Long-term Evolution of Magnetic Fields in Sunspots from Measurements at MWO

Luca Bertello and Alexei Pevtsov

National Solar Observatory

3rd Sunspot Number Workshop

January 22 - 25, 2013 - NSO Tucson, Arizona

Main motivations

- Create a unique, consistent, and up-to-date data set of sunspot field strength measurements that goes back to 1917.
- Investigate the consistency of these measurements with similar observations from other observatories (e.g. W. Livingston, former USSR).
- Inter-comparison with other instruments (e.g. MDI, HMI, SOLIS, etc...).
- Study the distribution of sunspot magnetic field strength over several solar cycles, both as a function of latitude and time.
- Understand to what degree the Penn-Livingston effect is detectable in various solar cycles.

The MWO sunspot field strength measurements

A significant subset of the original drawings is available in digital form, from 1/4/1917 to present, at ftp://howard.astro.ucla.edu/pub/obs/drawings/

Published tables of data

- The PASP (Publications of the Astronomical Society of the Pacific) period: 5/1920 - 1/1959.
  - We produced a digital version of all the PASP tables available from NASA/ADS.
  - We fixed errors introduced by this process and completed the tables for missing observations.
- The Solar-Geophysical Data Reports period: 1962 - 2004. Data available from NOAA/NGDC website, and, in tabular form, from the UCLA website.

1950PASP...62..121.

MAGNETIC CLASSIFICATION OF SUNSPOTS FOR MARCH AND APRIL, 1950

No.	C.M.P.	Lat.	H	First Seen	Last Seen	Classification
10250	Mar. 6.3	− 4°	32	Mar. 2	Mar. 11	*dβpl*
10251	7.6	+ 5	33	2	11	*lαpd*
10252	3.5	+27	27	3	9	*dαpl*
10253	6.4	+ 8	23	3	6	*dβd*
10254	3.1	+10	19	3	5	*dαpd*
10255	9.0	+13	(2)	3	5	*dβd*
10256	10.6	−17	(6)	3	9	*lβd*
10257	10.0	−26	(5)	4	9	*dαpd*
10258	11.5	+18	(5)	5	7	*dxd*
10259	5.2	−15	(3)	6	7	*dxd*
10260	8.2	+11	(5)	6	9	*dαpd*
10261	12.0	+22	24	6	17	*lβpl*
10262	13.4	−16	40	6	19	*lβpl*
10263	12.6	+11	16	6	17	*lαpd*
10264	2.5	+10	(20)	7	8	*dxl*
10265	7.8	+28	15	7	14	*dβpl*
10266	6.9	+21	5	8	11	*dβd*
10267	15.8	− 9	5	9	16	*lαpd*
10268	16.9	+14	15	10	19	*lαpd*
10269	10.6	−20	2	11	11	*dαpd*
10270	12.4	+ 5	(1)	11	11	*dxd*
10271	18.6	+12	23	12	23	*lαpd*
10272	19.7	+21	28	13	24	*lαpl*
10273	10.0	−25	2	14	15	*dαpd*
10274	12.1	−18	4	14	15	*dβd*

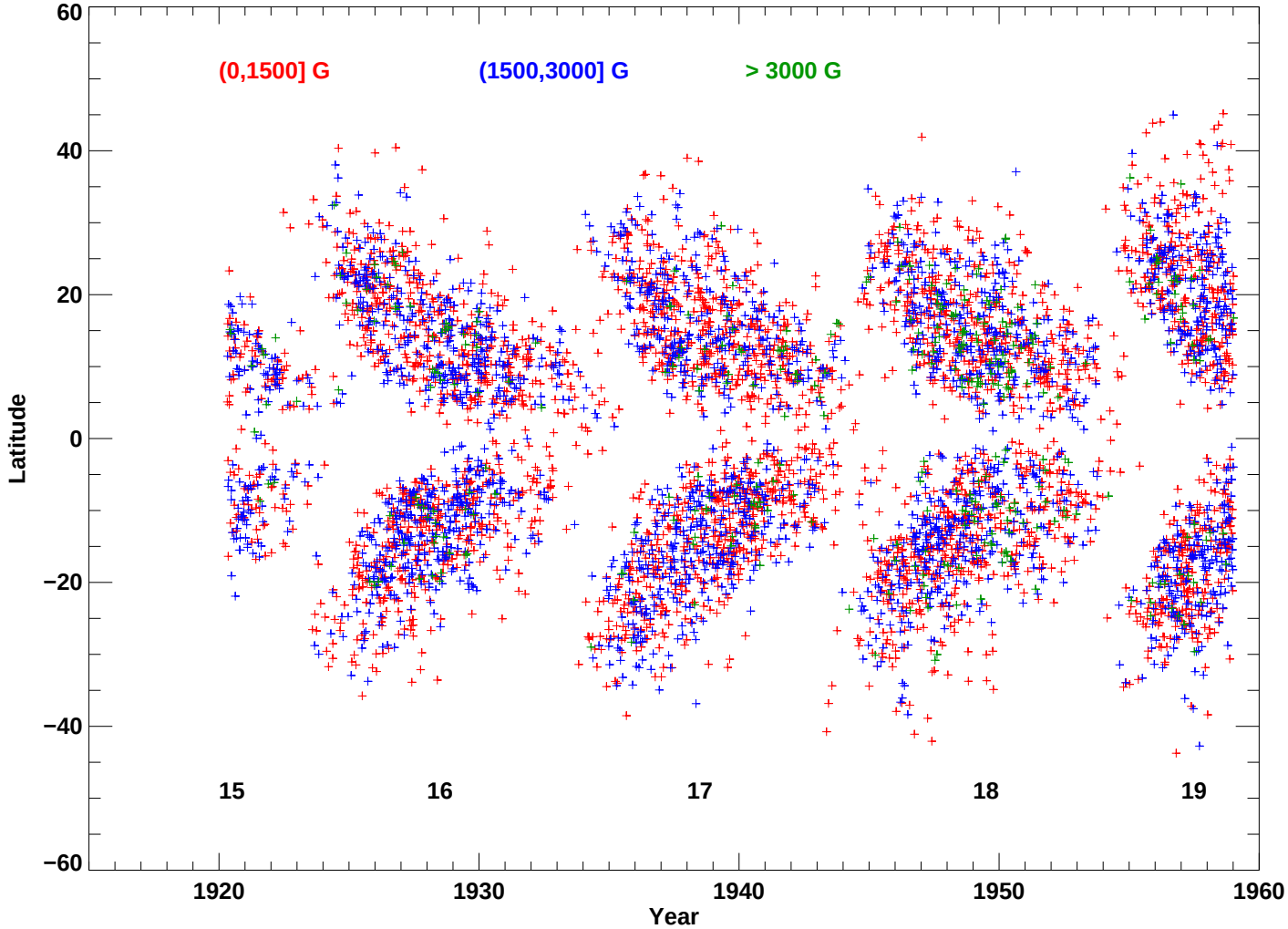
Available MWO sunspot data in tabular form

