CAN SOLAR ACTIVITY INFLUENCE THE OCCURRENCE OF ECONOMIC RECESSIONS?

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Outline

- What are the sunspots, solar cycles, and solar maximums and how does solar activity impact Earth?
- Literature: Jevons and Chizhevsky; recent research
- Methodology: Comparison of smoothed series; average of "stacked" cycles centered along solar maximums; using economic models and simulations.
- Findings: Recessions do occur more often around and after solar maximums!
- Implications: What worked for the solar maximum of 2014
- Open discussion

What Are the Sunspots, Solar Cycles, and Solar Maximums?

Solar activity fluctuates with approximate 11-year period known as the “solar cycle”. The cycle is not exactly regular, and significant variations have been observed over centuries.

The cycle can be measured by counting the “sunspots” on the sun surface. Sunspots are temporary phenomena on the photosphere of the sun that appear visibly as dark spots compared to surrounding regions.

The period of elevated solar activity with the highest number of sunspots during the cycle is called “solar maximum”.

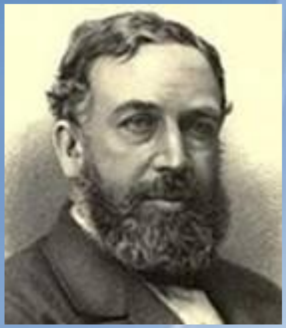
Around solar maximums, various types of solar activity reach their maximums levels: ultraviolet radiation and X-rays, proton emission, solar wind, solar flares, coronal mass ejections (CME), etc.

Impact on Earth

Physical impact: Disruptions of radio and telecommunications; fluctuations in the geomagnetic field (“magnetic storms”); electromagnetic impulses in power grids. “Carrington event” in 1859; “solar storms” in 774/775 and 993/994? Superstorm of July 2012 that missed the Earth by one week.

Human health hazard: Geomagnetic storms caused by solar activity affect people with cardiovascular health conditions, increasing chances of stroke and heart attack and exacerbating brain disorders.

Literature: From Classics to Modern



Willliam Stanley Jevons (1875-79): “Commercial crises” in Europe in the XIX century occurred at intervals of 11 years, broadly matching the average solar cycle length. “Beautiful coincidence“. Link to bad harvests.

Alexander Chizhevsky (1924, 1938, 1976): Revolutions and “most important historical events involving large numbers of people” occur much more often in the three years around sunspot maximums.

Modern research: Growing body of literature documenting various aspects of solar activity’s impact on Earth.

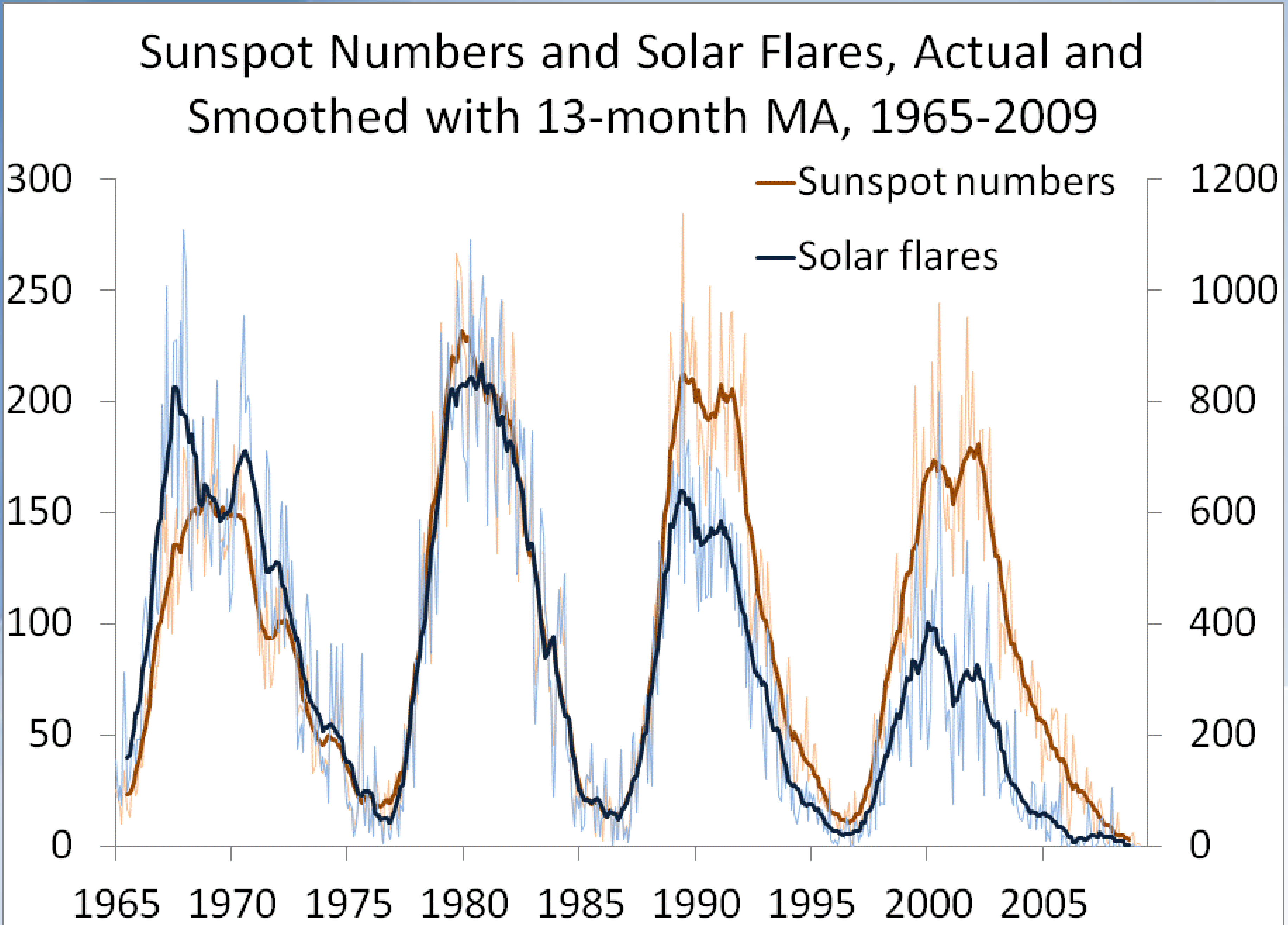
Methodology

Comparison of smoothed series. Smoothing series with moving average; de-trending with HP filter or another technique; comparing smoothed economic series with the series for sunspots or other indicators of solar or geomagnetic activity.

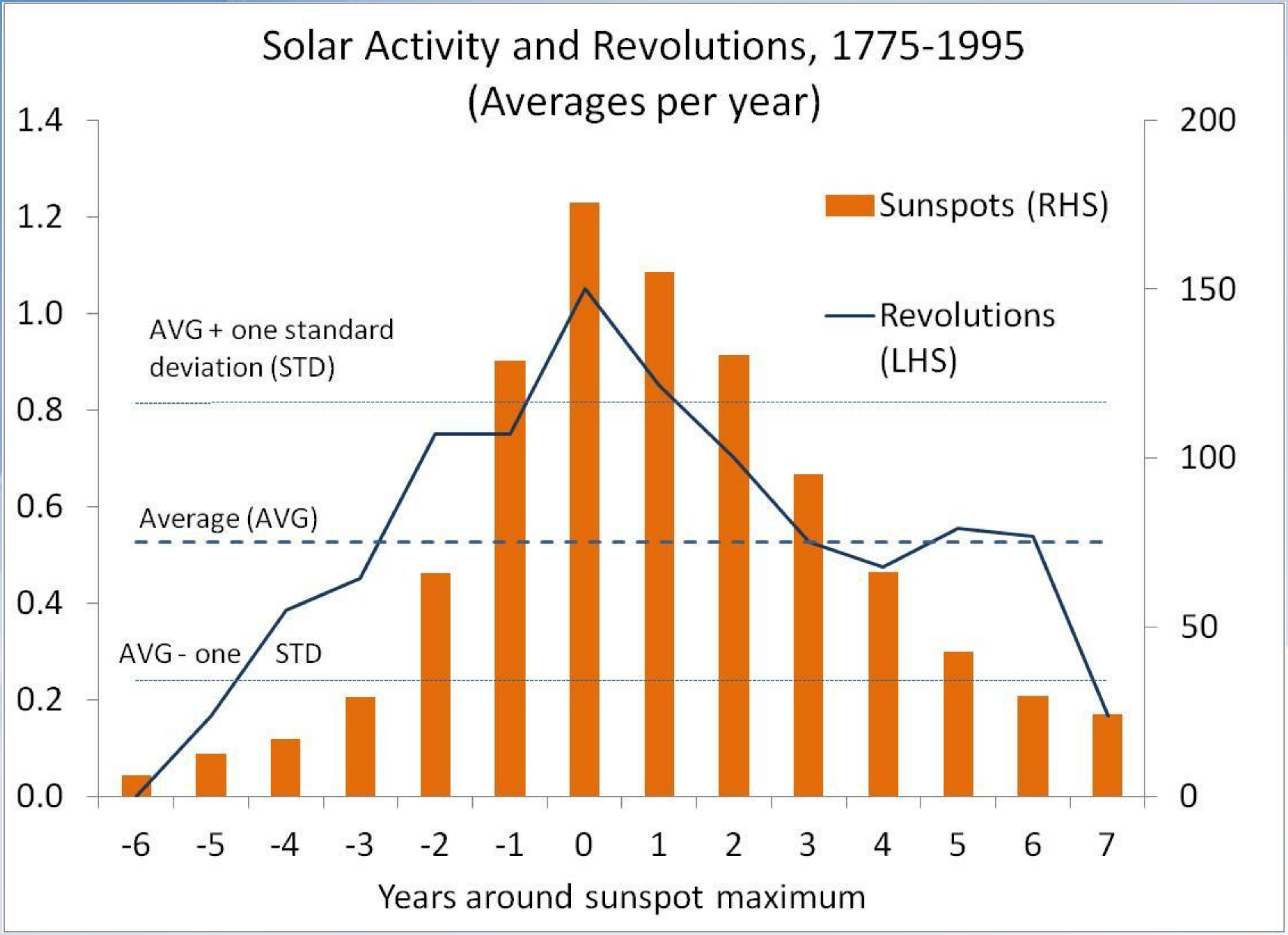
“Stacked cycles”. Identifying cycles, finding their maximum and minimum points, “stacking” cycles so that their maximum points overlap, finding average values corresponding to particular years or months counting from the solar maximum.

Econometric models. Using sunspot numbers as explanatory variable in econometric models for US recessions.

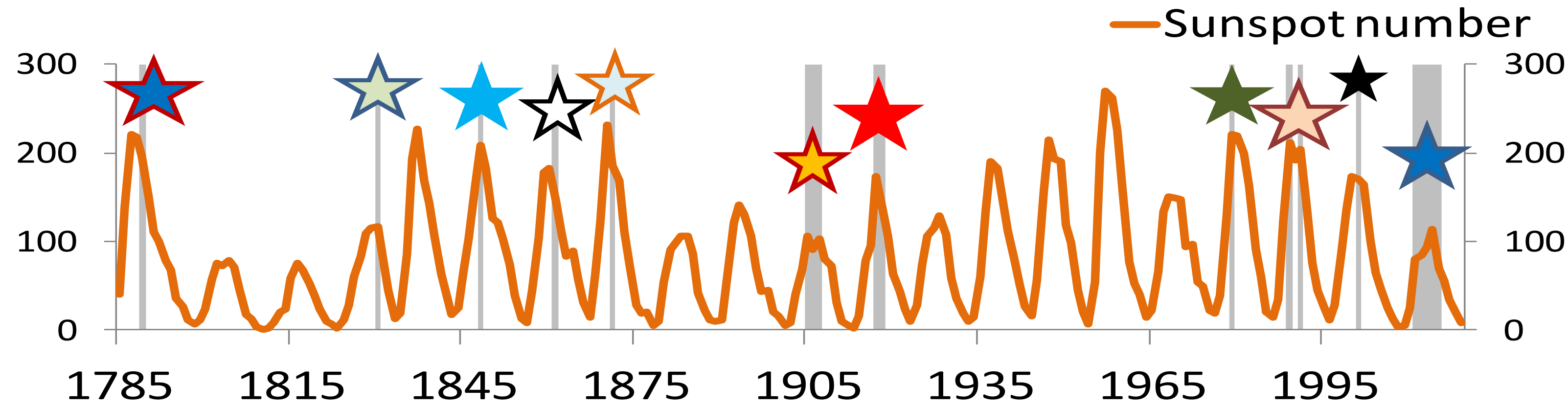
Simulations. Running program simulations to emulate the actual data for the US recessions and determine their probability chances.


