

A COMPARISON OF THE EARLY TWENTY-FIRST CENTURY DROUGHT IN THE UNITED STATES TO THE 1930S AND 1950S DROUGHT EPISODES

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DETERMINATION OF DROUGHT EPISODES. The 13 major drought episodes for the period from January 1900 through December 2014 were determined based on an analysis of the percent area of the contiguous United States (CONUS) with Palmer drought severity index (PDSI) ≤ -2.00 . Two thresholds were examined: 10% and 20%. A new drought episode occurred if the percent area fell below the threshold. An automated analysis resulted in 40 drought episodes using the 10% threshold and 27 episodes using the 20% threshold. This approach yields a new drought episode if the percent area drops below the threshold for even 1 month. There are many cases in the period of record where the percent area oscillates around the threshold every other month: for example (year, month, percent area with PDSI ≤ -2.00),

1944	3	14.0
1944	4	9.1
1944	5	11.4
1944	6	6.7
1944	7	12.3
1944	8	13.1

1944	9	9.2
1944	10	15.7

In this example, four drought episodes would occur during the period March–October 1944 if a purely automated process were applied.

These objective results had to be consolidated by manually examining the percent area record and applying a decision tree that involved the magnitude of the percent area values, rate of change in value from month to month, nature of the break in the episode when the value fell below the threshold (e.g., oscillation of values above and below the threshold), duration of the break, and duration of the surrounding drought periods (months greater than the threshold). This manual consolidation process resulted in 13 major drought episodes. For some of them (e.g., October 1908–November 1911), the percent area in drought never fell below the 10% area threshold for the duration of the episode, while for others there were periods where the drought area did fall below the threshold for a few months (e.g., July 1928–May 1942). In each of these 13 major drought episodes, drought covered 10% or more of the CONUS for 87% or more of the months.

TABLE ESI. Mean climatic statistics for the 1930s (Jul 1928–May 1942), 1950s (Jul 1949–Sep 1957), and Jun 1998–Dec 2014 drought episodes. Temp = CONUS area-averaged annual-mean temperature (°C), precip = CONUS area-averaged annual precipitation (mm), PA_{xx}SPI_{DRY} = average percent area xx -month SPI ≤ -1.0 for all months. PA_{xx}SPI_{WET} = average percent area xx -month SPI $\geq +1.0$ for all months. For temp and precip, only whole years were included in the calculation; any partial years at the beginning and end of the periods were not included.

Drought episode	Jul 1928–May 1942	Jul 1949–Sep 1957	Jun 1998–Dec 2014
Temp	11.4	11.2	11.8
Precip	730	711	765
PA01SPI _{DRY}	17.6	19.1	15.5
PA02SPI _{DRY}	18.3	19.7	15.9
PA03SPI _{DRY}	19.1	20.5	16.4
PA06SPI _{DRY}	20.9	23.7	16.2
PA12SPI _{DRY}	23.6	26.5	16.3
PA24SPI _{DRY}	26.9	30.1	17.2
PA01SPI _{WET}	14.5	13.3	16.1
PA02SPI _{WET}	14.2	12.4	16.2
PA03SPI _{WET}	13.7	12.1	16.8
PA06SPI _{WET}	13.2	12.2	17.6
PA12SPI _{WET}	11.5	10.3	18.6
PA24SPI _{WET}	9.7	9.4	19.9

TABLE ES2. Mean percent area of the CONUS with 3-month SPI < -1.0 (dry) and $\geq +1.0$ (wet), and mean potential evapotranspiration (mm), by season, for the 1930s (Jul 1928–May 1942), 1950s (Jul 1949–Sep 1957), and Jun 1998–Dec 2014 drought episodes. Seasons: Mar–May (MAM) = spring, Jun–Aug (JJA) = summer, Sep–Nov (SON) = autumn, and Dec–Feb (DJF) = winter.