- Digitization of PASP tables:
  - 9362 total entries, from 4/30/1920 to 1/7/1959, saved as a ASCII table containing the date of the CM crossing, latitude, and field strength.
  - A separate table with 6032 entries, containing only the observation with the maximum field strength for a given date.
- Compilation by L. Webster and T. Schieber of sunspot group field strengths from January 1917 to April 2000. Extended to August 2004 by J. Harvey.

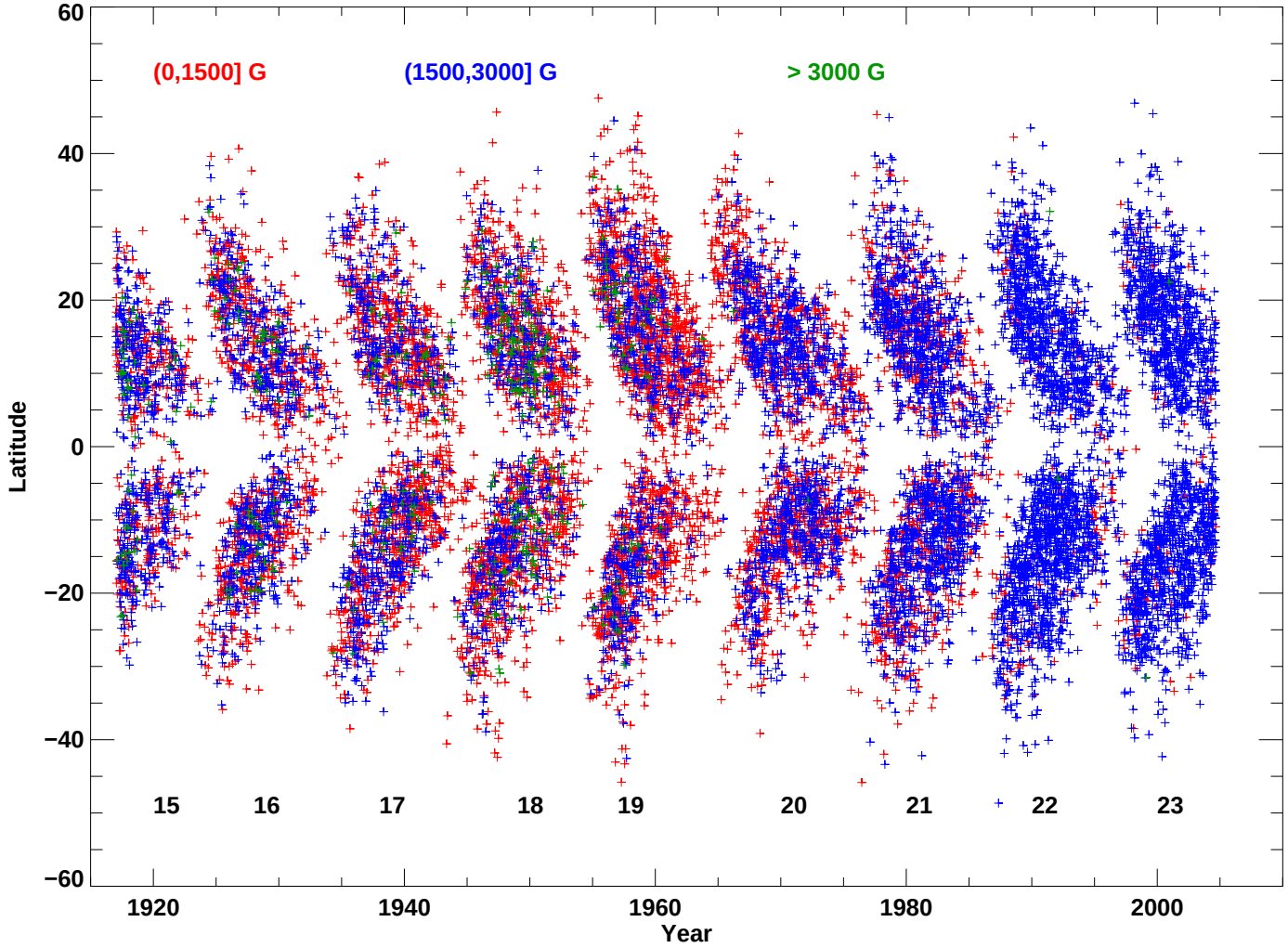
Significant facts about MWO measurements