Sunspot Numbers and Solar Flares, Actual and Smoothed with 13-month MA, 1965-2009
Sunspot numbers
Solar flares
300
250
200
150
100
50
0
1200
1000
800
600
400
200
0
1965
1970
1975
1980
1985
1990
1995
2000
2005

On average, revolutions occur more often in the years of solar maximums

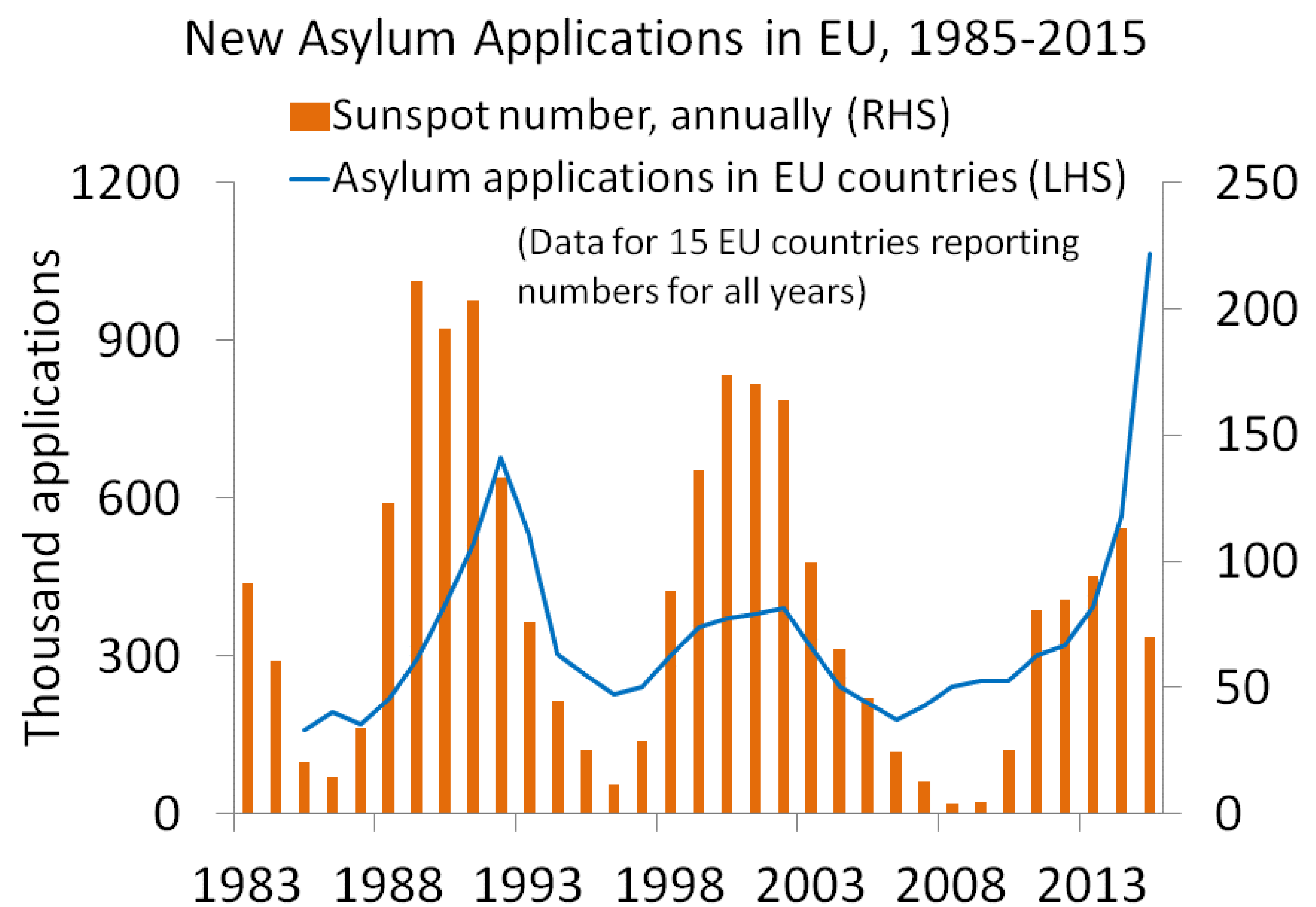


Revolutions overlapping with solar maximums



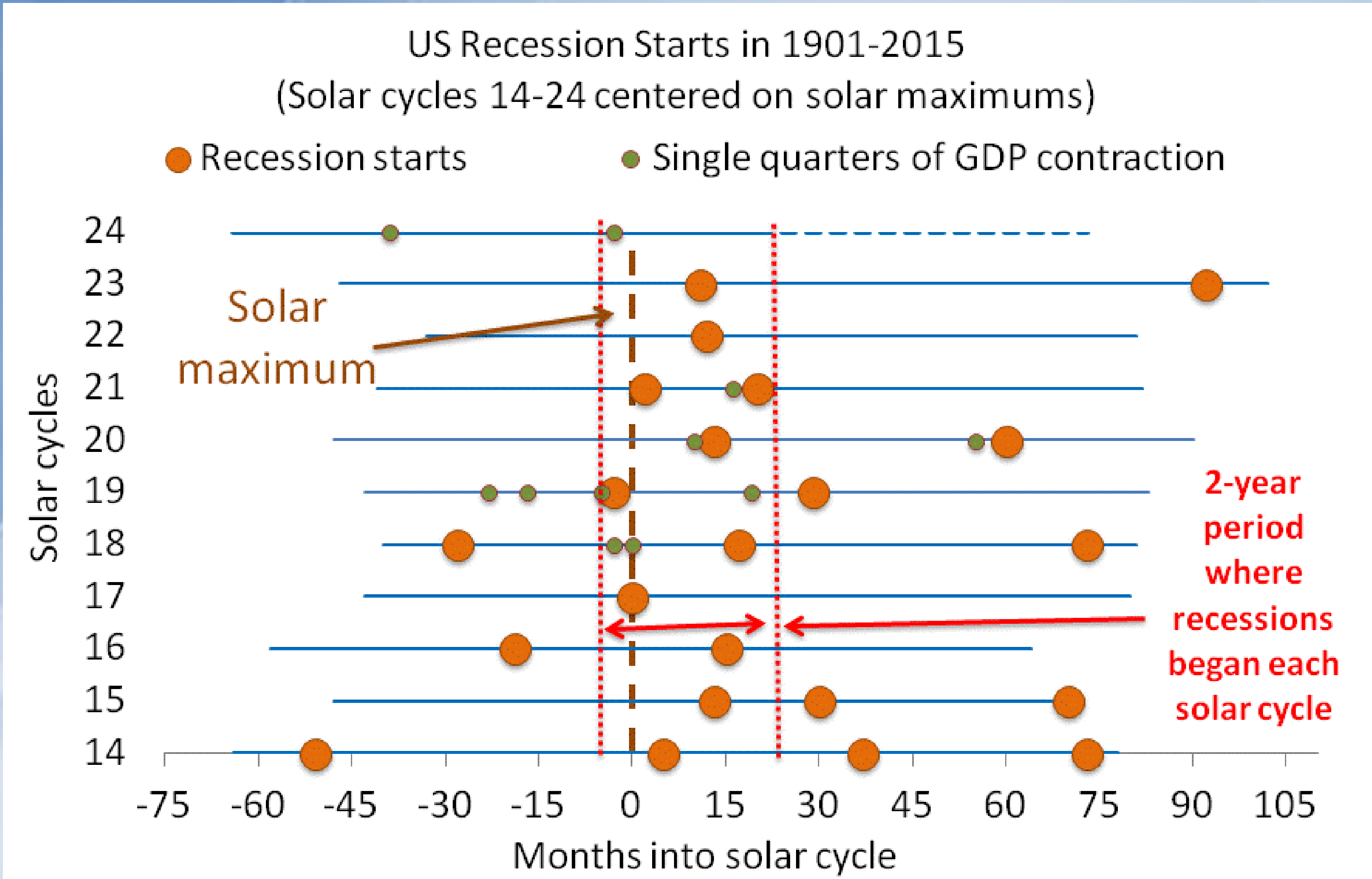
	1789	Great French Revolution
	1830	Revolutions in Europe (France, Poland, Germany, Italy, Greece)
	1848	Revolutions in Europe (Italy, France, Germany, Austria, etc.)
	1861	Secession of the southern US states that formed the C.S.A.
	1871	Uprising in Paris, “Paris Commune”
	1905-07	Revolution of 1905-07 in the Russian Empire
	1917 1918	February Revolution, Great October Socialist Revolution in Russia Revolutions in Germany and Hungary, collapse of Austro-Hungarian Empire
	1979	Islamic Revolution in Iran
	1989 1991	Fall of Berlin Wall, collapse of communism in Eastern Europe Collapse of Soviet Union and Yugoslavia
	2001	Rise of al-Qaeda, terrorist attack on the U.S. on September 11
	2011-13 2013-14 2015	“Arab Spring”: Revolutions in Egypt, Libya, Syria, Yemen, Tunisia Revolution in Ukraine Rise of ISIS, terrorist attacks against France, Russia

What starts with revolutions ends in … refugee flows



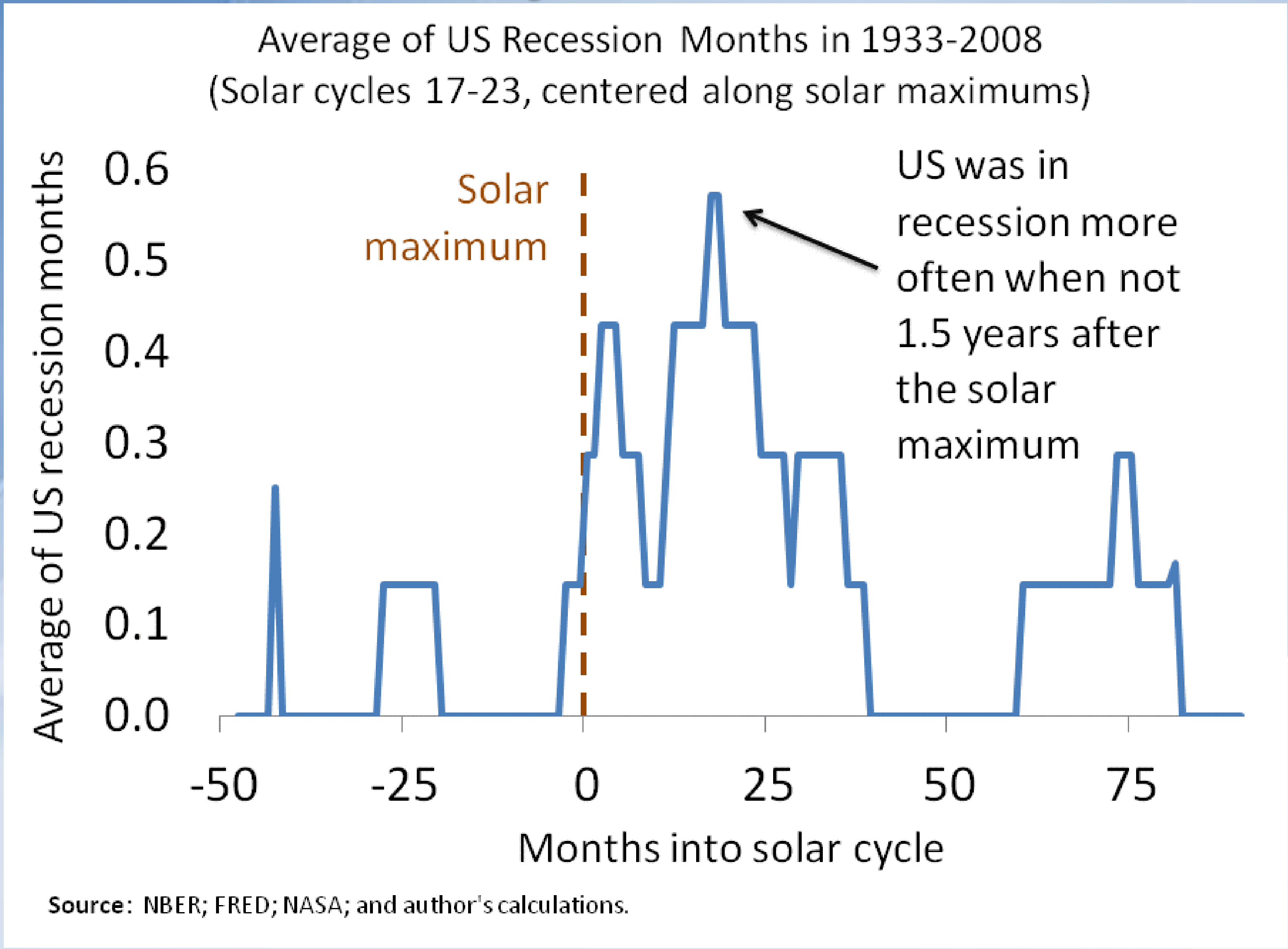
Sources: Eurostat; NASA; and author's calculations.

For over 100 years, each solar maximum overlapped with a recession in US economy

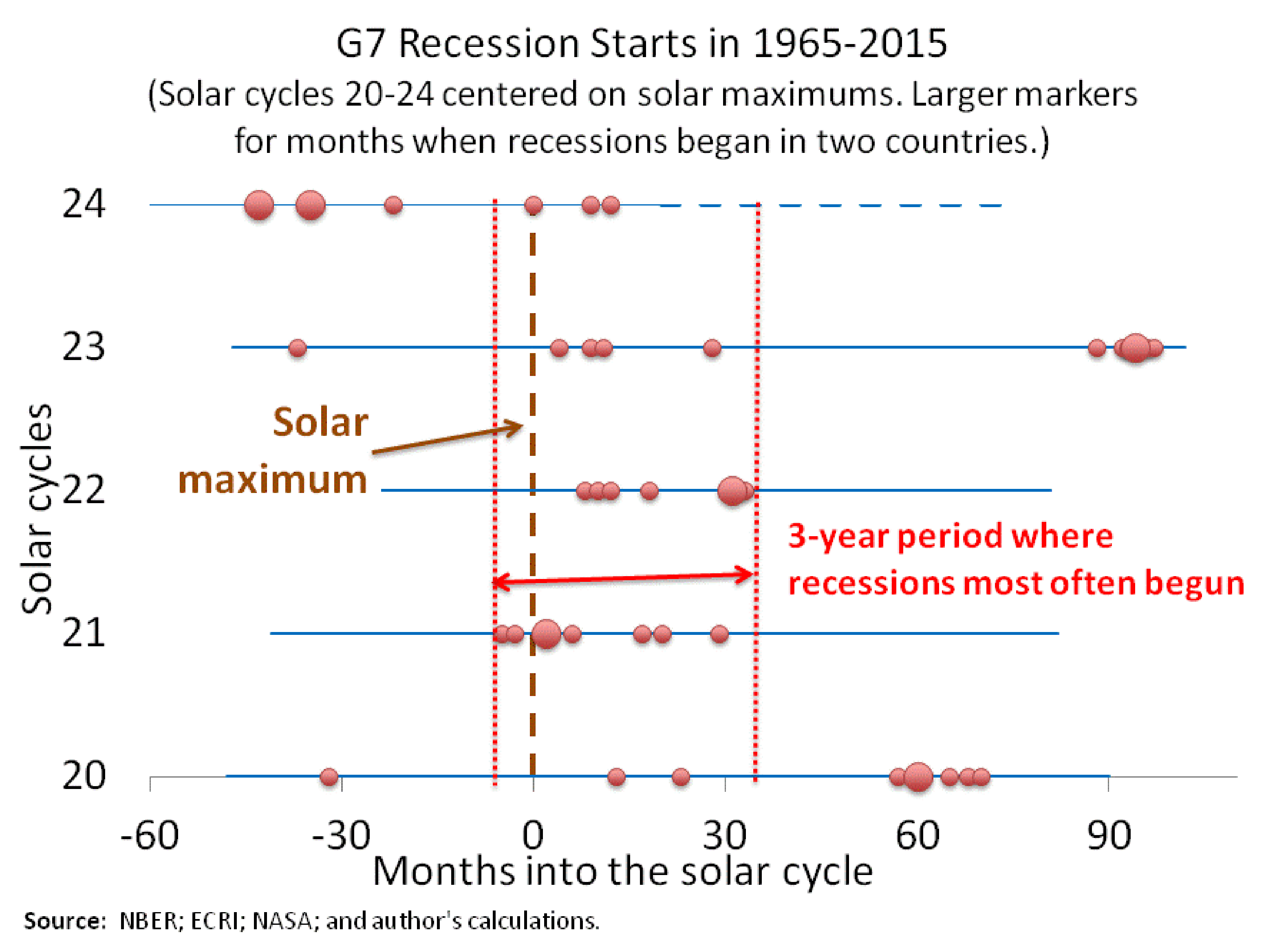


Sources: NBER; FRED; NASA; and author's calculations.

