2022 Sun-Climate Symposium

Beyond Terminators, Sun-Ocean Warming Threshold is *Climate Change Tipping Point* through Holocene

by Robert Weber
Orcid# 0000 0002 4394 5317

Abstract

- Ironically, climate science ranks solar forcing last after CO2, while recent advances in solar physics have linked La Niña to the time after sunspot minima when old cycle magnetic bands terminate. This link was extended here to the last 9 cycles by identifying asymmetric 1°C decreases in the eastern tropical Pacific due to changes from solar maxima to the next minima (and vice versa). Prior work established a solar activity threshold for decadal ocean warming using one climate record.
- Here 71 records/reconstructions were compared using their cumulative departure from average zero-crossings, signifying a breakeven period and level for sunspot number (SN) averages. The method converged on 95±10 v2 SN for all records, the climate change tipping point. The first 3 months ≥95 SN of a new cycle starts 6.4 months on average after old cycle termination, as spotless days dwindle; is predicted for SC25 with an exponential decay curve of annual spotless days versus annual SN.
- As annual SN nears 95, trade winds initiate El Niño, more clouds, rain, CO2, ACE, and ice melt that all lag SN on a spatiotemporal continuum. CONUS precipitation had the lowest sensitivity to sunspots tested. Holocene temperatures in Antarctica and Greenland, and Saharan desertification 6-8 kya are linked to solar cooling <95 SN via the Multi-Messenger Sunspot Number. The Solar Modern Maximum, 1935-2004, when v2 SN averaged 108.5 for 70 years, warmed the climate.

Introduction

Climate tipping points as a subject entered the scientific lexicon in recent decades. Research was aimed toward identifying the severity and timing of potential future warming, and an arbitrary threshold was established, a 1.5°C warming limit above pre-industrial temperatures, based on the herein falsified consensus theory of man-made CO2 emissions-caused global warming.

Modern science has mainly focused on the immediate solar forcing of the atmosphere, rather than of the ocean, and has all but neglected lagged effects. More recently, Leamon etal (2020) linked the solar minimum magnetic band terminator time to the concurrent La Niña over the previous 5 solar cycles.

The author originally used HadSST3 global data alone in 2014 to identify a distinct solar cycle ocean influence and to find a decadal ocean warming threshold of 95 SN (v2 SN). (SN= Sunspot Number)

The sun-ocean threshold is defined as the amount of average solar activity between two select zero-crossings of a climate timeseries's cumulative departure from average (CDA) function, signifying endpoints where the climate indice is maintained at zero trend for the time period, then used to calculate the average sunspot activity.

This research is meant to find the broad scope of the solar threshold.

Methods

- Sunspot data records & 71 climate timeseries were used
- TSI and emissivity models were used to verify TSI-climate response
- A Tropical SST pattern was established for 9 solar cycles by differencing solar maximum and solar minimum SST
- Old-cycle Terminators were mapped by time-indexing each solar cycle Terminator onto exponential decay curves of Annual # Spotless Days vs Annual SN
- Current solar cycle #25 progression was examined
- A cumulative departure from average (CDA) was computed for each timeseries with a custom function named "idsmn(f(t))"
- Each timeseries CDA was plotted, and the date of CDA zero-crossings were identified to use as sunspot average endpoints
- All timeseries CDA values were mapped versus SN
- Other relationships and methods are noted as needed

Results and Discussion

Sea surface temperatures have increased since the early 1900s, and by the 1950s, after the Solar Modern Maximum in sunspot activity started in 1935, and rose above the late 1800s Solar Centennial Minimum level, as depicted with ERSSTv5 in the top panel of Figure 1 below.

The Modern Maximum is determined by the inflection points in 1935 and 2004 of the integrated sunspot number, shown in Fig. 1, second panel black line, detrended with the mean subtracted. The Centennial Minimum was similarly determined, and the average World Data Center (WDC) sunspot number v2 was computed for the two periods, and for the equal-length 70 years prior to the Modern Maximum, 1865-1934.

The 70y Modern Maximum averaged 108.5 SN compared to 65.8 for the previous 70 years. Several SN-TSI models were used to find 13-19 W/m2 more TSI available during the Modern Maximum. The Stefan-Boltzmann emissivity equation, with 0.3 albedo, and the author's non-linear SN-PMOD TSI model gave the closest to the actual ΔT of ~0.6 °C. The ocean warmed from this higher TSI and absorbed solar radiation.