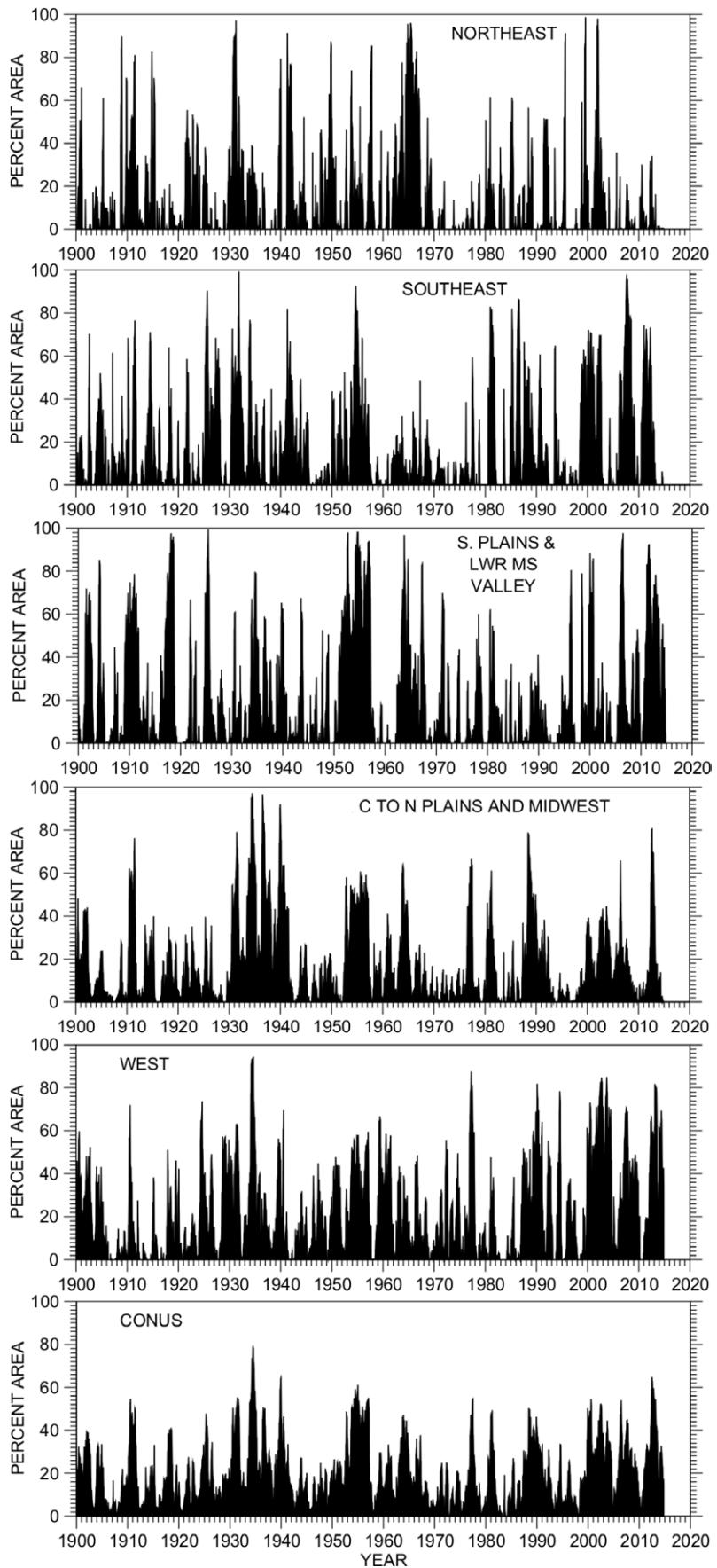
	Jul 1928–May 1942	Jul 1949–Sep 1957	Jun 1998–Dec 2014
Dry			
MAM	18.7	13.8	16.7
JJA	23.0	20.6	16.3
SON	22.4	31.7	12.0
DJF	16.8	15.7	17.4
Wet			
MAM	13.6	13.2	16.3
JJA	12.5	13.1	16.8
SON	13.9	5.8	17.8
DJF	16.4	13.7	13.7
Potential evapotranspiration			
MAM	153.7	147.7	163.1
JJA	414.2	404.8	415.9
SON	157.4	157.4	162.9
DJF	17.3	20.0	19.3

TABLE ES3. Mean percent area of the CONUS with seasonal and annual (ANN) values for select variables exceeding the 10th percentile for the 1930s (1928–41), 1950s (1949–57), and 1998–2014 drought episodes. Seasons as in Table ES2. Variables indicate the percent of the CONUS with seasonal- or annual-average maximum temperature or minimum temperature much above normal (upper 10th percentile; warm Tmax and warm Tmin, respectively) or much below normal (bottom 10th percentile; cold Tmax and cold Tmin, respectively); percent of the CONUS with seasonal or annual precipitation derived from extreme (equivalent to the highest 10th percentile) 1-day precipitation events (extreme 1-day precip); percent of the CONUS with a much greater than normal (highest 10th percentile) number of days with precipitation in the season or year (number of days with precip); and percent of the CONUS with a much greater than normal (highest 10th percentile) number of days without precipitation in the season or year (number of days without precip).