Since 1933, US economy spent 1/3 of time in recession in about 3 years after solar maximums



Since 1965, 3/5 of G7 recessions started in 3 years around and after solar maximums



In a simple regression, sunspots series is as good as traditional predictors of US recessions

Dependent Variable: NBER_REC
Method: Least Squares
Date: 09/08/15 Time: 14:53
Sample (adjusted): 1960M04 2015M08
Included observations: 665 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
OIL_YY(-3)	0.001262	0.000321	3.932902	0.0001
SPR_PROB	0.638476	0.067140	9.509618	0.0000
SSN(-15)	0.001039	0.000211	4.924585	0.0000
SP500_YY	-0.009408	0.000657	-14.32315	0.0000
C	0.049146	0.018911	2.598731	0.0096

R-squared	0.442957	Mean dependent var	0.139850
Adjusted R-squared	0.439581	S.D. dependent var	0.347092
S.E. of regression	0.259837	Akaike info criterion	0.149966
Sum squared resid	44.56007	Schwarz criterion	0.183799
Log likelihood	-44.86360	Hannan-Quinn criter.	0.163075
F-statistic	131.2071	Durbin-Watson stat	0.375048
Prob(F-statistic)	0.000000		

In a simple PROBIT model, sunspots series is doing better than traditional predictors!

Dependent Variable: REC_START
Method: ML - Binary Probit (Quadratic hill climbing)
Date: 09/08/15 Time: 15:03
Sample (adjusted): 1960M08 2015M08
Included observations: 661 after adjustments
Convergence achieved after 6 iterations
Covariance matrix computed using second derivatives

Variable	Coefficient	Std. Error	z-Statistic	Prob.
SPR_PROB(-7)	0.476048	0.733303	0.649183	0.5162
SSN(-15)	0.005071	0.003100	1.635523	0.1019
OIL_YY(-3)	0.001776	0.003898	0.455616	0.6487
SP500_YY	-0.014333	0.009654	-1.484648	0.1376
C	-2.775637	0.332758	-8.341296	0.0000

McFadden R-squared	0.089014	Mean dependent var	0.010590
S.D. dependent var	0.102439	S.E. of regression	0.102401
Akaike info criterion	0.122070	Sum squared resid	6.878840
Schwarz criterion	0.156062	Log likelihood	-35.34415
Hannan-Quinn criter.	0.135245	Deviance	70.68830
Restr. deviance	77.59542	Restr. log likelihood	-38.79771
LR statistic	6.907116	Avg. log likelihood	-0.053471
Prob(LR statistic)	0.140879		

Obs with Dep=0	654	Total obs	661
Obs with Dep=1	7		

Simulations confirm low chances of US recessions fitting solar maximums "by coincidence"

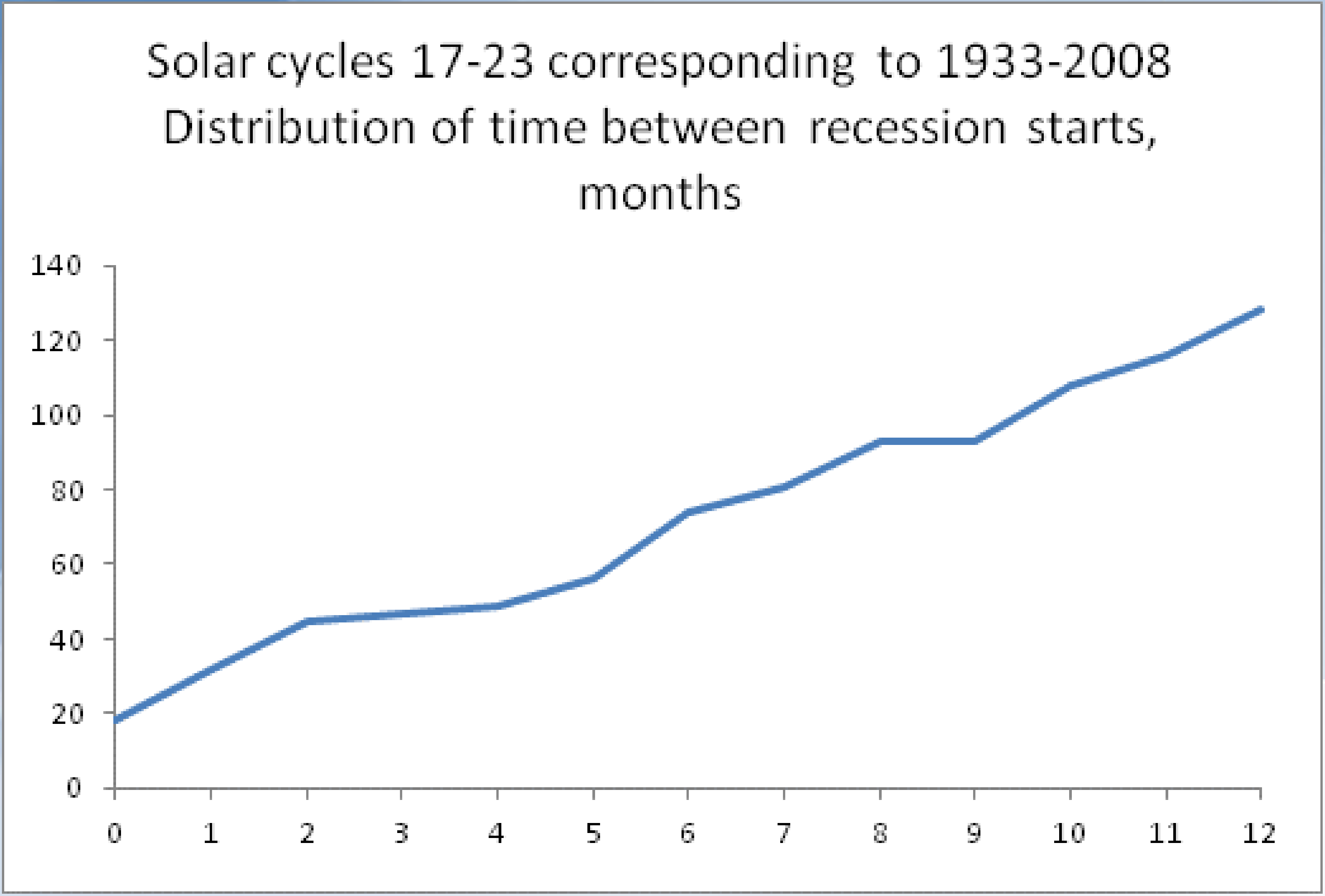
Simulations for two periods: 1933-2008 (solar cycles 17-23) and 1901-2008 (solar cycles 14-23)

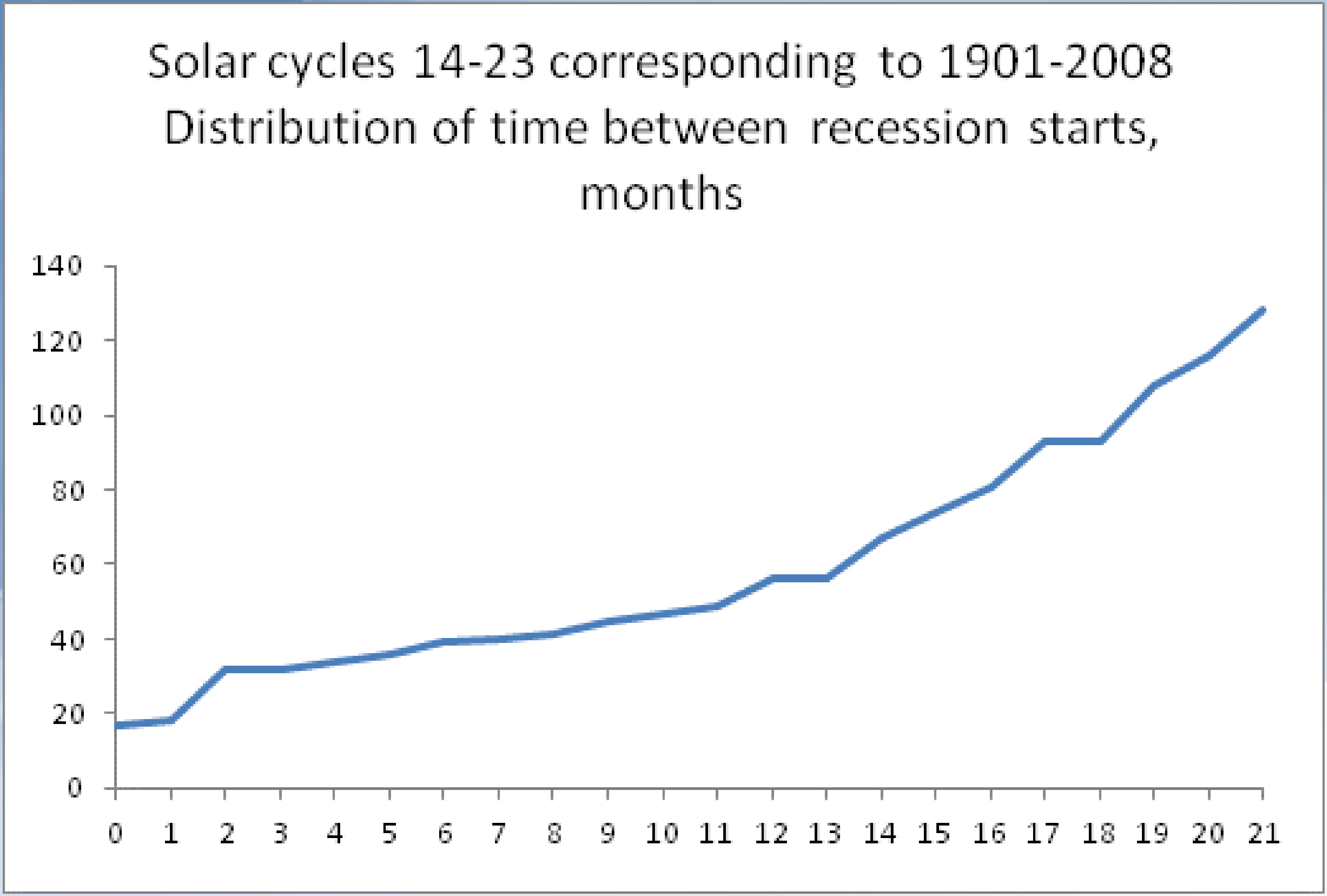
Using the actually observed pattern of recessions, drawing out of distribution of times between recession starts

With and without constraining assumption that the first recession in the time period overlaps with the solar maximum

Outcome: probability of 8 recessions (1933-2008) or 11 recessions (1901-2008) occurring in the two-year period around and after solar maximums is a fraction of a percent

Hypothesis of no relation between solar cycle and US recessions is rejected at 0.1 percent confidence level

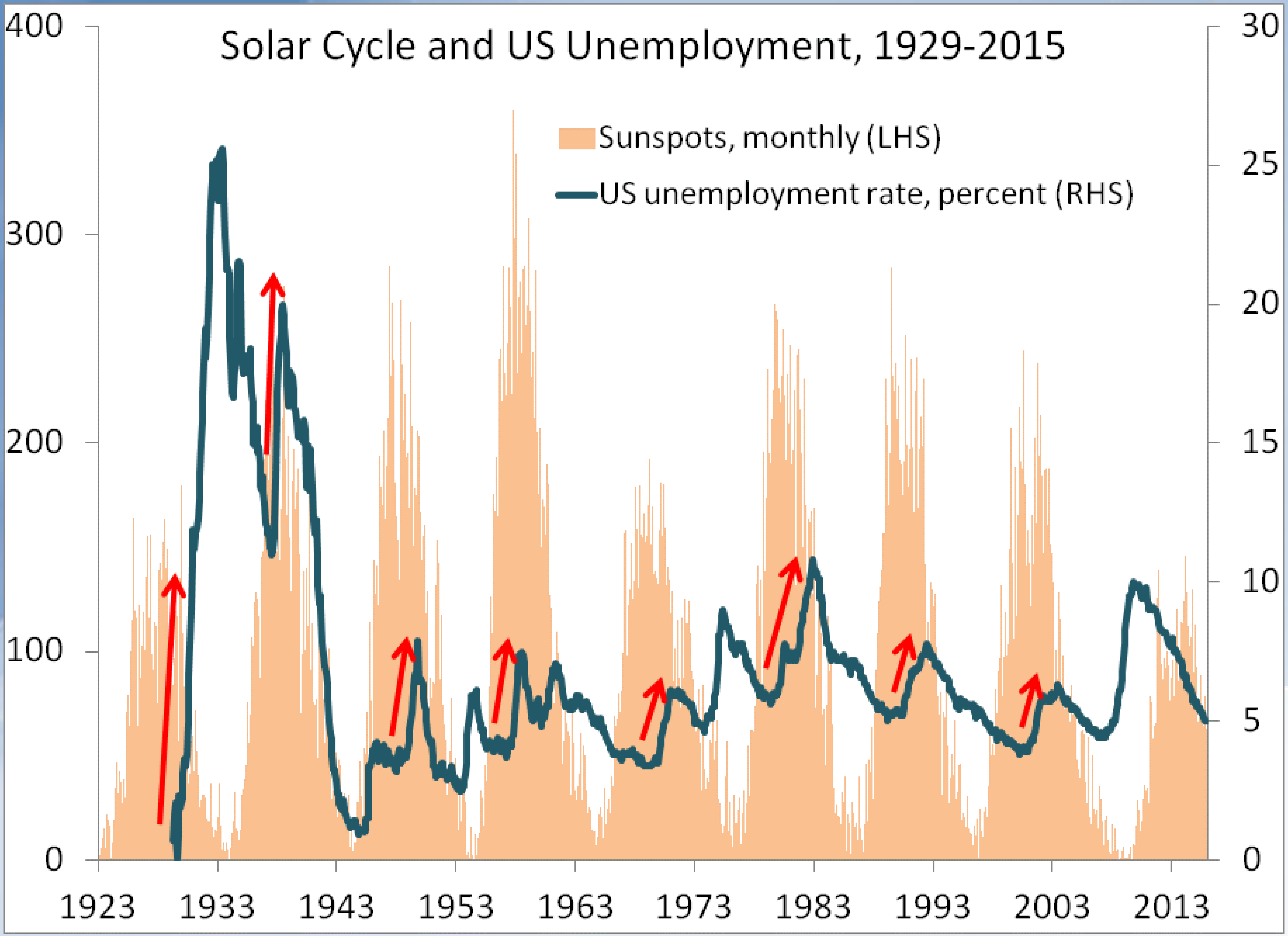

Solar cycles 17-23 corresponding to 1933-2008
Distribution of time between recession starts, months
140
120
100
80
60
40
20
0
0
1
2
3
4
5
6
7
8
9
10
11
12



Solar cycles 14-23 corresponding to 1901-2008
Distribution of time between recession starts, months
140
120
100
80
60
40
20
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21