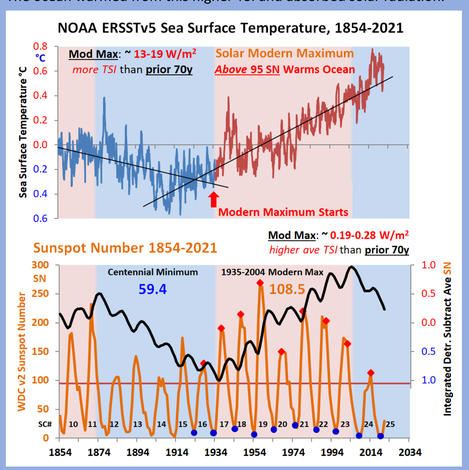

Figure 1. ERSSTv5, Sunspots, and the Modern Maximum

Solar Cycle Induced Tropical Warming/Cooling Pattern Found

Asymmetrical Tropical 1°C step-up/down was found by differencing:

- Step-up: subtract previous solar min years SST from solar maxs SST
- Step-down: subtract previous solar max years SST from solar mins

The solar maximum and solar minimum years of Fig.1, second panel, are shown with red and blue dots for the 9 solar cycles studied in Fig. 2.

Typically the ENSO region warms (cools) first, leading to general global ocean warming (cooling), following solar activity increases (decreases) above (below) the solar threshold, demonstrated below with ERSSTv5. *The odds are 1.9x1011:1 against this pattern recurring 9 times in a row.*

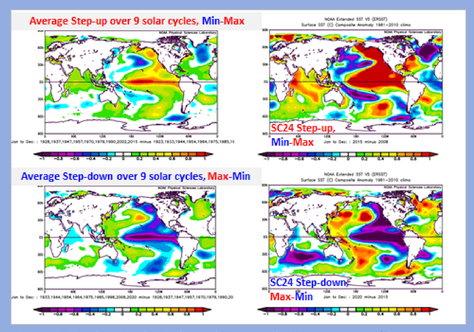

Figure 2. Solar Cycle Induced Tropical SST Step-ups/downs

The ocean net heat flux, Fig. 3a, drives Earth's energy imbalance. The average solar cycle tropical 1°C step-up pattern of Fig. 2 and the tropical CO2 mean flux from 2001-2018 of Fig. 3b correlate with the net heat flux pattern. The highest CO2 flux occurred where net heat flux is highest.

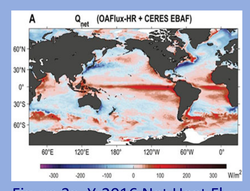

Figure 3a. Yr2016 Net Heat Flux

Below, Rathore, etal attributed 2005-2015 ocean warming to 'climate change and internal variability', whereas when SORCE v17 TSI is overlaid onto their Fig. 1 it is clear TSI was the dominate forcing particularly over the southern ocean as it peaked near the perihelion, enhancing seasonal insolation.

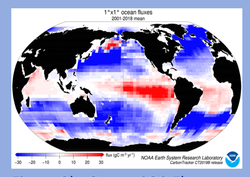

Figure 3b. Ocean CO2 Fluxes

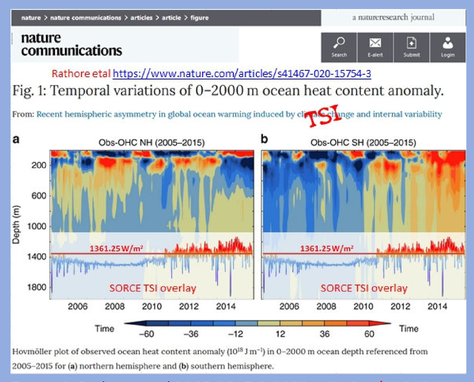

Figure 4. Rathore et al 2005-2015 0-2000m OHC w/SORCE TSI

Terminators, the Threshold, and Solar Cycle #25 Progression

Old-cycle terminators (McIntosh, etal 2020) were mapped onto their respective solar cycles in Fig. 5, third panel. The 4.4-year terminator window sunspot averages are shown in the second panel with the average TSI differences between the Modern Max and Centennial Min. Two terminators from the Dalton Minmum solar cycles are not shown as they are beyond the +36 month plot.