	Jul 1928– May 1942	Jul 1949– Sep 1957	Jun 1998– Dec 2014		Jul 1928– May 1942	Jul 1949– Sep 1957	Jun 1998– Dec 2014
Warm Tmax				Extreme 1-day precip			
ANN	17.6	14.7	23.8	ANN	8.5	9.6	14.8
MAM	9.7	3.8	19.4	MAM	8.2	8.1	12.7
JJA	17.3	12.5	19.3	JJA	8.4	8.2	10.7
SON	15.3	17.2	17.2	SON	8.5	8.3	10.1
DJF	12.4	16.8	19.1	DJF	7.9	7.8	11.1
Cold Tmax				No. of days with precip			
ANN	6.7	9.2	2.4	ANN	6.9	6.8	13.0
MAM	7.3	10.0	3.7	MAM	6.5	9.7	9.7
JJA	2.9	10.9	6.2	JJA	5.8	8.3	10.7
SON	7.5	4.7	2.6	SON	6.3	3.2	9.9
DJF	14.1	4.0	5.2	DJF	9.1	8.1	11.5
Warm Tmin				No. of days without precip			
ANN	12.2	3.4	26.3	ANN	14.5	15.0	7.7
MAM	8.6	3.1	20.8	MAM	10.5	6.9	8.2
JJA	11.1	6.4	28.3	JJA	12.4	8.2	6.3
SON	10.7	5.3	21.7	SON	12.9	17.2	5.8
DJF	13.0	13.8	15.2	DJF	8.3	6.5	6.9
Cold Tmin							
ANN	9.2	12.2	1.2				
MAM	8.0	15.1	4.2				
JJA	5.7	12.0	2.1				
SON	10.9	15.5	1.5				
DJF	15.1	5.0	3.2				

TABLE ES4. Percent area with extreme 1-day precipitation events (extreme 1-day precip), excessive number of days with precipitation (days with precip), excessive number of days without precipitation (days without precip), PHDI ≤ -2.0 (drought), and PHDI $\geq +2.0$ (wet spell) for the three drought episodes Jul 1928–May 1942 (1930s), Jul 1949–Sep 1957 (1950s), and Jun 1998–Dec 2014 (2000s), for each of the five regions defined in Fig. 1: Southeast, Northeast, West, southern Great Plains and lower Mississippi Valley (S. Plains and Miss Vly), and central to northern Plains and Midwest (C-N Plains and Midwest). These percent area statistics were averaged for all months in the drought episode.

	1930s	1950s	2000s
Extreme 1-day precip (mean percent area with extreme 1-day precipitation events)			
Southeast	9.3	8.1	11.7
Northeast	8.2	11.0	15.1
West	8.0	7.5	8.2
S. Plains and Miss Vly	8.0	7.9	11.5
C-N Plains and Midwest	8.1	8.2	12.1
Days with precip (mean percent area with excessive number of days with precipitation)			
Southeast	8.8	4.9	9.3
Northeast	5.8	8.7	17.3
West	6.5	8.2	8.9
S. Plains and Miss Vly	8.2	7.1	7.7
C-N Plains and Midwest	6.1	6.9	12.1
Days without precip (mean percent area with excessive number of days without precipitation)			
Southeast	10.7	9.3	8.7
Northeast	11.9	7.2	6.3
West	10.4	8.1	6.8
S. Plains and Miss Vly	8.7	12.5	9.6
C-N Plains and Midwest	13.0	10.5	5.1
Drought (mean percent area with PHDI ≤ -2.0)			
Southeast	22.3	28.6	31.5
Northeast	21.4	20.4	11.7
West	29.3	31.2	39.9
S. Plains and Miss Vly	19.9	53.8	31.3
C-N Plains and Midwest	38.9	28.8	19.2
Wet spell (mean percent area with PHDI $\geq +2.0$)			
Southeast	13.9	8.4	14.4
Northeast	8.6	19.1	29.2
West	17.2	14.4	13.7
S. Plains and Miss Vly	16.9	8.4	16.8
C-N Plains and Midwest	12.5	20.8	29.9



► **Fig. ESI.** Percent area of the CONUS and each of the regions (defined in Fig. 1 in the main paper) experiencing moderate to extreme drought ($\text{PDSI} \leq -2.0$) from Jan 1900 to Dec 2014, based on area-weighted climate division data.