	1933-2008				
	Probability of 8 or more recessions				
	2 years (25 months) around solar max				
Sim #	constrained	unconstrained	constrained - discrete	unconstrained - discrete	All combinations
0	0.0087	0.0025	0.0752	0.0161	
1	0.0208	0.0069	0.1340	0.0288	
2	0.0138	0.0020	0.1670	0.0159	
3	0.0163	0.0072	0.1711	0.0245	
4	0.0147	0.0026	0.0896	0.0235	
5	0.0093	0.0003	0.1180	0.0526	
6	0.0166	0.0055	0.1133	0.0539	
7	0.0085	0.0019	0.1085	0.0161	
8	0.0051	0.0046	0.1077	0.0220	
9	0.0061	0.0027	0.1230	0.0304	
Average	**0.0120**	**0.0036**	**0.1207**	**0.0284**	**0.062**
STD	0.0052	0.0023	0.0303	0.0141	
+/- 3 STD	-0.0035	-0.0033	0.0297	-0.0138	
	0.0275	0.0105	0.2118	0.0706	

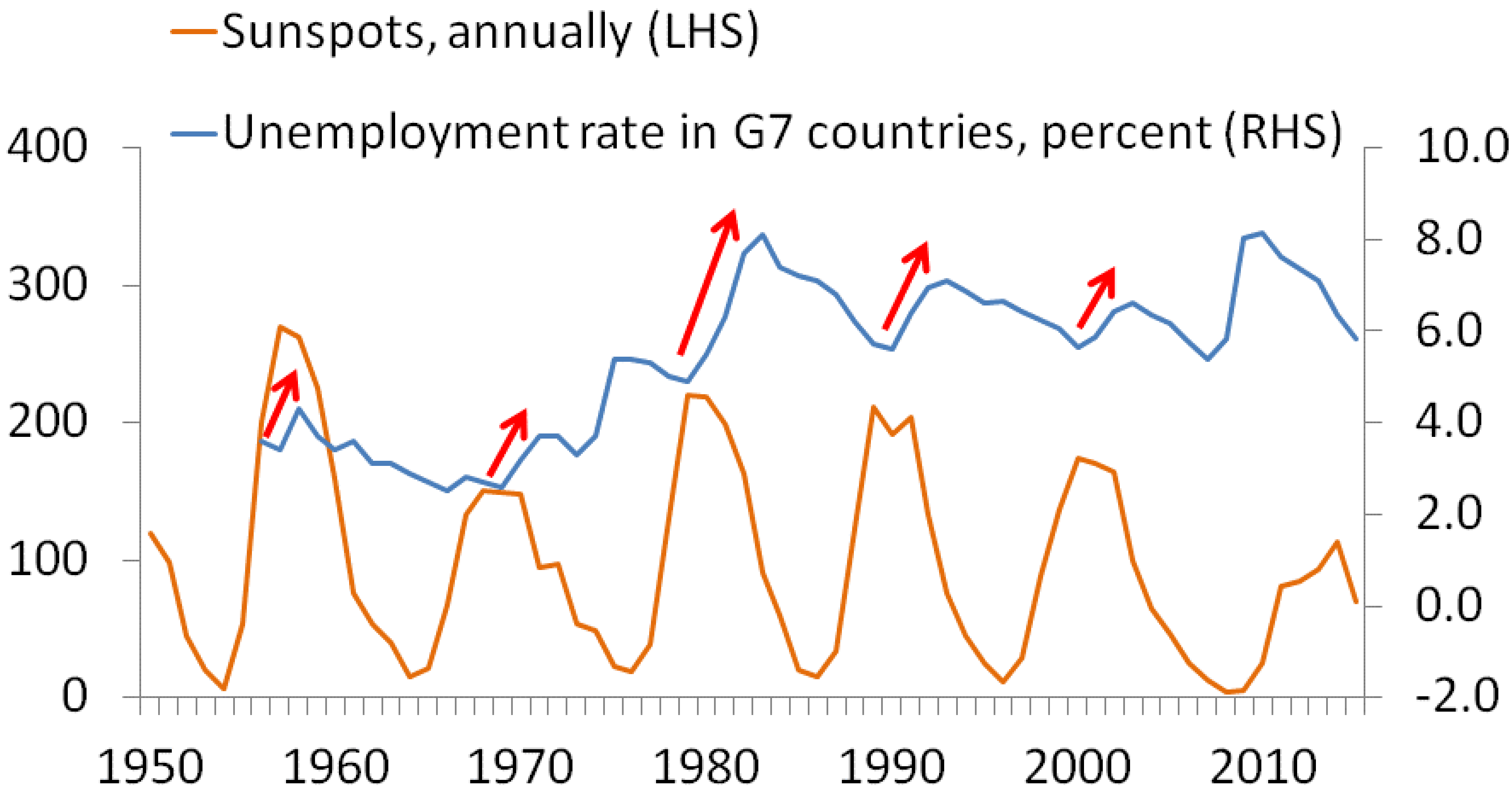
	1901-2008			
	Probability of 11 or more recessions			
	2 years (25 months) around solar max			
Sim #	constrained	unconstrained	constrained - discrete	unconstrained - discrete
0	0.0241	0.0061	0.0315	0.0144
1	0.0197	0.0121	0.0867	0.0196
2	0.0277	0.0059	0.0307	0.0111
3	0.0056	0.0127	0.0327	0.0055
4	0.0068	0.0013	0.0429	0.0070
5	0.0089	0.0015	0.0400	0.0086
6	0.0115	0.0051	0.0338	0.0094
7	0.0137	0.0042	0.0417	0.0187
8	0.0188	0.0080	0.0445	0.0099
9	0.0243	0.0098	0.0498	0.0155
Average	**0.0161**	**0.0067**	**0.0434**	**0.0120**
STD	0.0079	0.0040	0.0165	0.0048
+/- 3 STD	-0.0076	-0.0053	-0.0060	-0.0026
	0.0398	0.0186	0.0928	0.0265



Solar Cycle and US Unemployment, 1929-2015
Sunspots, monthly (LHS)
US unemployment rate, percent (RHS)
400
300
200
100
0
30
25
20
15
10
5
0
1923
1933
1943
1953
1963
1973
1983
1993
2003
2013

Solar Cycle and G7 Unemployment, 1956-2015

Five solar maximums overlapped with minimums of unemployment rate in G7 countries followed by its sharp increase



Sources: OECD; IMF *WEO (October 2014)*; NASA.

Solar maximum of April 2014 and current economic developments and outlook

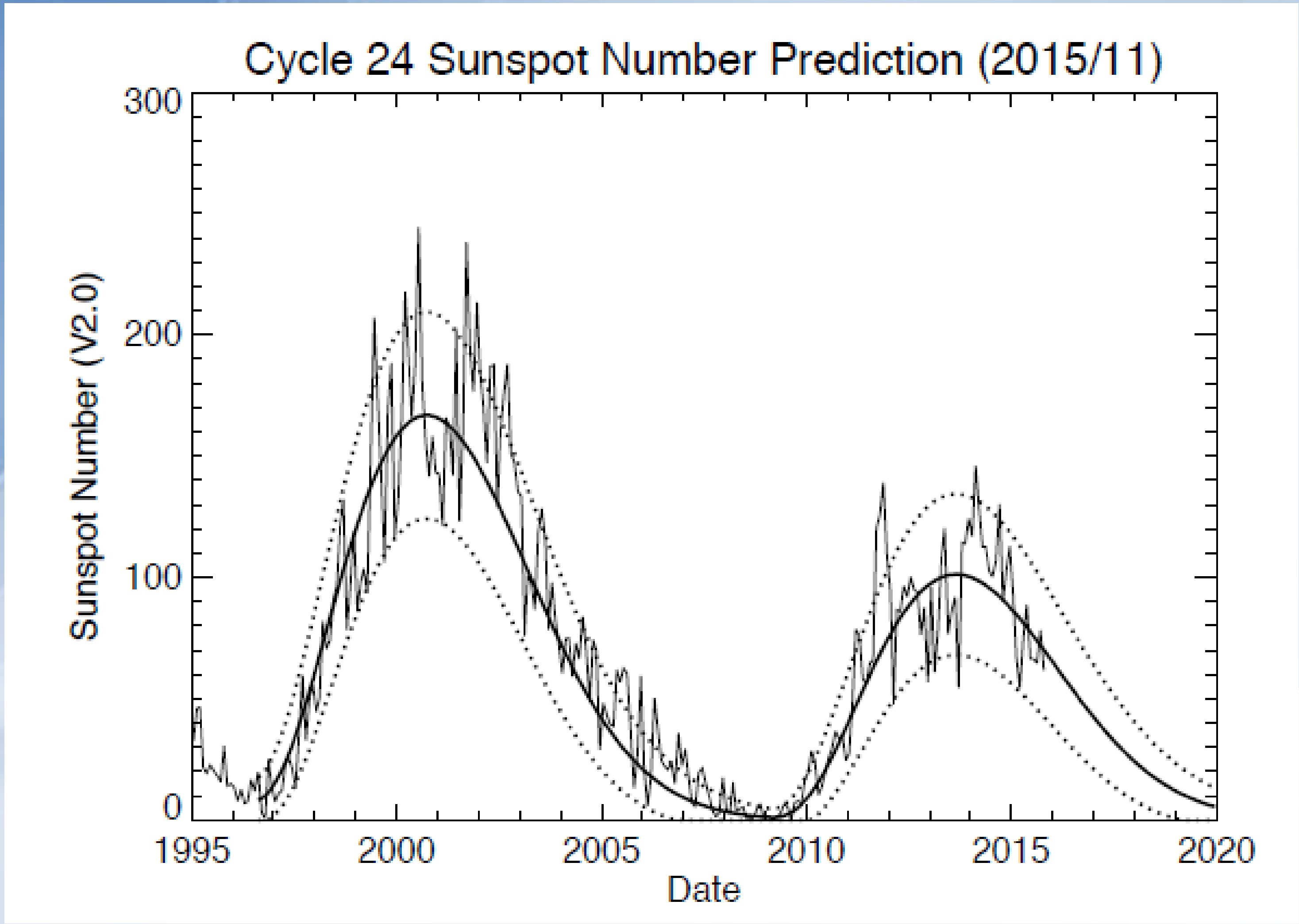
Global economic performance and outlook in 2015-16 proved weaker than previously projected

However, US unemployment is declining, deviating from previous pattern

And there was no US recession in 2014-15. Not yet?

With so many countries in trouble, is it a “global economic slowdown” or “global economic crisis”?

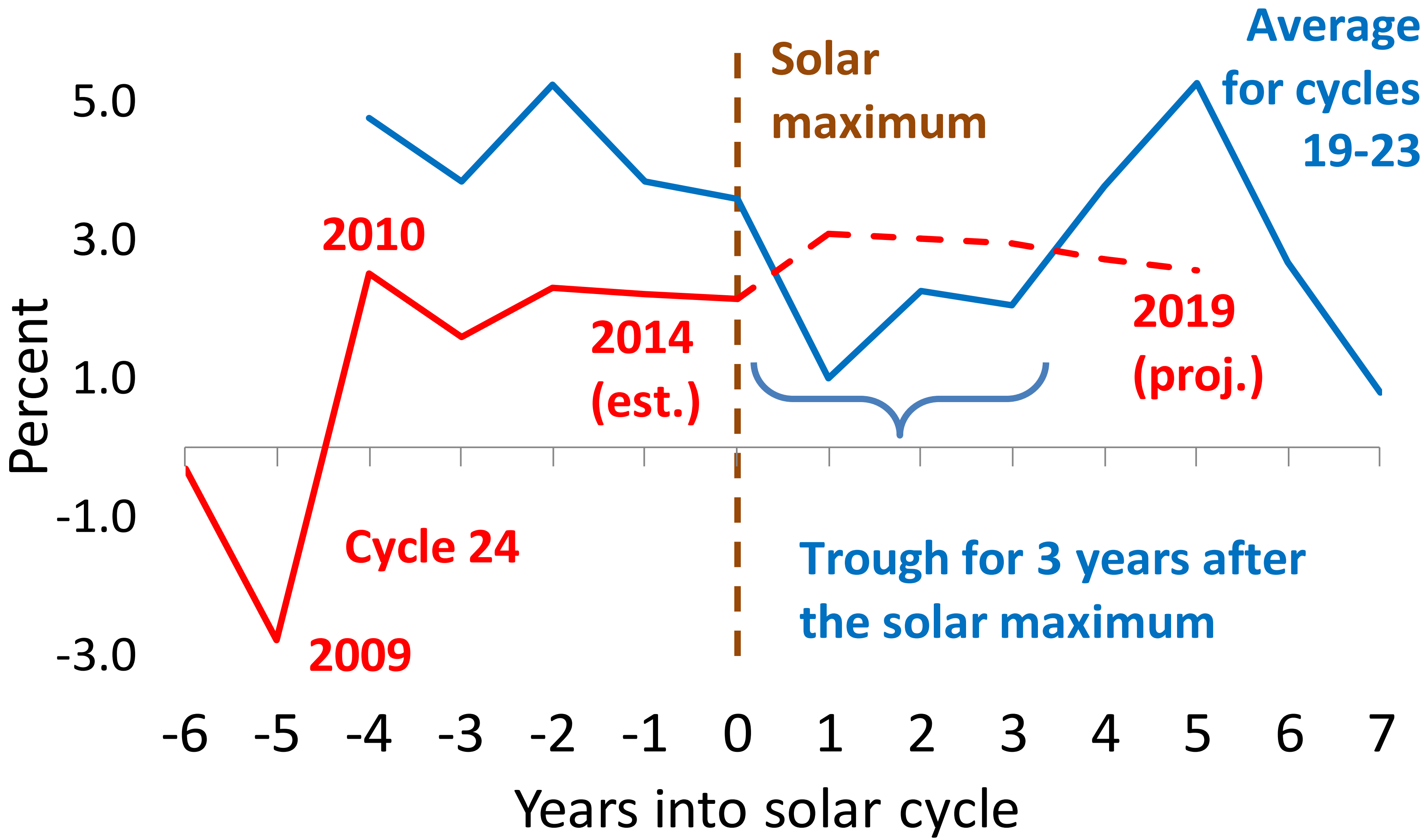
According to NASA, currently unfolding 24th solar cycle reached its maximum in April 2014