- In October 1961, the use of the 617.3 nm line was terminated in favor of the 525.0 nm line in order to accommodate increasing use of the photoelectric magnetograph.
- At the same time the recording of the maximum field strength changed from the original scale in units of 100 G to a 500-G scale, using a code value ranging from 1 (100-500 G) to 10 ($>$4500 G).
- Because of inadequate calibration and limited range of the tipping plate micrometer, Mt. Wilson observers never reported fields much in excess of 3 kG after 1962.
- The conversion of tip angle to field strength depends on the dispersion of the spectrograph and the known Landé factor for the spectrum line. Livingston et al. 2006 (Solar Phys. 239: 41-68) recommended to correct the original Mt. Wilson measurements according to a suggested table of values.

MWO butterfly diagram: 1920 - 1959



MWO butterfly diagram: 1920 - 2004

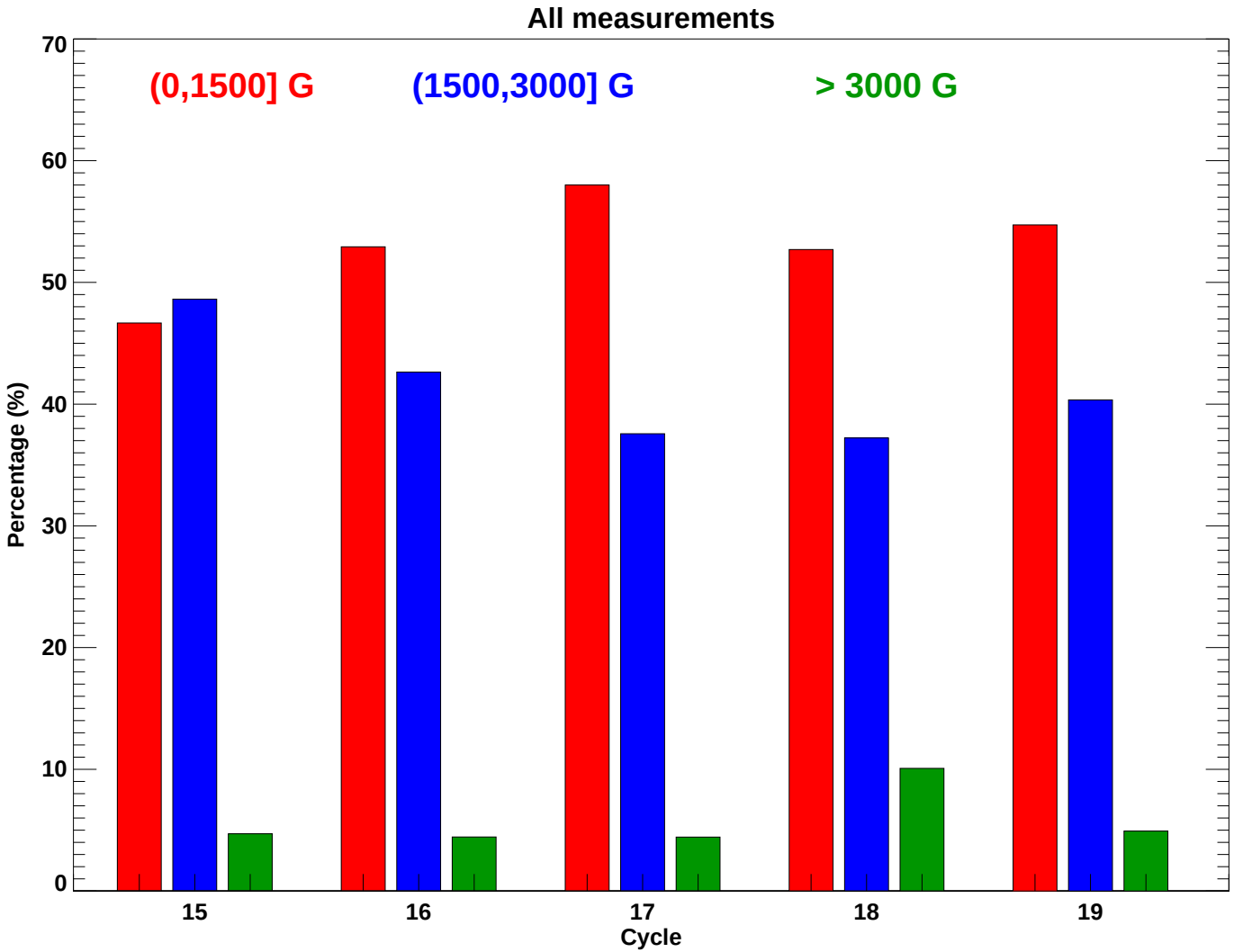


Mt. Wilson measurements: 1920 - 1959

	All measurements			Low latitudes ($\|\phi\| <$ 15 degrees)		
Cycle	$H \leq 15$	$15 < H \leq 30$	$H > 30$	$H \leq 15$	$15 < H \leq 30$	$H > 30$
15	119	124	12	108	110	12
16	787	634	66	455	389	37
17	968	627	74	566	332	58
18	868	613	166	463	341	107
19	533	393	48	160	108	11
	High latitudes ($\|\phi\| >$ 15 degrees)			**Northern hemisphere**		
15	11	14	0	65	64	8
16	332	245	29	423	319	39
17	402	295	16	482	293	40
18	405	272	59	426	304	95
19	373	285	37	291	204	28
	Southern Hemisphere					
15	54	58	3			
16	363	315	27			
17	486	334	34			
18	442	309	71			
19	242	189	20			