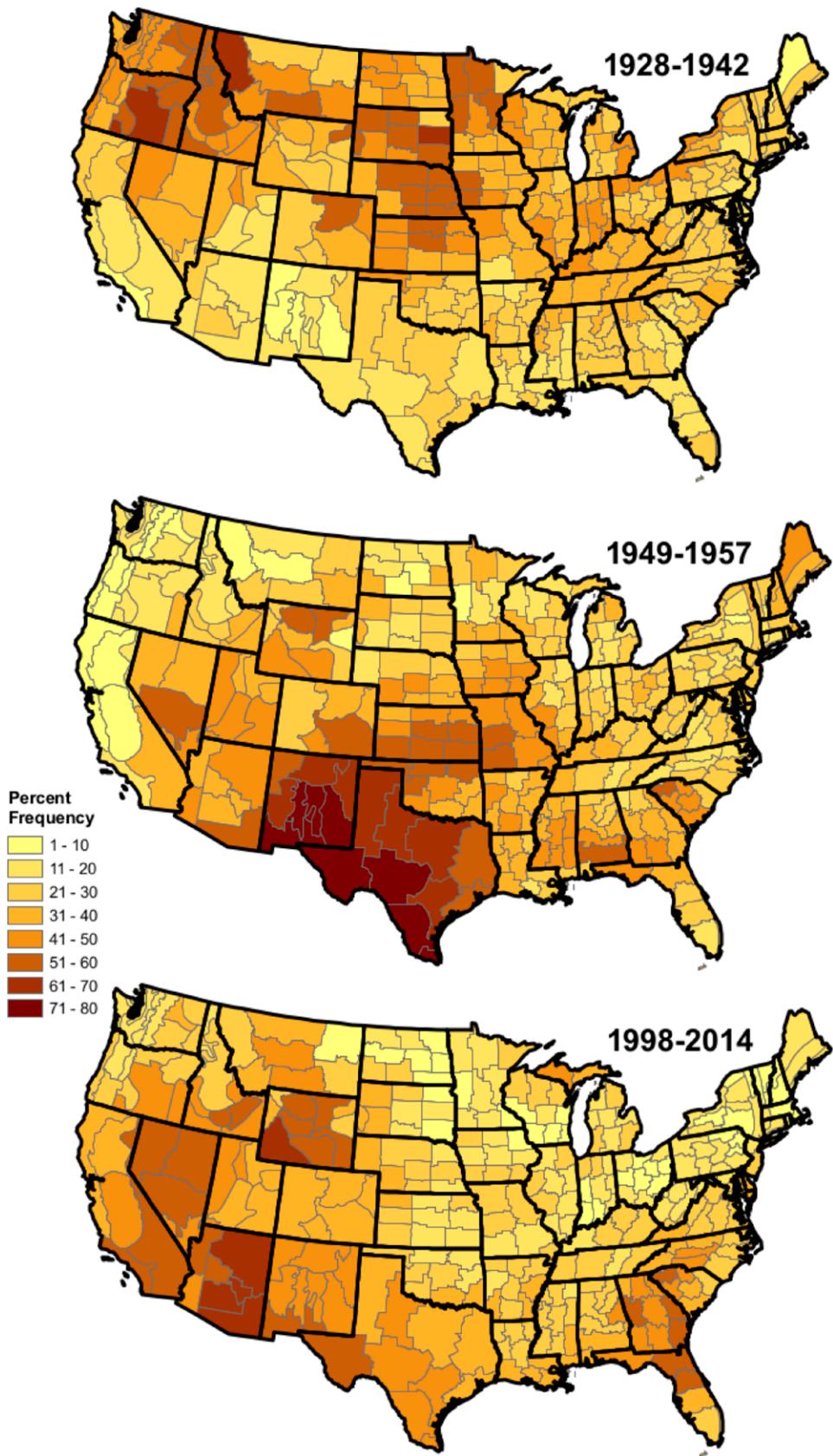
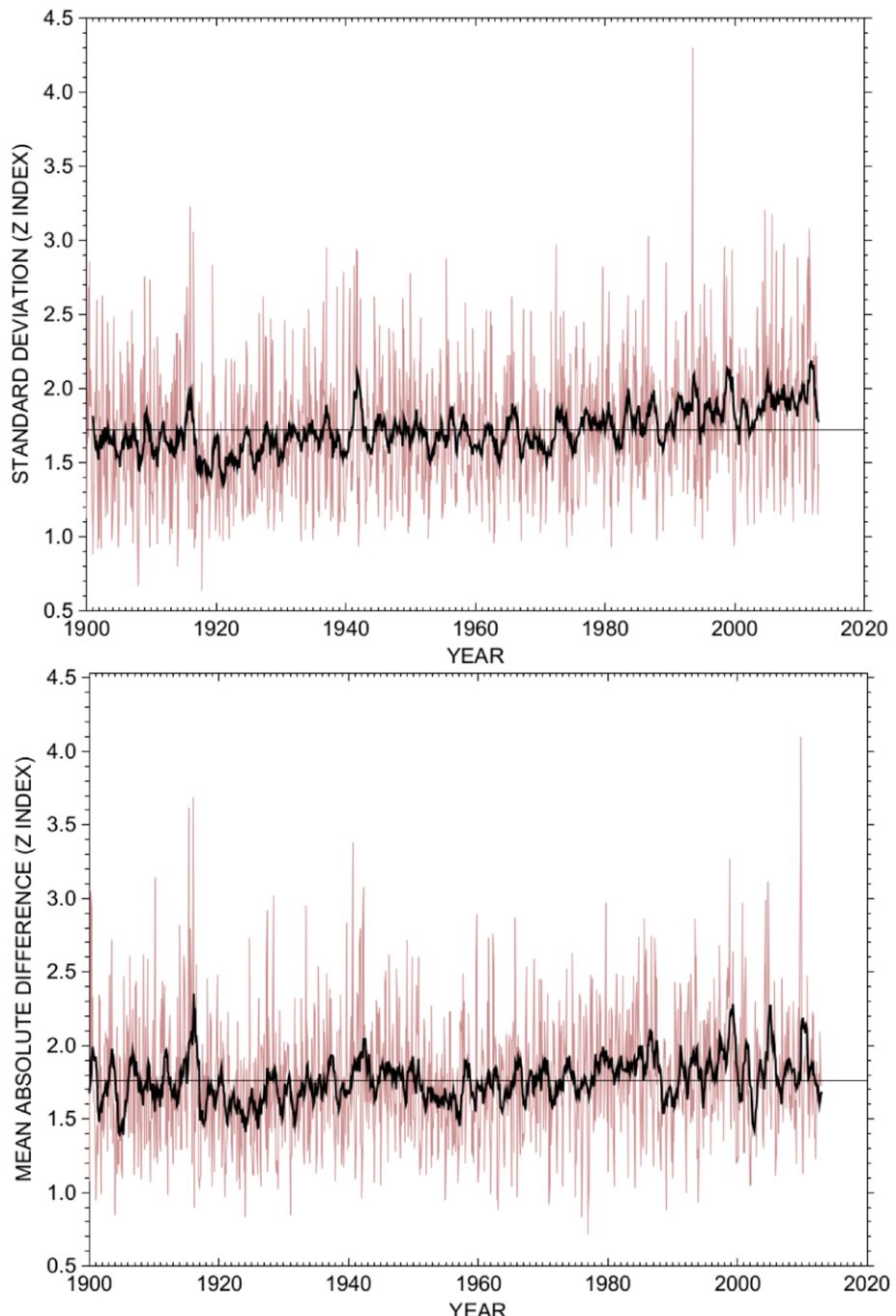