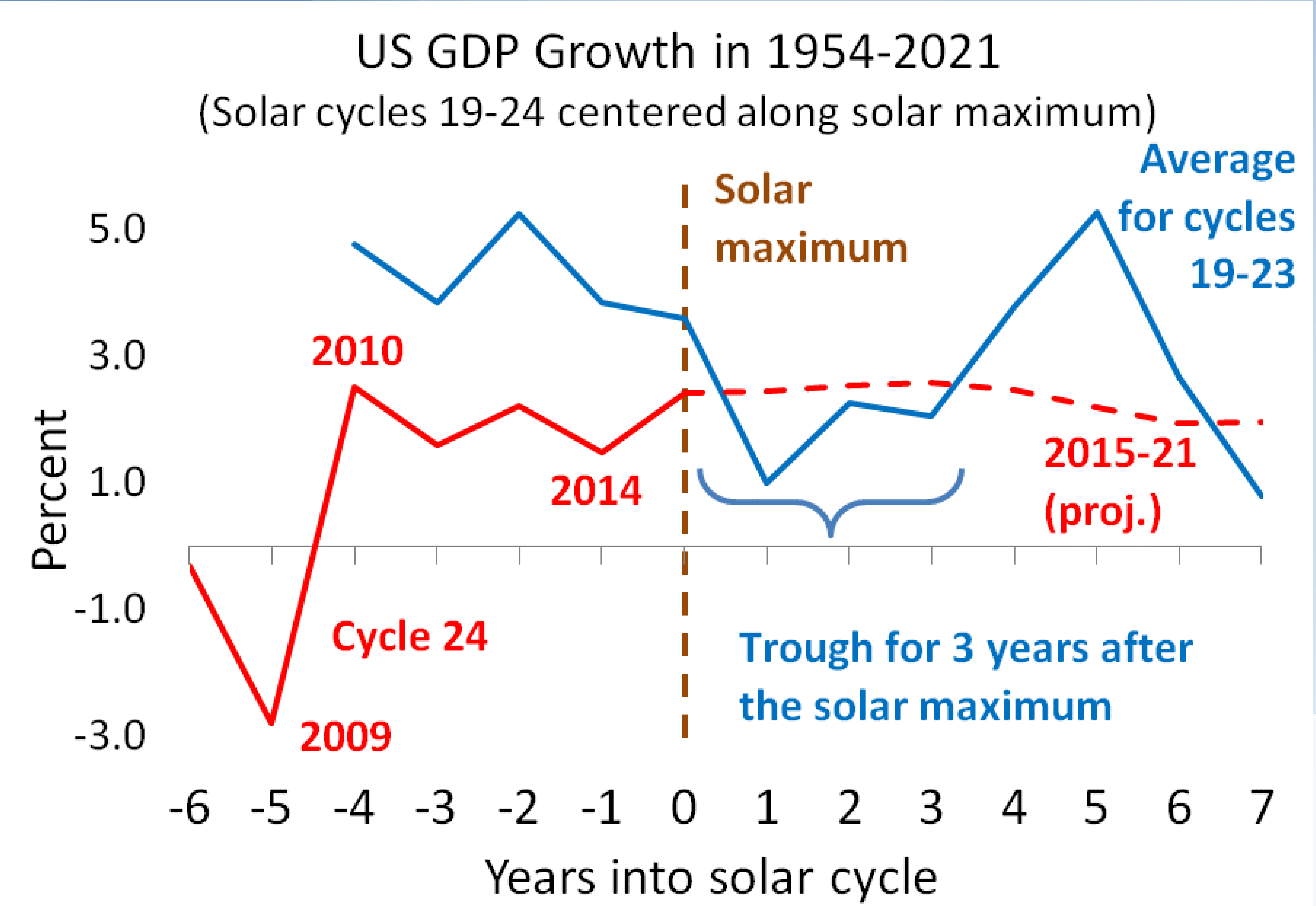
Source: NASA, solarscience.msfc.nasa.gov/predict.shtml

Figure 16. US GDP Growth in 1954-2014

(Solar cycles 19-24 centered along solar maximum)

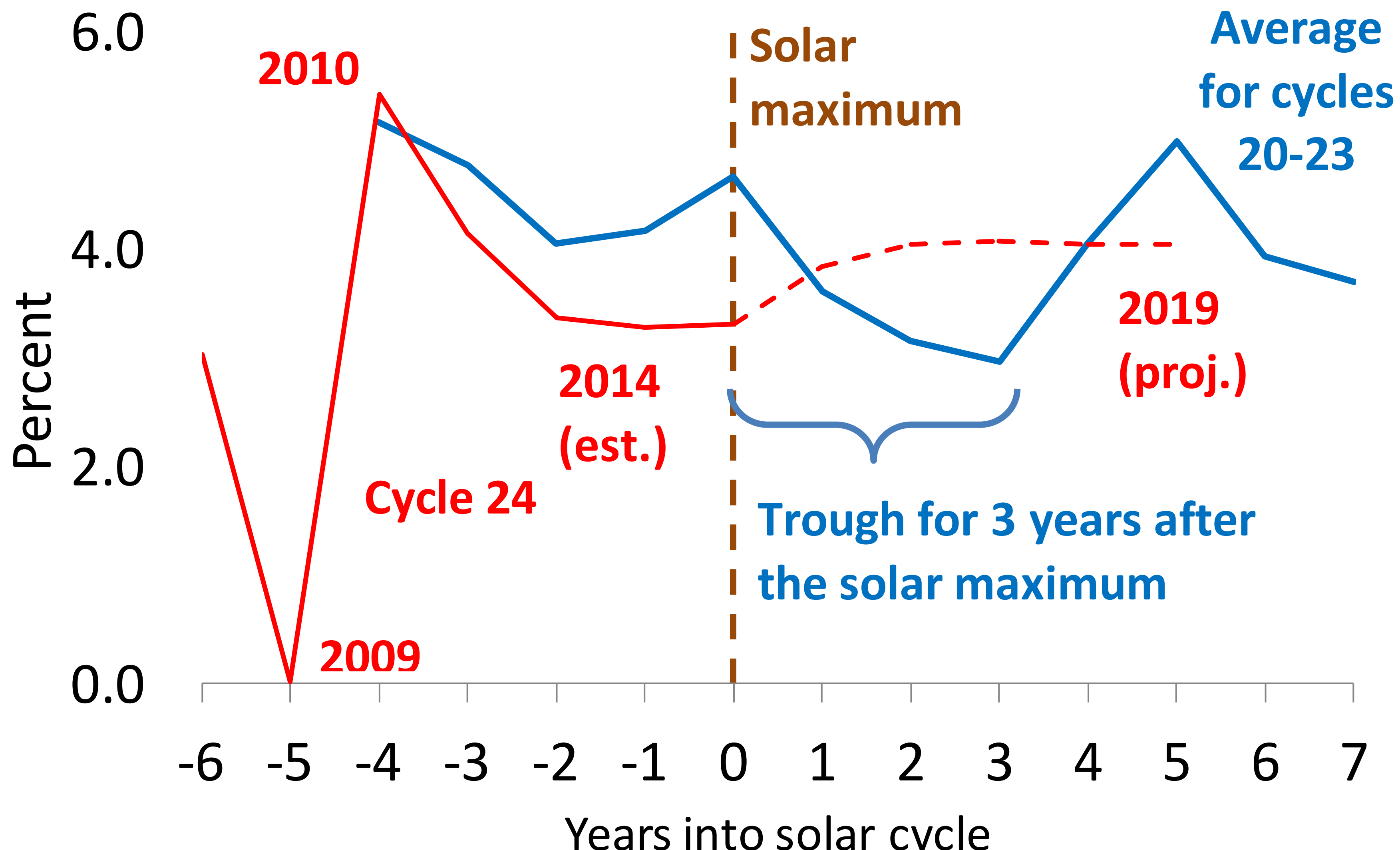


Source: Bureau of Economic Analysis; IMF *WEO* ; NASA; and author's calculations.

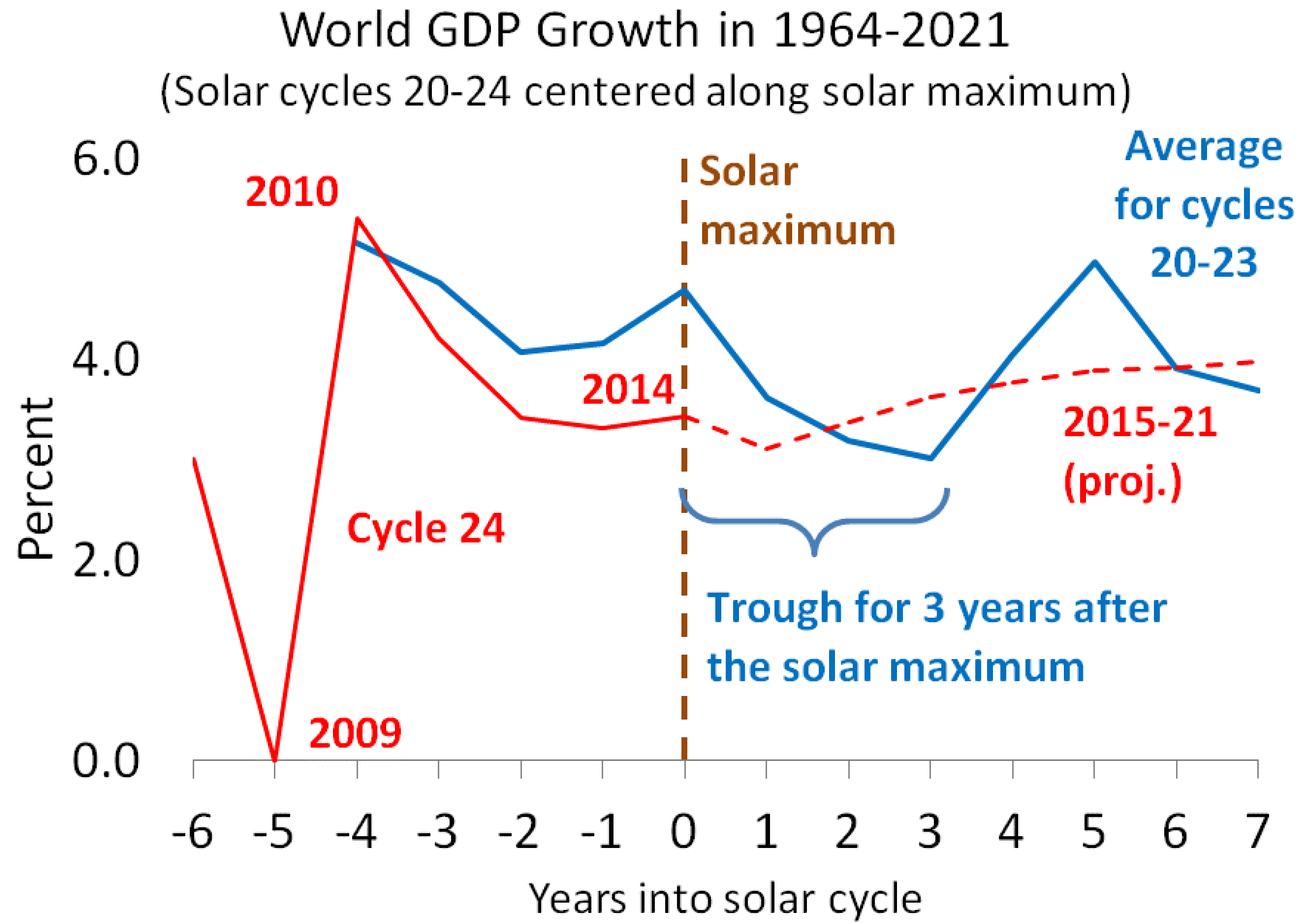


Source: Bureau of Economic Analysis; IMF *WEO (January 2016)* ; NASA; and author's calculations.

Figure 17. World GDP Growth in 1964-2014
(Solar cycles 20-24 centered along solar maximum)



Source: IMF *WEO* ; NASA; and author's calculations.



Source: IMF *WEO (January 2016)*; NASA; and author's calculations.