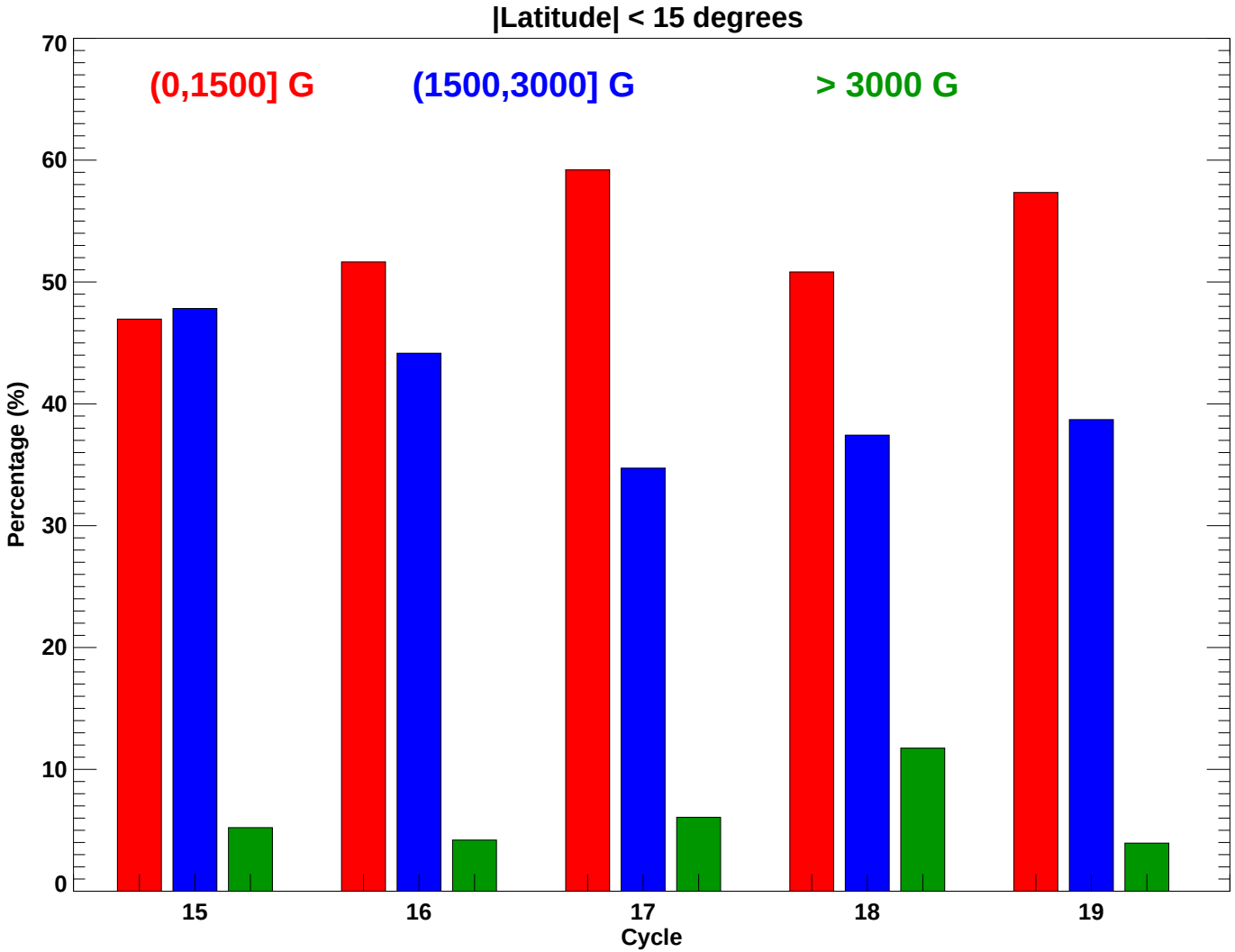
Total number of measurements: 6032

Distribution of MWO measurements

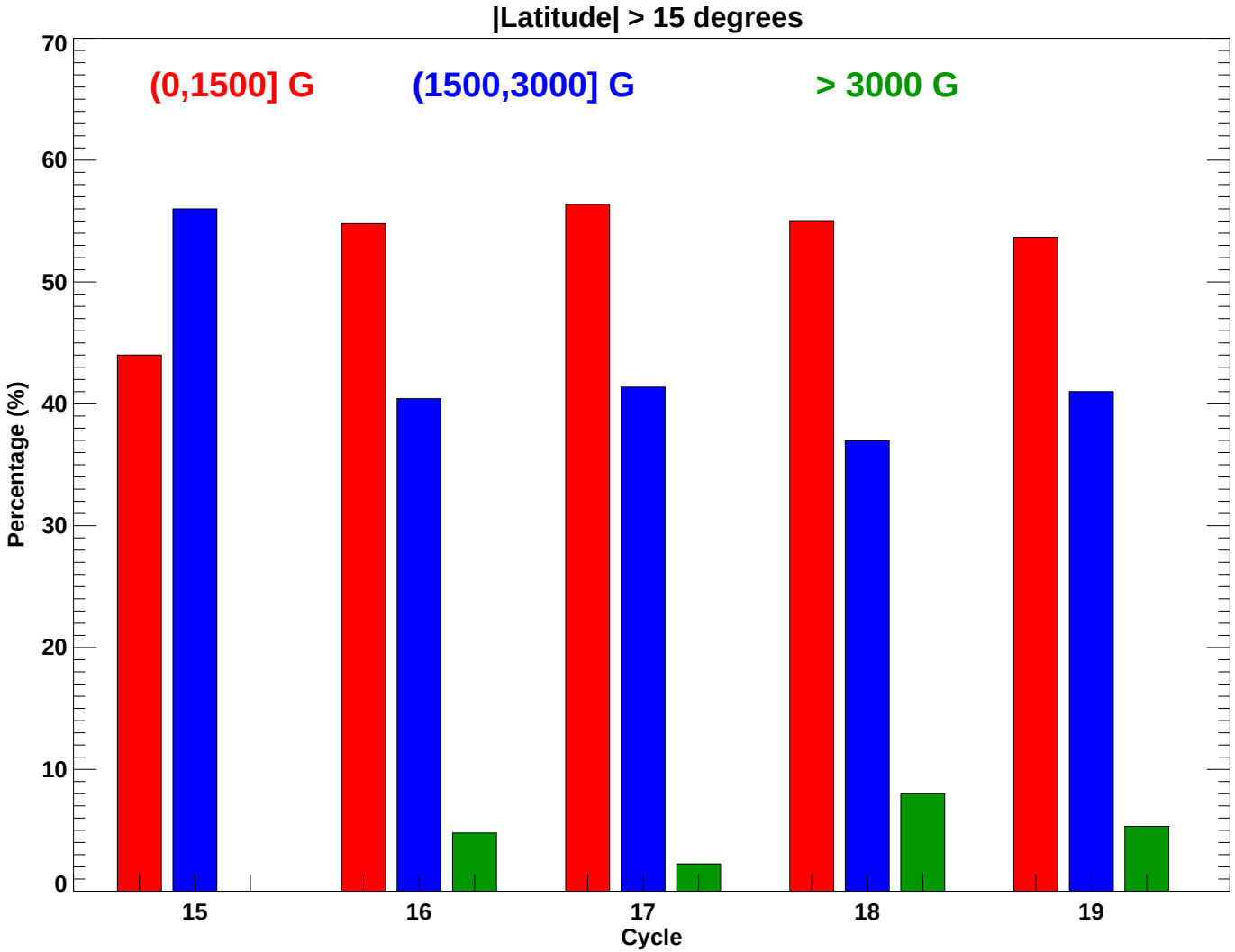


Cycle 18 shows a significantly larger number of sunspots with high-field measurements, by almost a factor 2, compared to other cycles.

