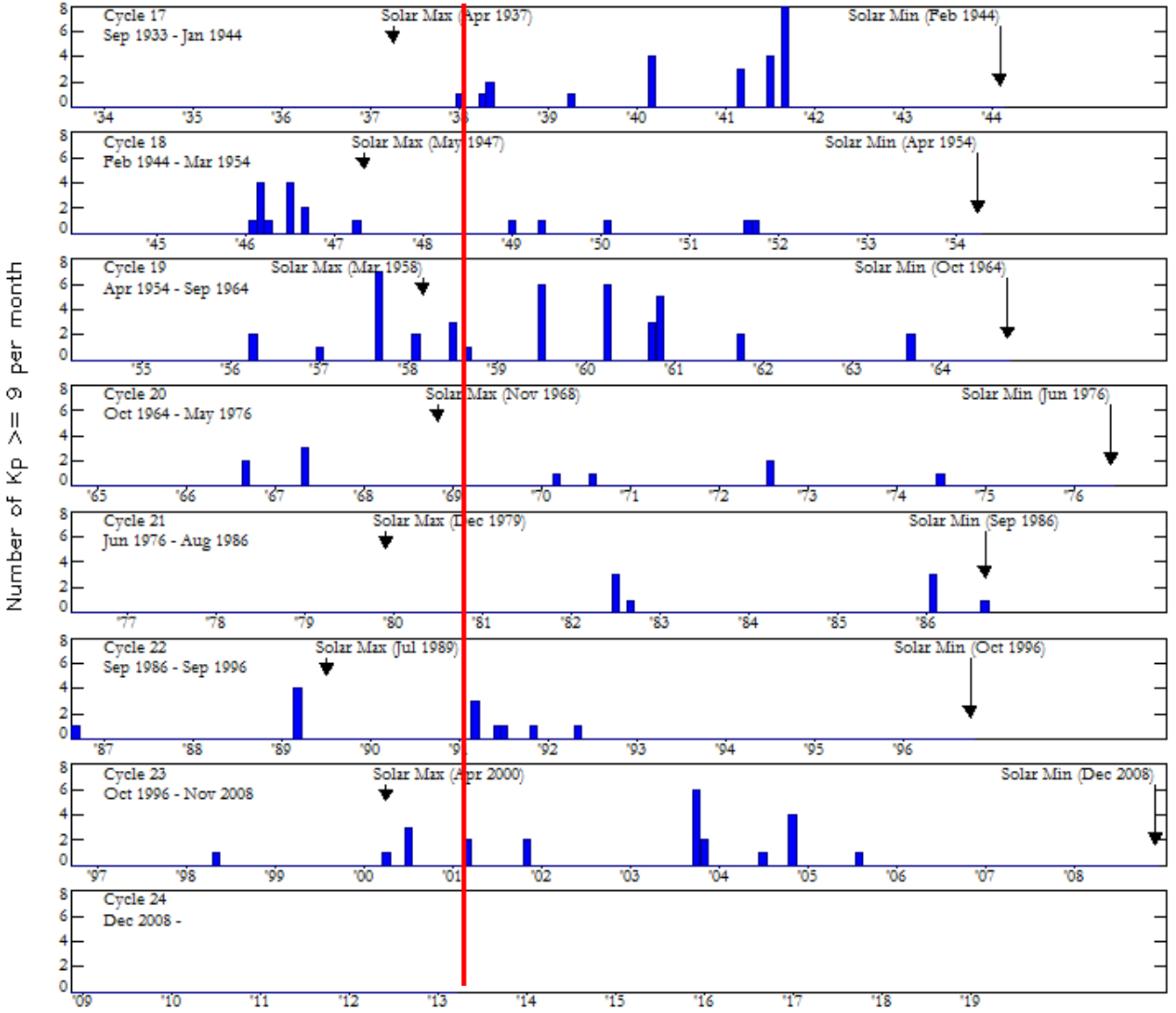


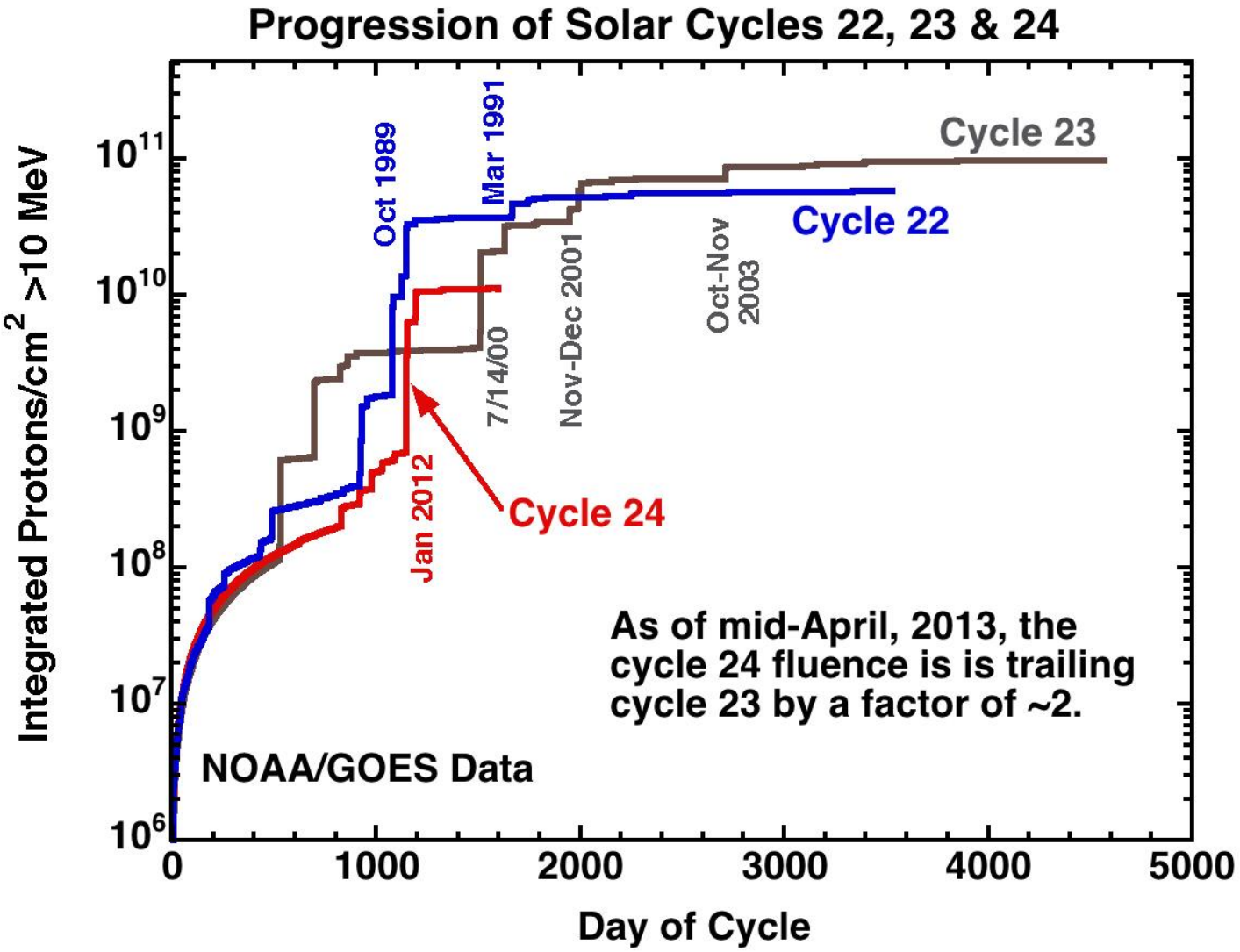
Periods with Kp >= 9

March 2013

(Month 52)






Progression of Solar Cycles 22, 23 & 24
Integrated Protons/cm^2 >10 MeV
10^{11}
10^{10}
10^9
10^8
10^7
10^6
0
1000
2000
3000
4000
5000
Day of Cycle
Oct 1989
Mar 1991
7/14/00
Nov-Dec 2001
Oct-Nov 2003
Jan 2012
Cycle 23
Cycle 22
Cycle 24
As of mid-April, 2013, the cycle 24 fluence is is trailing cycle 23 by a factor of ~2.
NOAA/GOES Data

R. Mewaldt

Conclusions

- I can't predict where the solar cycle will be
- The panel was right, insofar as a below average cycle was predicted
- A second peak in 2013 is possible, if the South chooses to participate
  - If not, then this will be an unusual maximum
- Forecasting future solar cycles absolutely must consider the hemispheres separately
- IF this cycle behaves like recent cycles, there's still lots of activity to come.