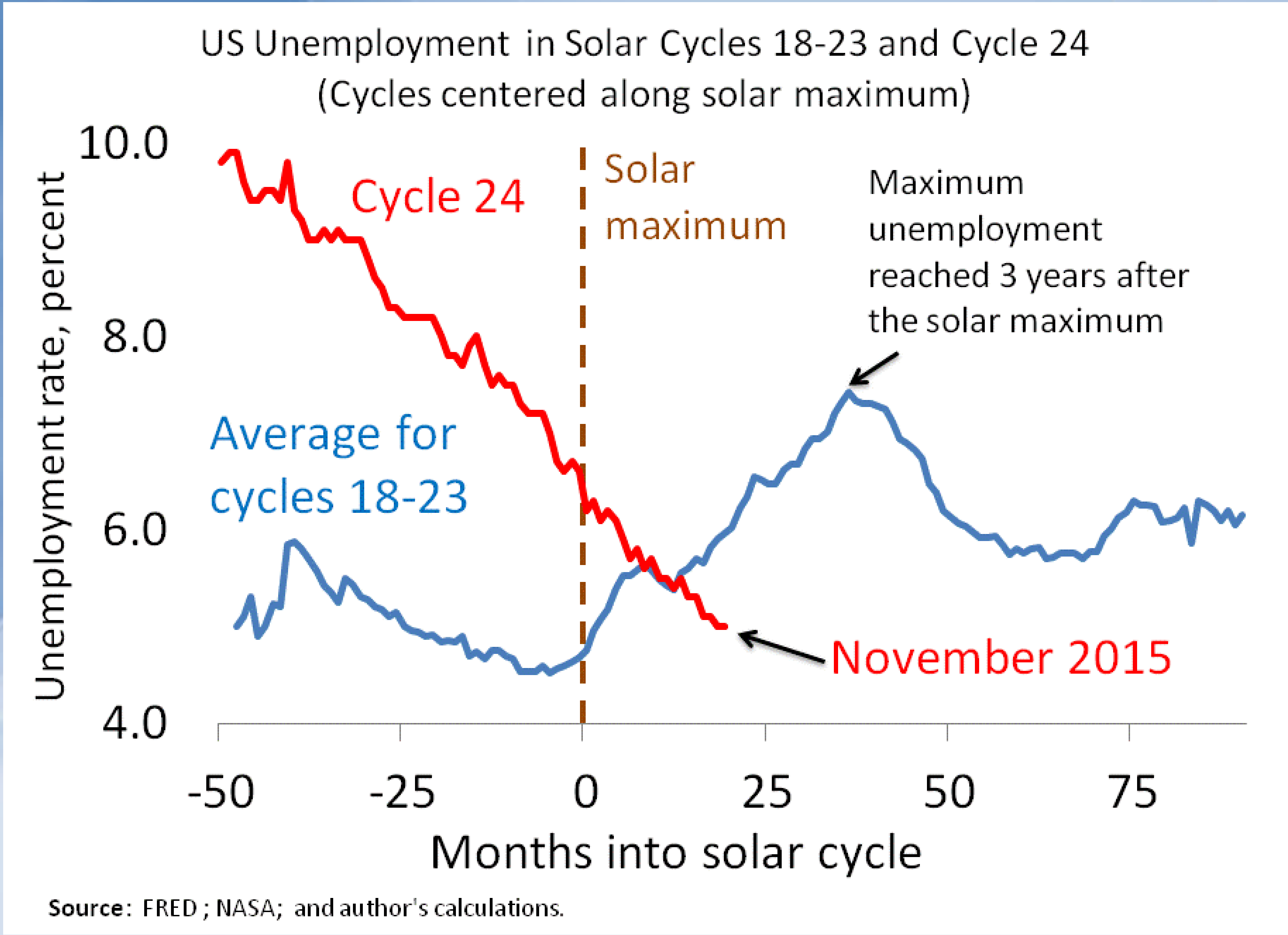
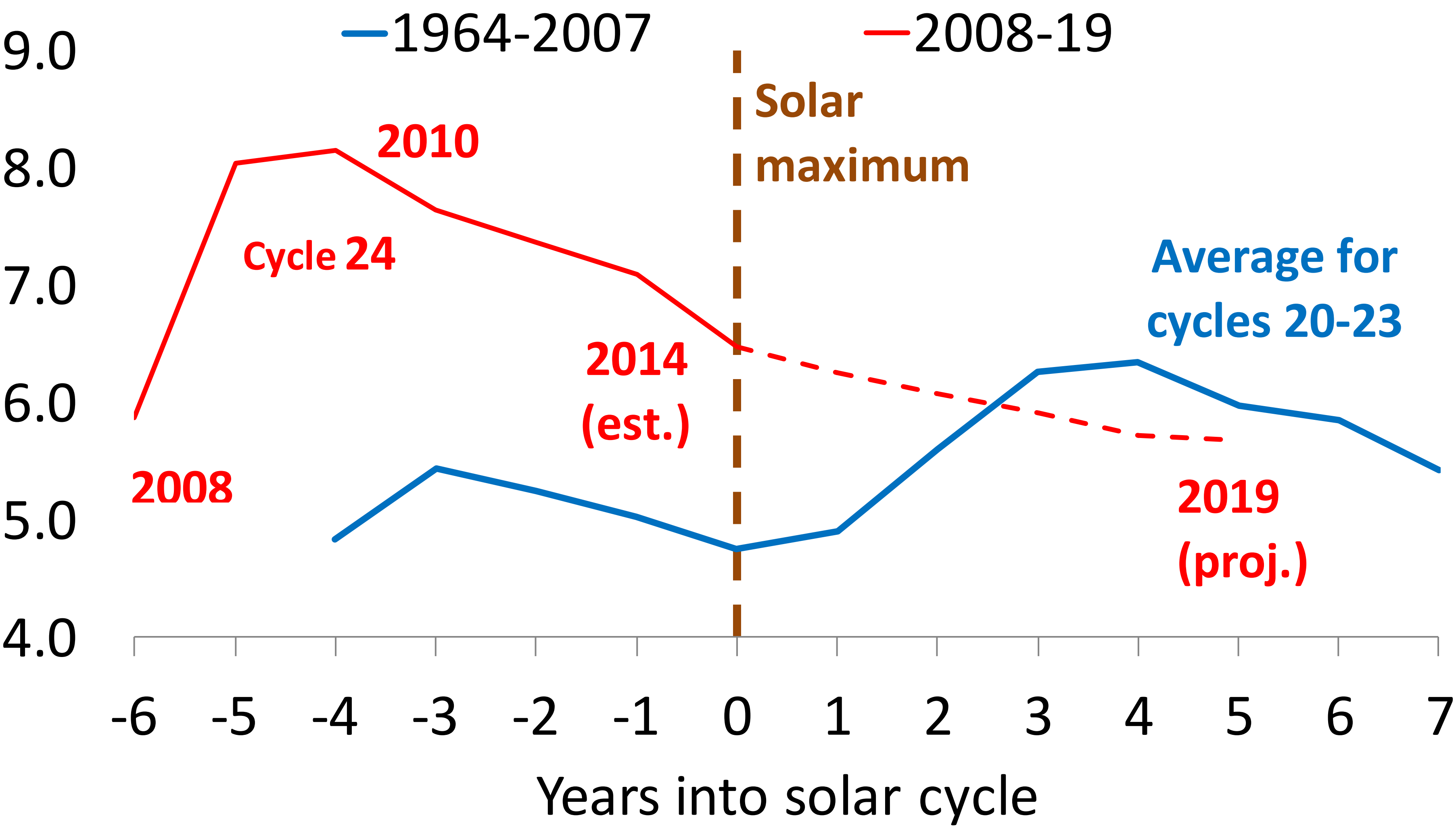
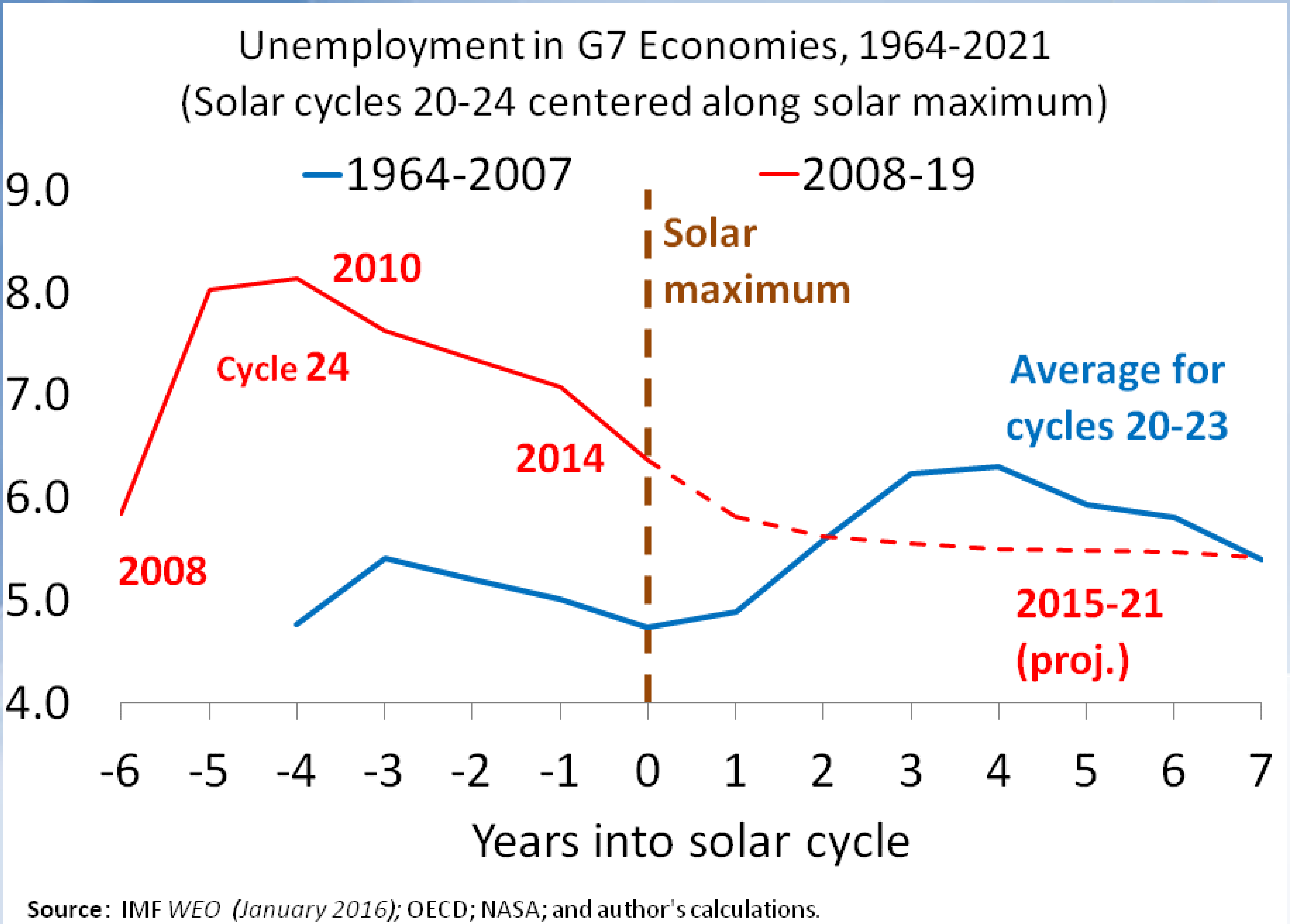

US Unemployment in Solar Cycles 18-23 and Cycle 24
(Cycles centered along solar maximum)
Unemployment rate, percent
10.0
8.0
6.0
4.0
Cycle 24
Solar maximum
Maximum unemployment reached 3 years after the solar maximum
Average for cycles 18-23
November 2015
-50
-25
0
25
50
75
Months into solar cycle
Source: FRED ; NASA; and author's calculations.

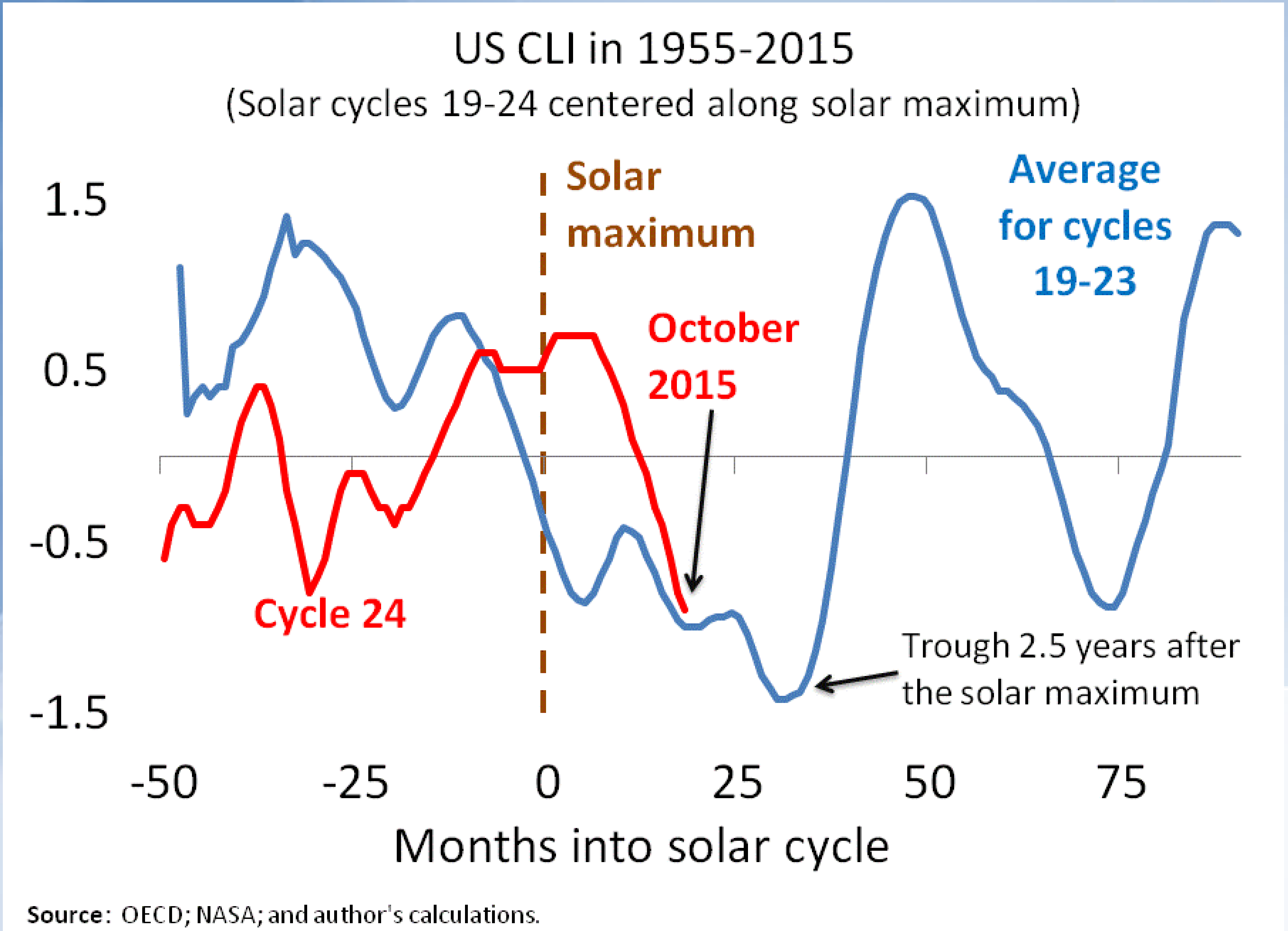
Figure 14. Unemployment in G7 Economies, 1964-2019
(Solar cycles 20-24 centered along solar maximum)



Source: IMF *WEO;* OECD; NASA; and author's calculations.



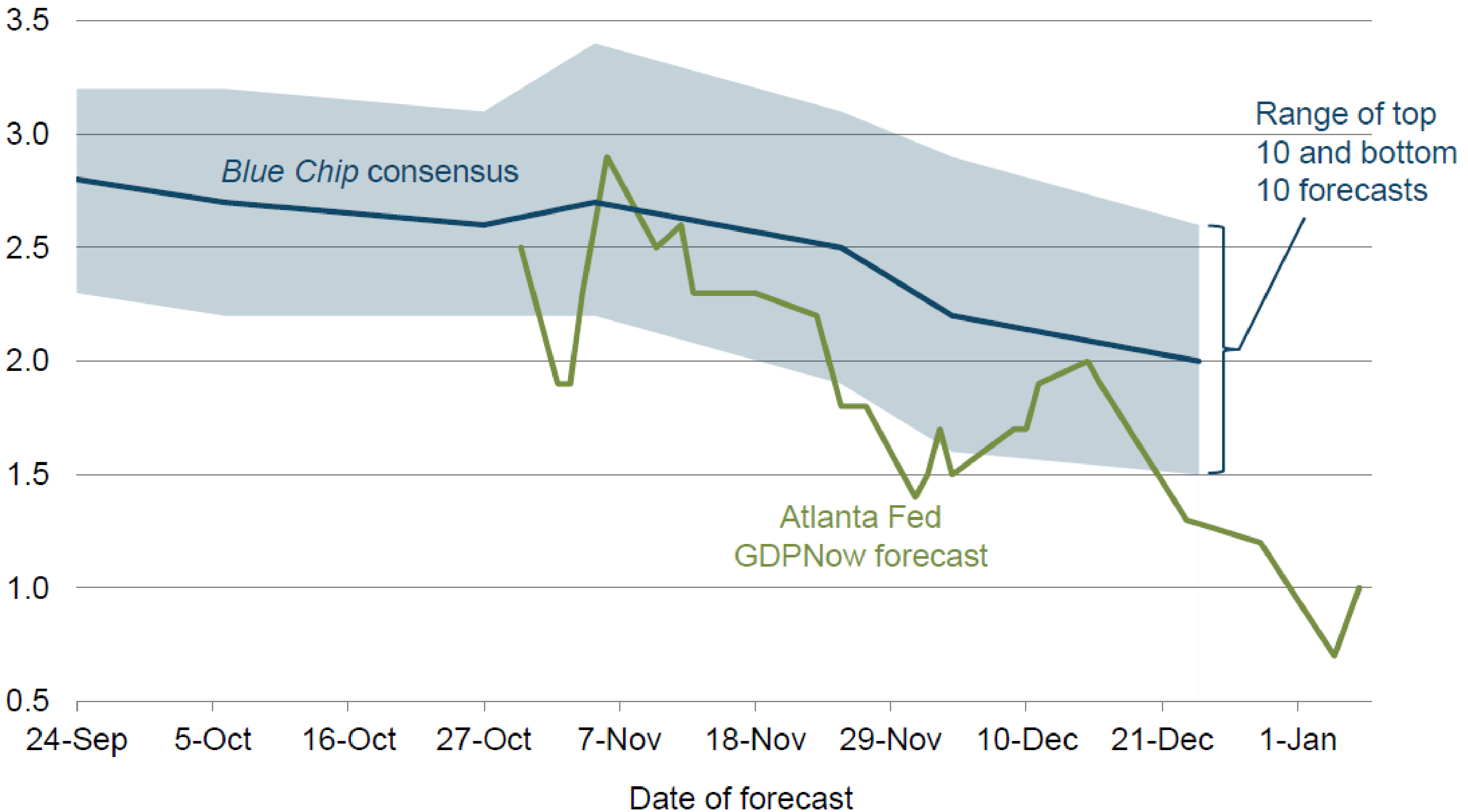
Unemployment in G7 Economies, 1964-2021
(Solar cycles 20-24 centered along solar maximum)
1964-2007
2008-19
9.0
8.0
7.0
6.0
5.0
4.0
Solar maximum
2010
Cycle 24
2014
2008
Average for cycles 20-23
2015-21 (proj.)
-6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7
Years into solar cycle
Source: IMF *WEO* (*January 2016*); OECD; NASA; and author's calculations.