Distribution of MWO measurements: Low latitudes

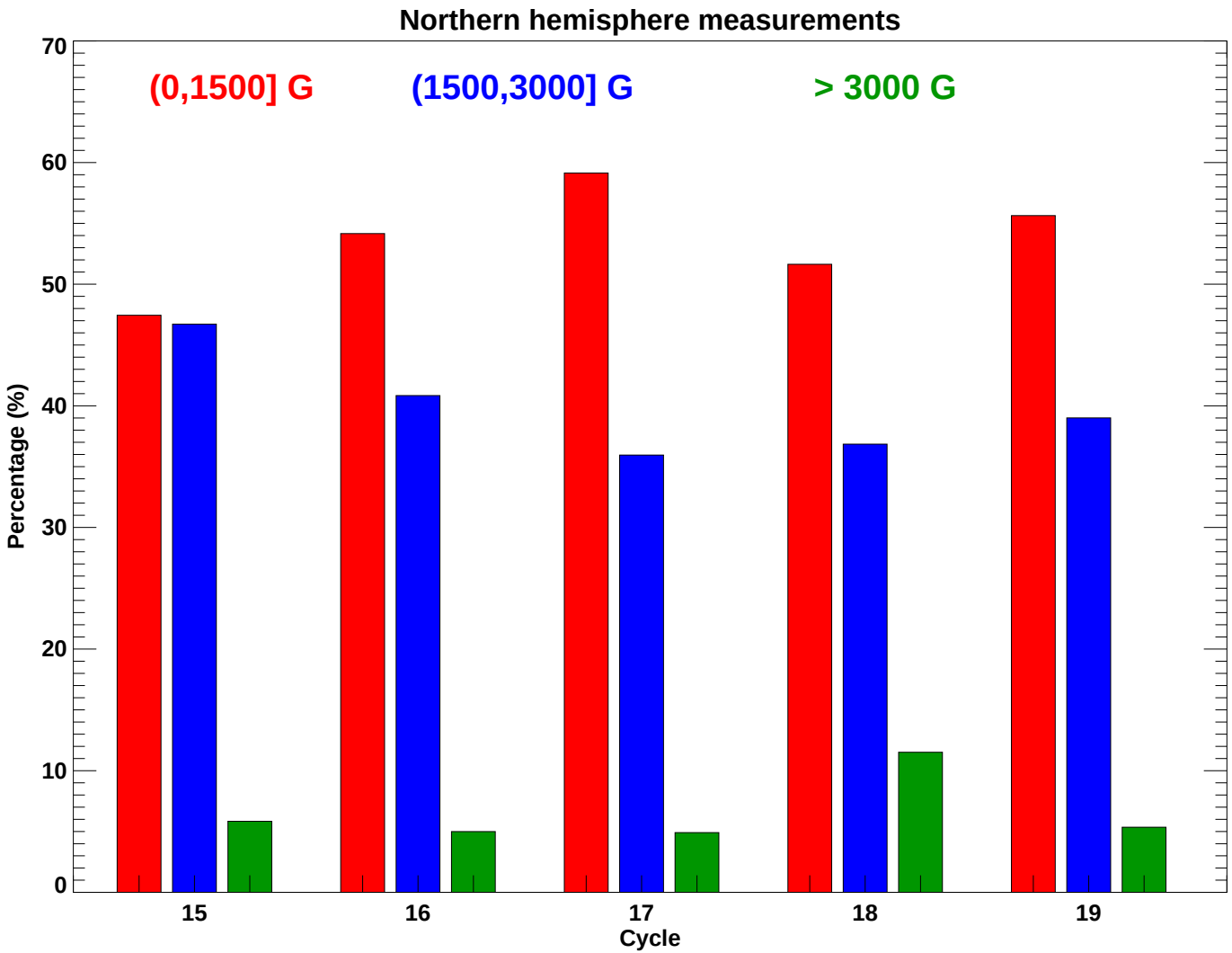


Distribution of MWO measurements: High latitudes

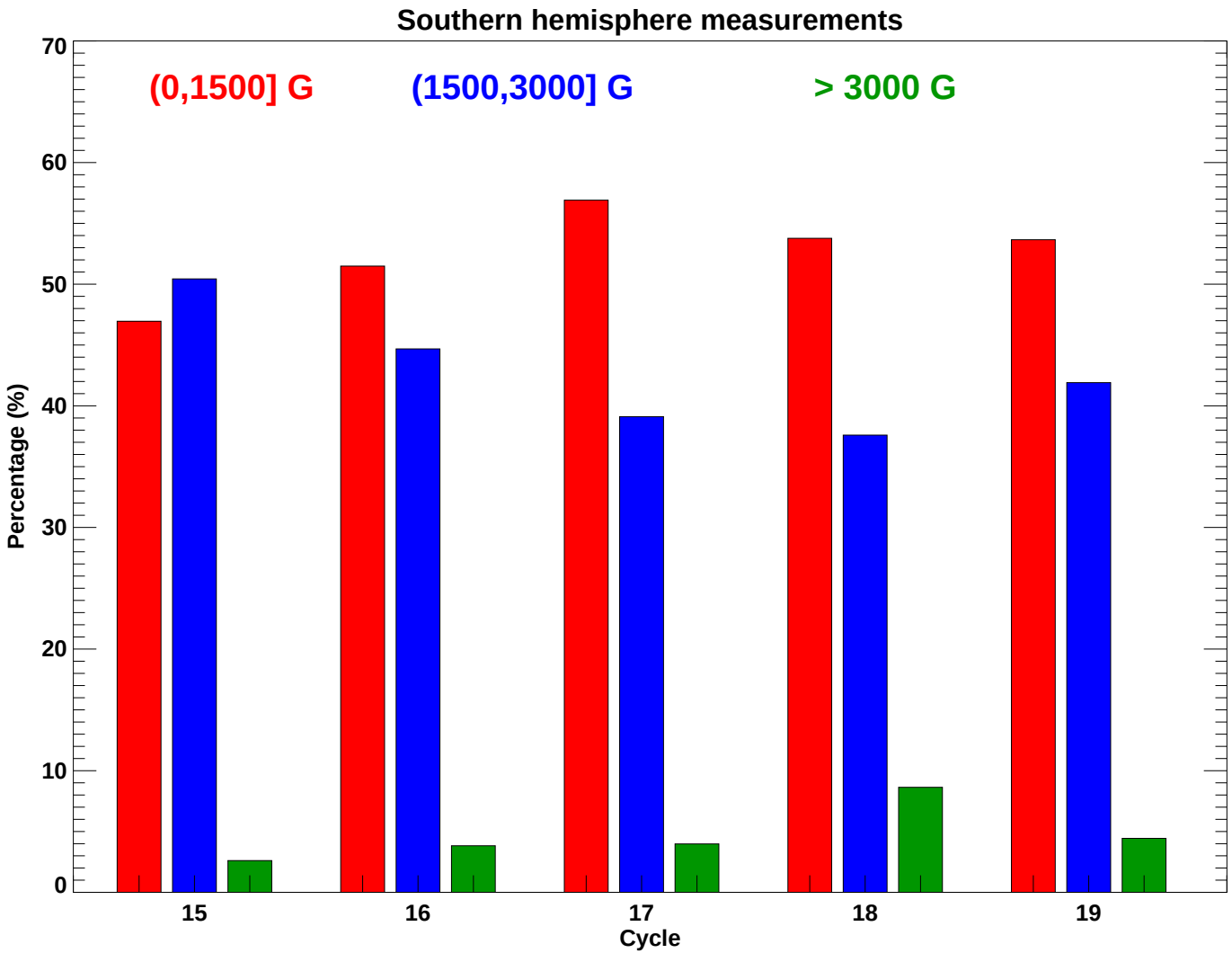


No high-latitude measurements of magnetic field strength above 3000 G during cycle 15!

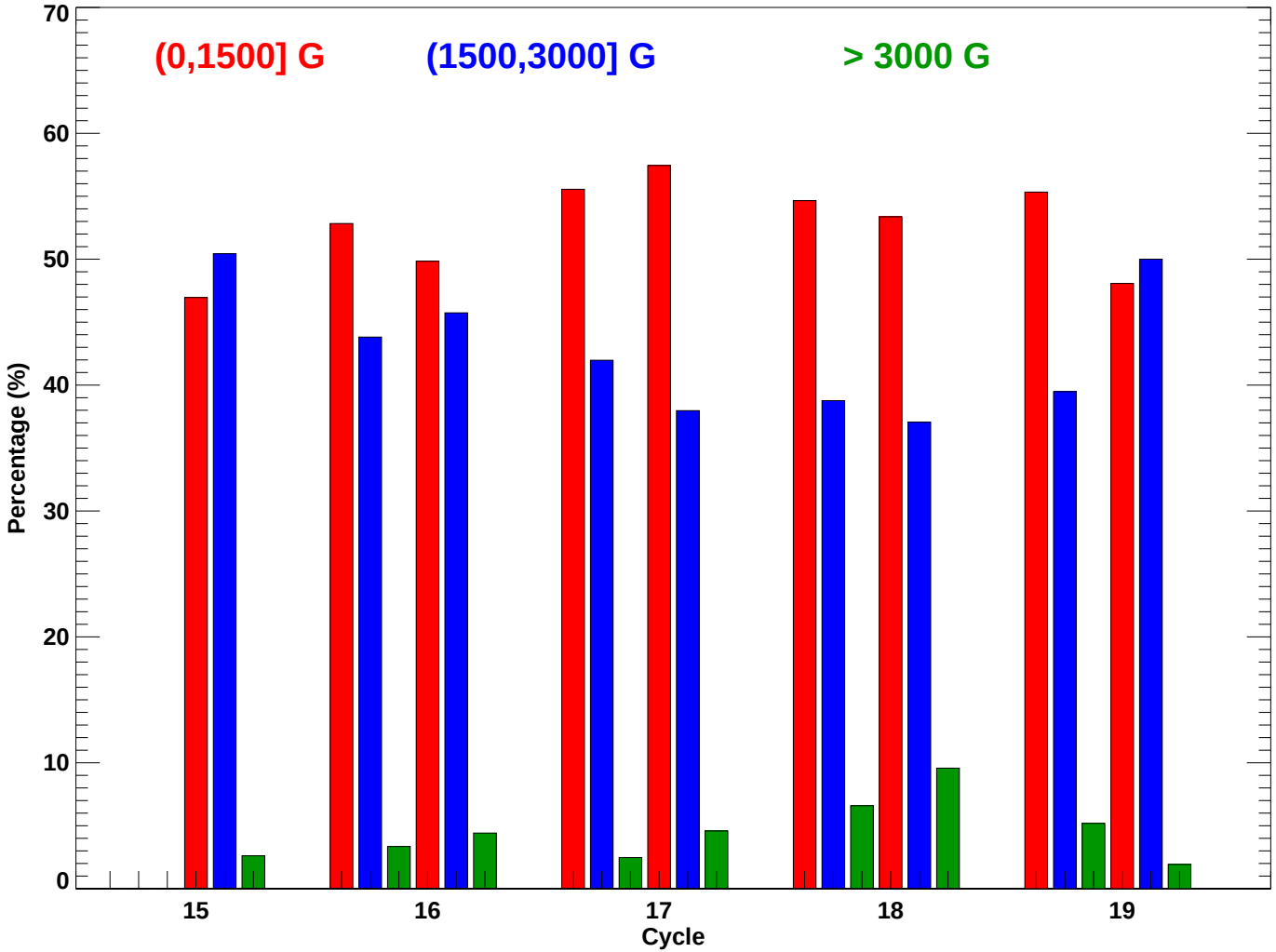
Distribution of MWO measurements: North



Distribution of MWO measurements: South



Distribution of MWO measurements: splitting the cycle



Distribution of all measurements during the rising (first three bars of each cycle) and declining (last three bars of each cycle) phase of solar cycles.