FIG. ES2. Percent of time (percent frequency) Palmer hydrological drought index (PHDI) ≤ -2.0 for three major drought episodes: (top) Jul 1928–May 1942, (middle) Jul 1949–Sep 1957, and (bottom) Jun 1998–Dec 2014.



► **Fig. ES3. (top)** Standard deviation (std dev) of divisional Palmer Z index showing spatial variability for each month and (bottom) area-averaged mean absolute difference in divisional Palmer Z index values from month to month showing temporal variability, Jan 1900–Dec 2012 (brown curve). Dark curve is a 12-month moving mean of the monthly values. Horizontal line is the period of record average (1.72 for top panel, 1.76 for bottom panel).

Both measures show considerable month-to-month, interannual, and interdecadal variability but no significant trend over the period of record. Linear regression of the monthly values yields a positive trend of 0.014 Z index units per year for spatial variability in the top panel and 0.018 Z index units per year for temporal variability in the bottom panel. However, an accelerated steadily increasing trend is evident in the spatial variability graph in recent decades: 0.064 Z index units per year for the 1970–2012 period, more than 4 times the period-of-record trend. These measures can be averaged over the three major drought episodes during the twentieth to twenty-first centuries. The average std dev value for the 1930s and 1950s drought episodes is 1.69 for each episode, while the average std dev value for the 1998–2014 drought episode is 1.86, indicating that it experienced greater spatial variability in moisture conditions than the earlier episodes (i.e., a greater occurrence of wet areas mixed in with the dry areas). The 1998–2014 drought episode had the highest measure of temporal variability (1.91 Z index units) of the three major drought episodes, the 1930s drought had the second highest value (1.83), and the 1950s drought had the smallest (1.76).

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