US CLI in 1955-2015
(Solar cycles 19-24 centered along solar maximum)
Solar maximum
Average for cycles 19-23
October 2015
Cycle 24
Trough 2.5 years after the solar maximum
1.5
0.5
-0.5
-1.5
-50
-25
0
25
50
75
Months into solar cycle
Source: OECD; NASA; and author's calculations.

Evolution of Atlanta Fed GDPNow real GDP forecast for 2015: Q4

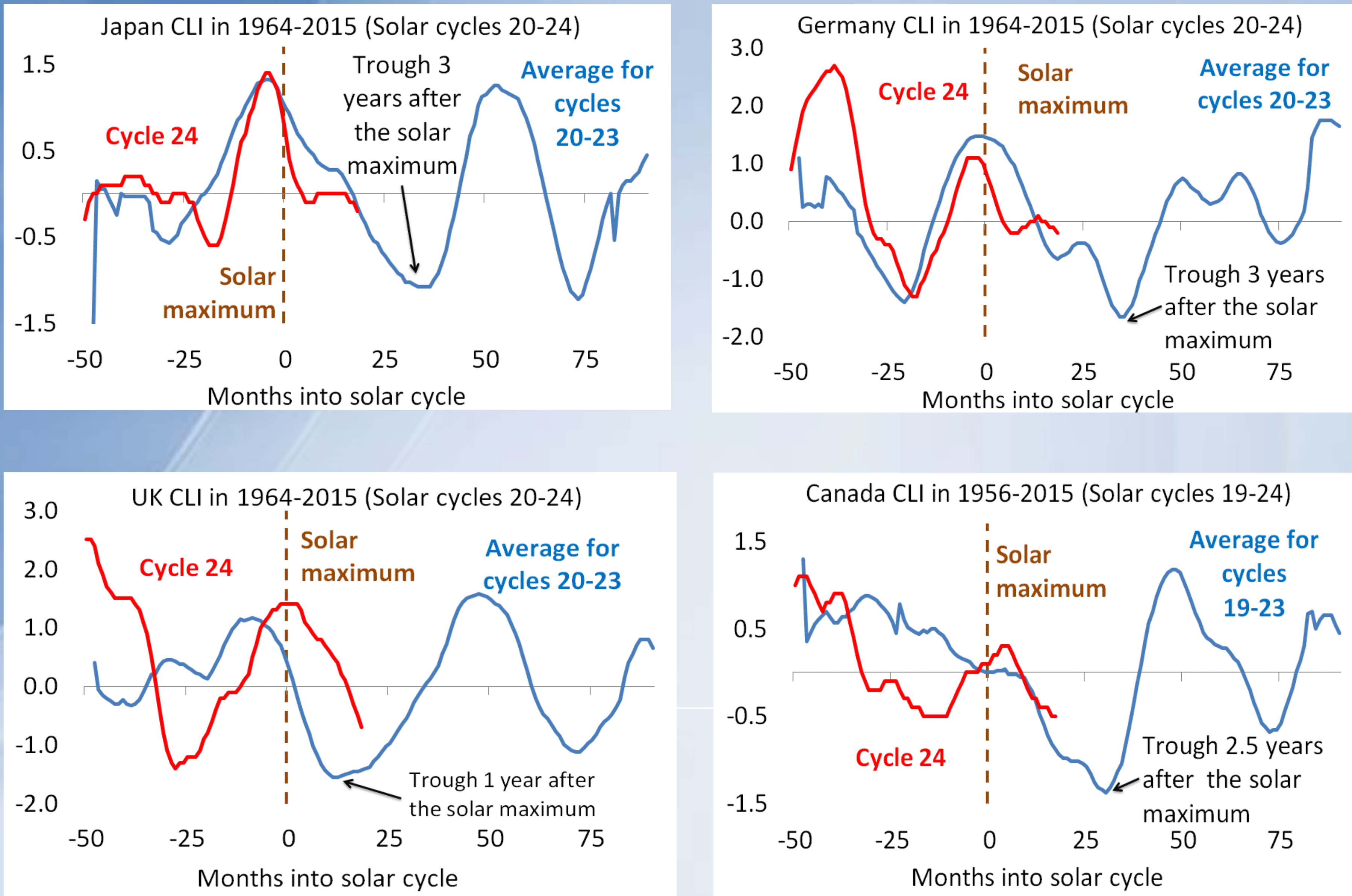
Quarterly percent change (SAAR)

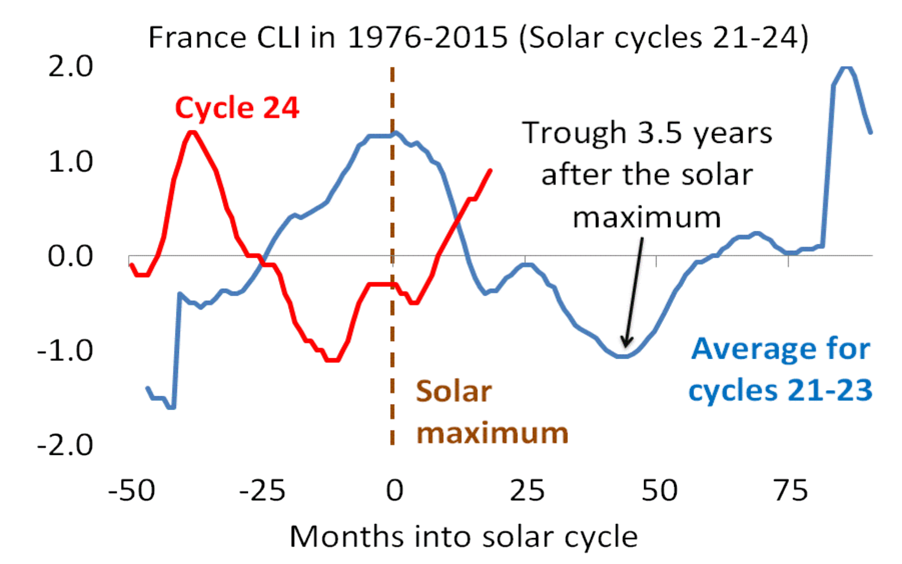
GDPNow™

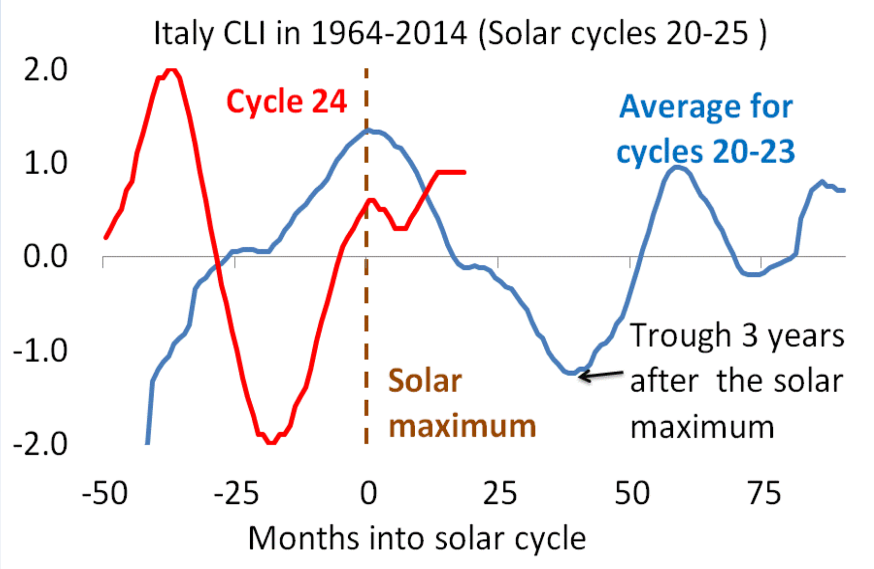


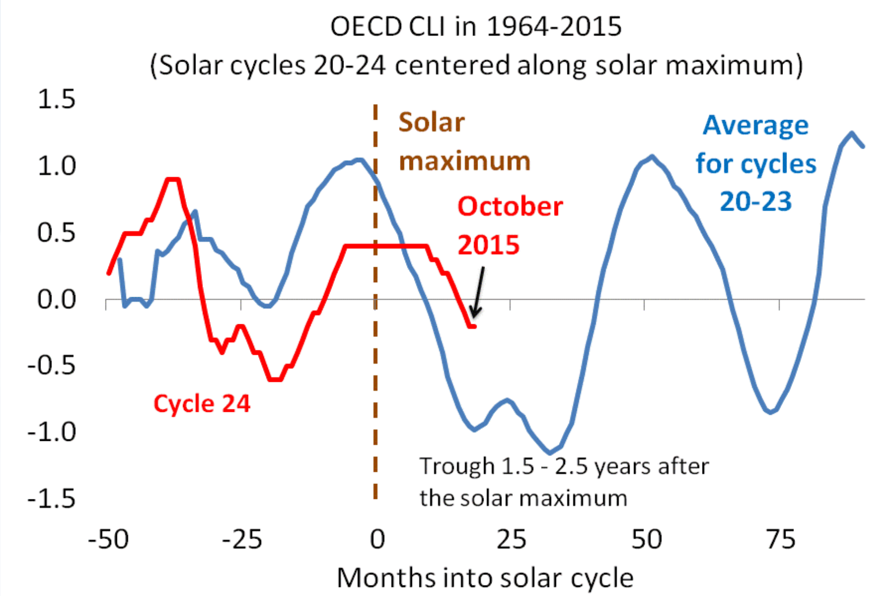
Sources: *Blue Chip Economic Indicators* and *Blue Chip Financial Forecasts*

FEDERAL RESERVE BANK *of* ATLANTA

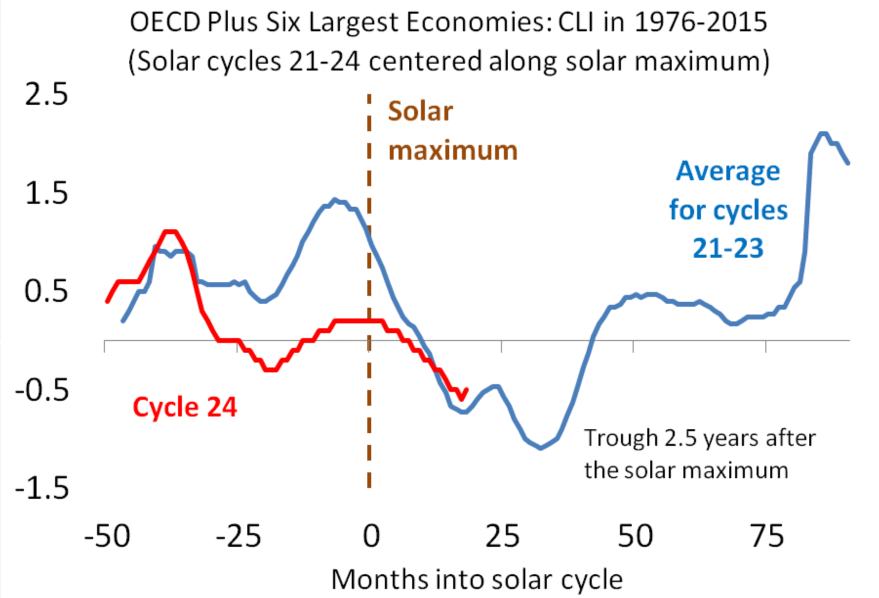

Japan CLI in 1964-2015 (Solar cycles 20-24)
Trough 3 years after the solar maximum
Average for cycles 20-23
Cycle 24
Solar maximum
1.5
0.5
-0.5
-1.5
-50
-25
0
25
50
75
Months into solar cycle
Germany CLI in 1964-2015 (Solar cycles 20-24)
Cycle 24
Solar maximum
Average for cycles 20-23
Trough 3 years after the solar maximum
3.0
2.0
1.0
0.0
-1.0
-2.0
-50
-25
0
25
50
75
Months into solar cycle
UK CLI in 1964-2015 (Solar cycles 20-24)
Solar maximum
Cycle 24
Average for cycles 20-23
Trough 1 year after the solar maximum
3.0
2.0
1.0
0.0
-1.0
-2.0
-50
-25
0
25
50
75
Months into solar cycle
Canada CLI in 1956-2015 (Solar cycles 19-24)
Solar maximum
Average for cycles 19-23
Cycle 24
Trough 2.5 years after the solar maximum
1.5
0.5
-0.5
-1.5
-50
-25
0
25
50
75
Months into solar cycle







Source: OECD; NASA; and author's calculations.



Source: OECD; NASA; and author's calculations.