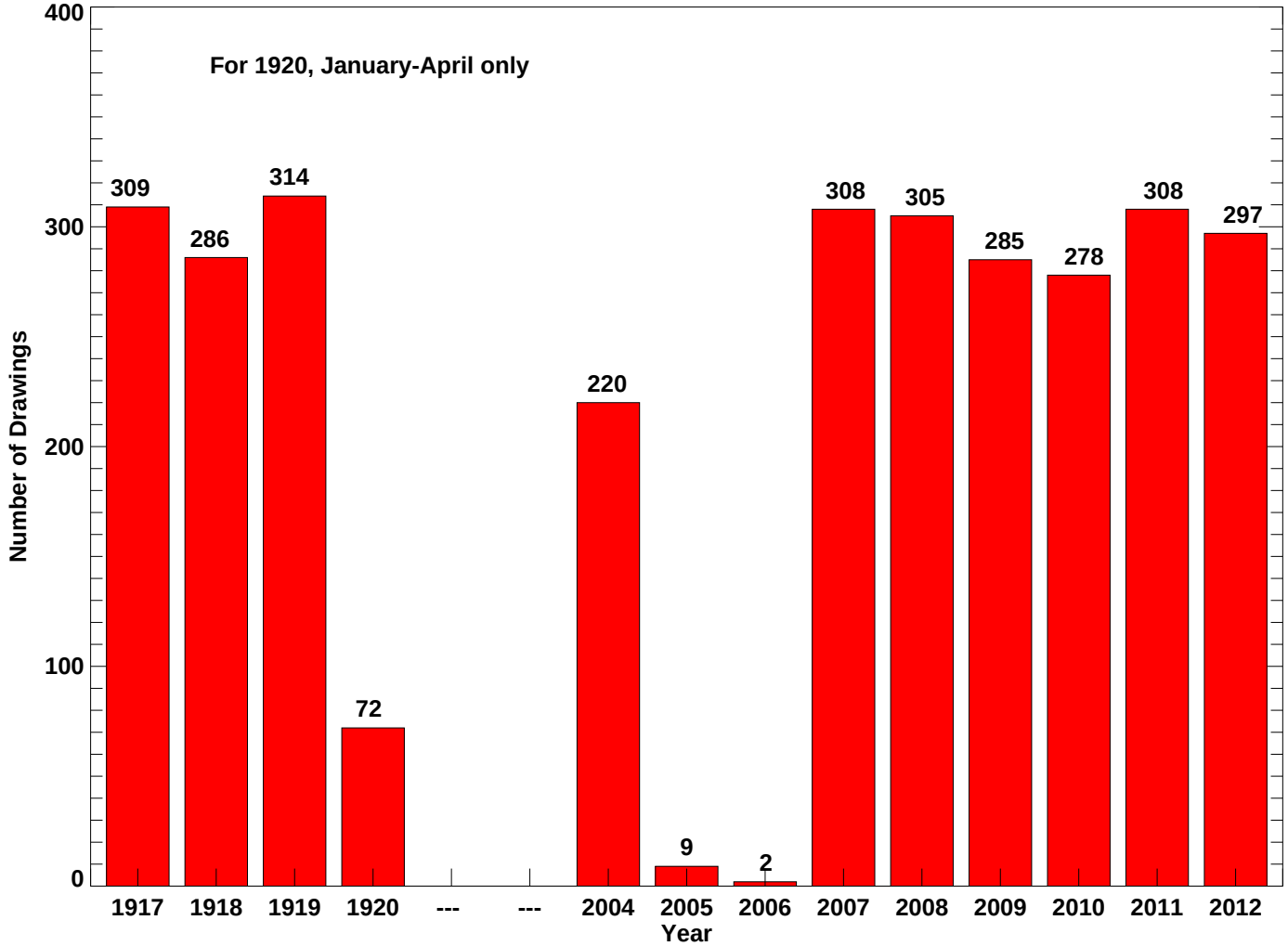
Summary

- Cycle 18 shows a significantly larger number of sunspots with high-field measurements, by almost a factor 2, compared to the other cycles investigated here.
- There are no measurements of magnetic field strength above 3000 G at high latitudes during cycle 15.
- The distribution between North and South seems to be quite uniform, with maybe some marginal differences for the intermediate classes.
- Is there a modulation over cycles for measurements of intermediate field strength?

Current project

- People: Alexei Pevtsov, Luca Bertello, Nina Karachik, and Alexander Pevtsov.
- Objective: Tabulate the drawings for the 1/1/17-4/30/20 and 1/1/2004 to present periods.
- Tool: IDL code written by Alexei to determine geometry, location of active regions, field strengths, and polarities.
- Final product: Table of active region parameters to complement pre-existence table.
- Distribution: public domain.

Distribution of drawings for selected periods



MWO drawing: 5/4/2011