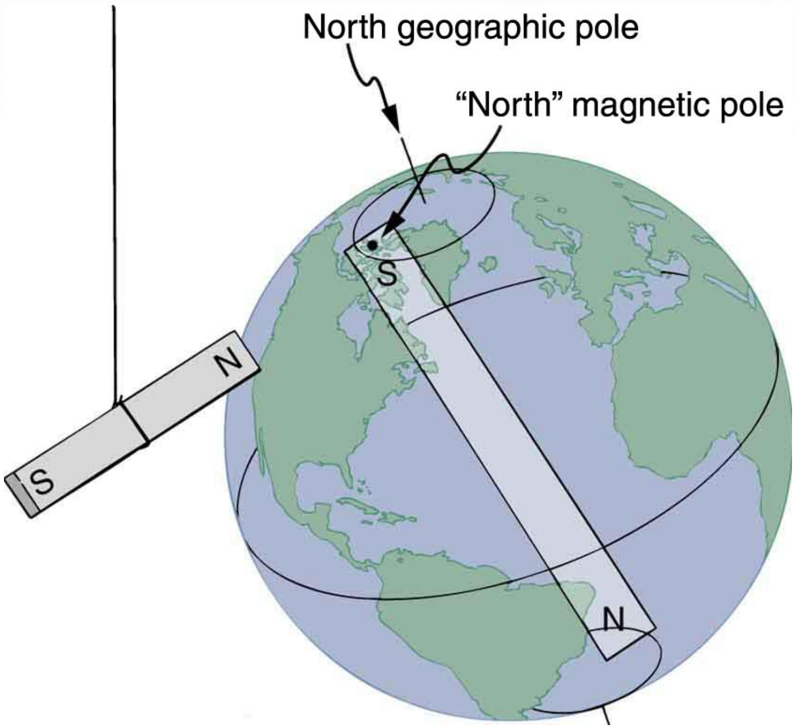
Open Discussion

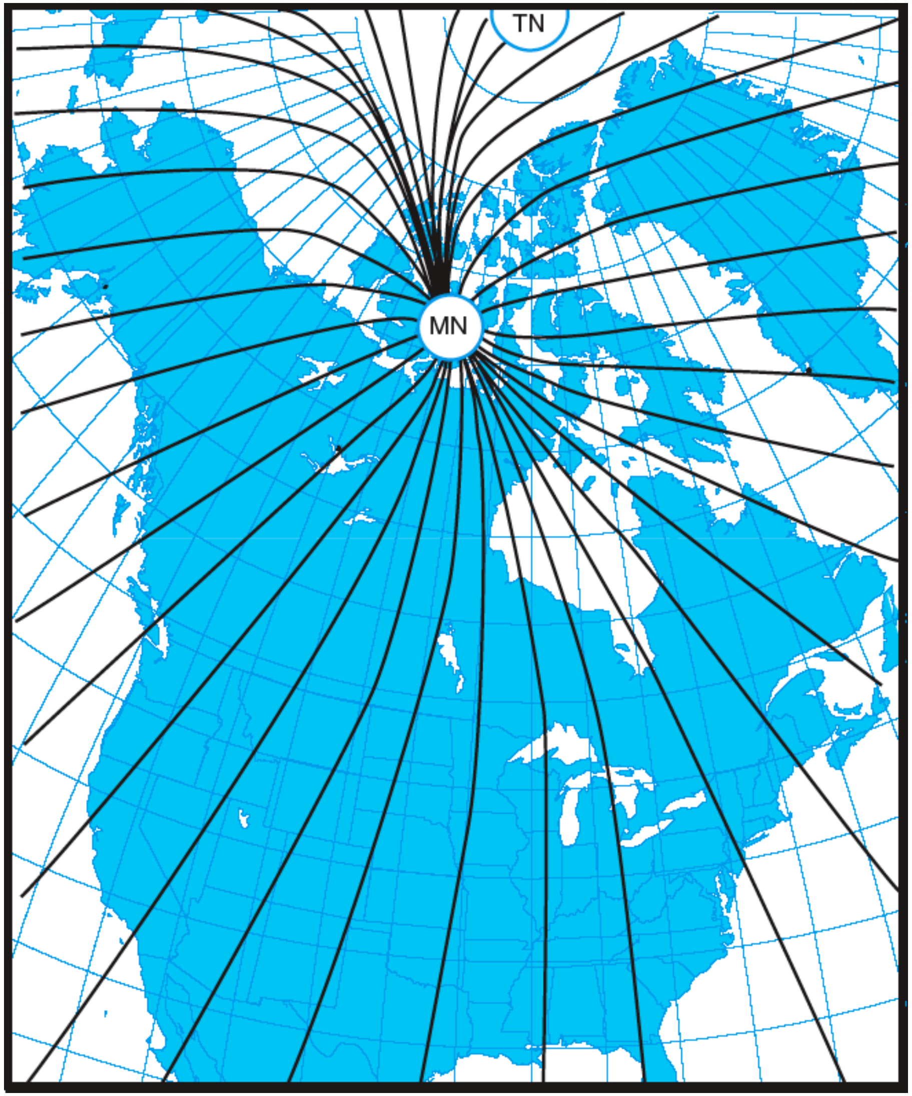
How to design statistical tests?

Use in econometric models?

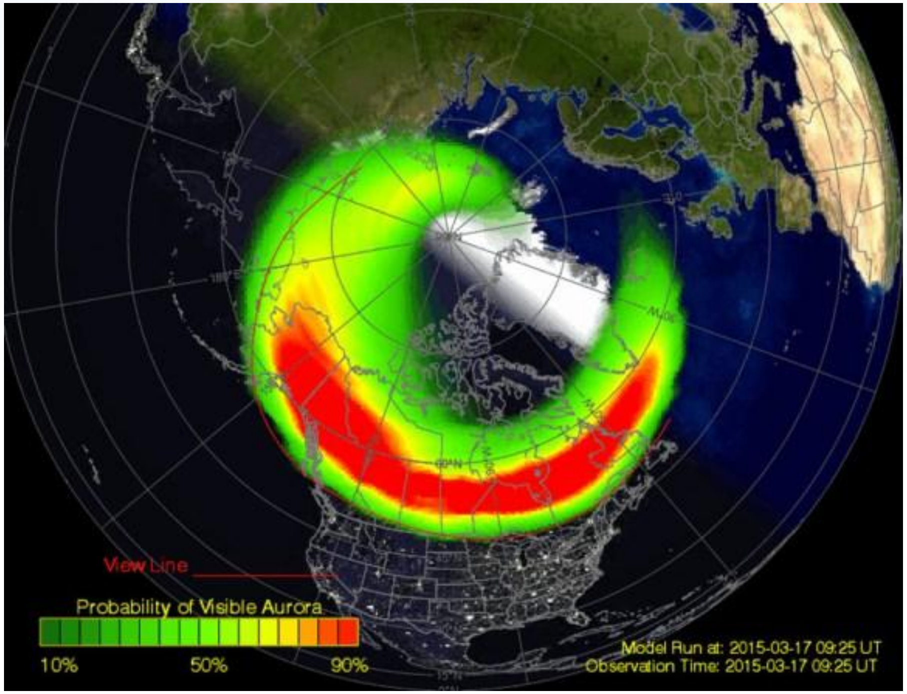
Value for projections and policy discussions?

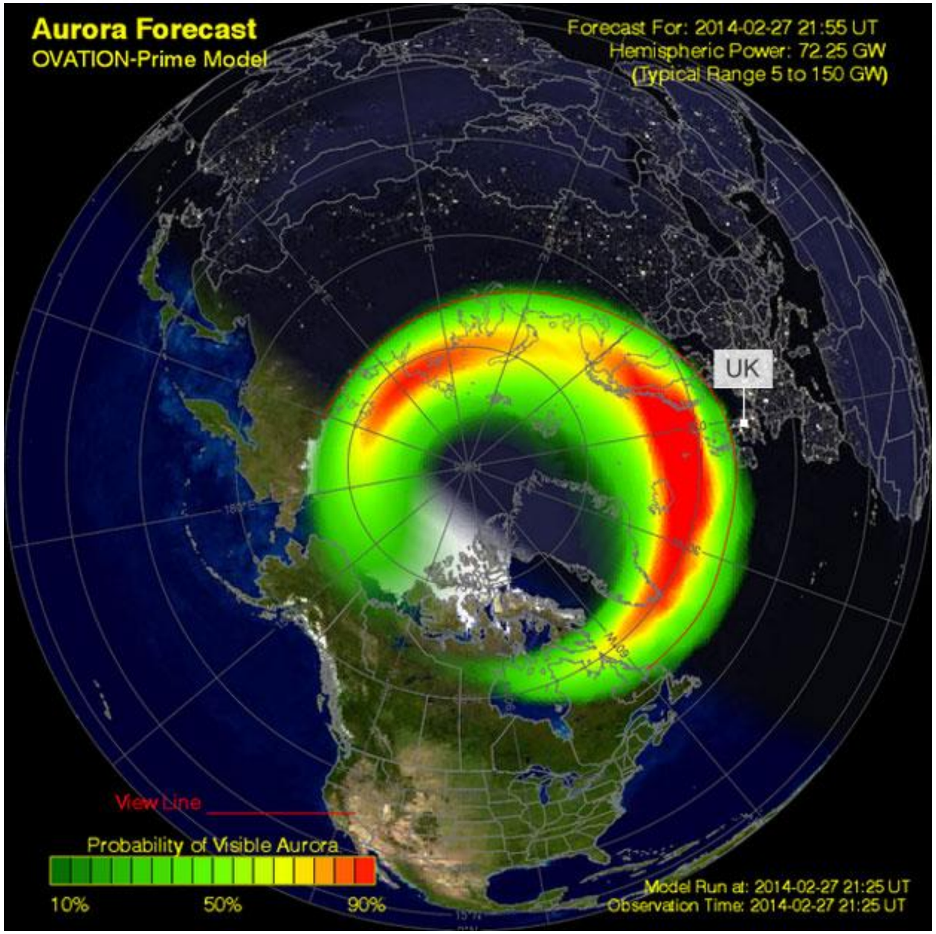
Earth’s South Magnetic Pole is in Canada





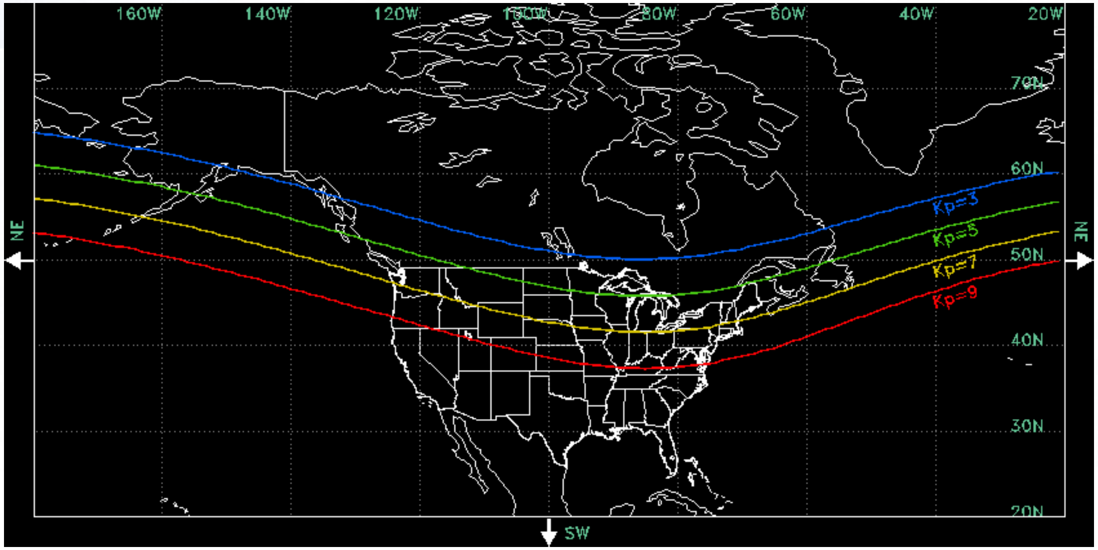
Aurora Oval

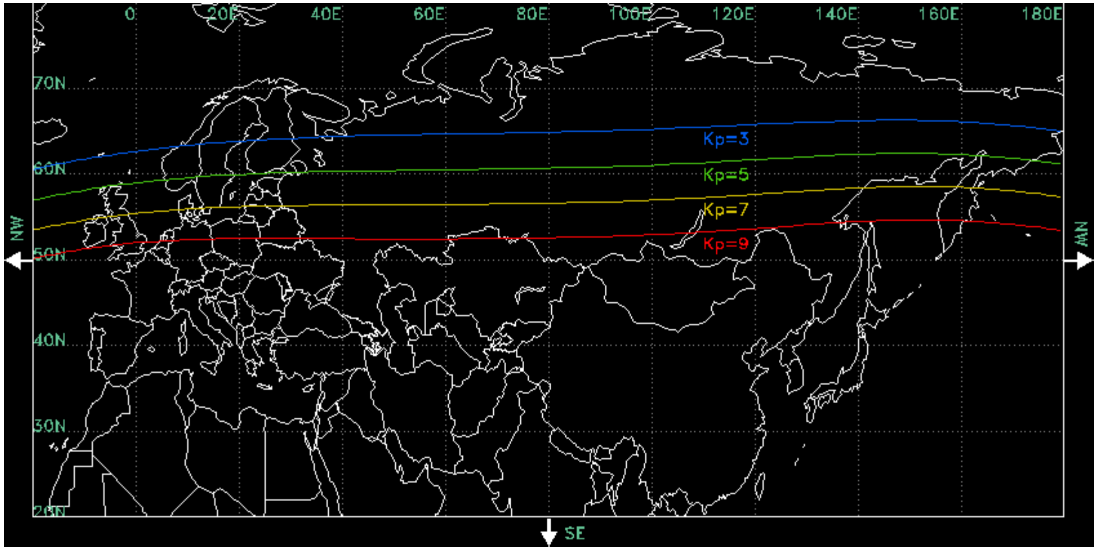

View Line
Probability of Visible Aurora
10%
50%
90%
Model Run at: 2015-03-17 09:25 UT
Observation Time: 2015-03-17 09:25 UT


Aurora Forecast
OVATION-Prime Model
Forecast For: 2014-02-27 21:55 UT
Hemispheric Power: 72.25 GW
(Typical Range 5 to 150 GW)
UK
View Line
Probability of Visible Aurora
10%
50%
90%
Model Run at: 2014-02-27 21:25 UT
Observation Time: 2014-02-27 21:25 UT

Boundary of the Aurora

Boundary of the aurora at different levels of geomagnetic activity; a Kp=3 corresponds to low levels of geomagnetic activity, while Kp=9 represents high levels





Useful links

ScienceCasts: Here Comes Solar Maximum
https://www.youtube.com/watch?v=k87JdeyQ-m8

Carrington-class CME Narrowly Misses Earth
https://www.youtube.com/watch?v=7ukQhycKOFw

Documentary on Solar Storm
https://www.youtube.com/watch?v=Mgt81Kr2Dk4