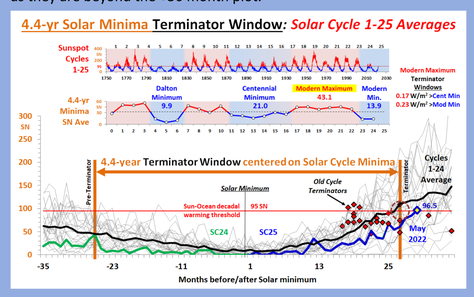

Figure 5. Terminator Window, Terminators, and Solar Cycles

Further, solar cycle terminators 6-24 were mapped onto an exponential decay curve of Annual # Spotless Days vs Annual SN, by indexing the terminator months. The average terminator occurs about halfway between zero sunspots and the 95 SN threshold, as noted in Fig. 6.

"*0* SN" designates **Annual # of Spotless Days**. The exponential decay curves are related to the length of solar cycle, like old cycle terminators.

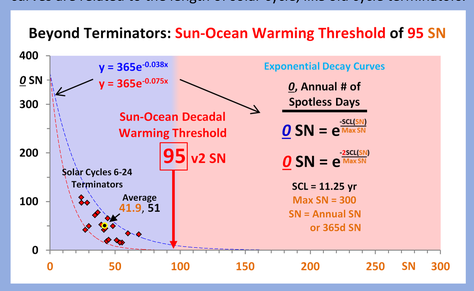

Figure 6.Sun-Ocean Warming Threshold is beyond Terminators

Solar Cycle #25 Progression

updated 6/17/2022

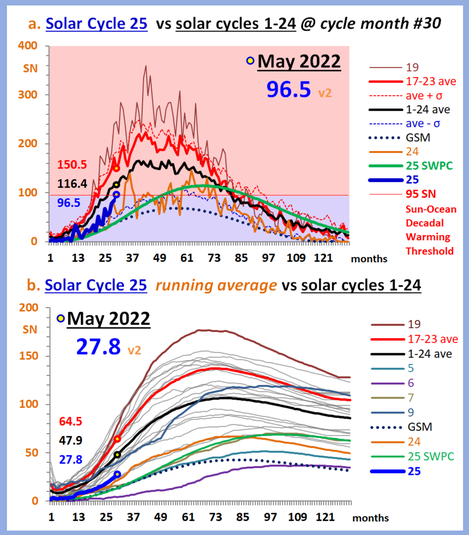

Figure 7a-b. Solar Cycle #25 Progression as of May, 2022.

SC #25 has progressed beyond the Dec. 2021 SC #24 terminator, and is nearing the first year of sunspot activity above the 95 SN threshold. Daily sunspot activity has exceeded the threshold since December, ultimately driving TSIS TSI above it's equivalent threshold as a result.

This May was the first month of SC #25 sunspot activity to reach 95 SN. The ≥95 number to beat for SC #25 is 23 months, the SC #24 ≥95 total.

The polar fields precursor method prediction of Dr. Leif Svalgaard for a cycle #25 sunspot activity of just above that of SC #24 appears to be on course as of this date. Fig. 7b indicates overall very few cycles change trajectory after the second year, so that prediction appears solid now.

The author's prediction for the first 3 months of sunspot level ≥95 SN was made by creating a scatterplot of previous solar cycle history, then estimating 7 months, July/Aug 2022, based on 1/1/2022 SC #25 activity.

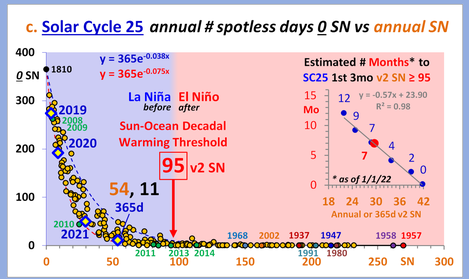

Figure 7c. Annual *0* SN vs Annual SN history, with a Prediction

The greatest likelihood of La Niña is before the threshold is reached and for El Niño, 1-3 years after, Fig. 7c. The 2020-2022 La Niña fits this pattern like most of the prior analog solar cycles did from Figs. 1 and 2. *It is likely the SC #25 tropical step-up will result in exceeding the 1.5°C.*

Warming Effect of Solar Modern Maximum Above Threshold

The Modern Maximum sun warmed the ocean and climate because of

- Higher, long duration above average sunspot activity SN ≥95
- Fewer months of very low solar minimum SN ≤10
- Multiple, successive high activity, higher brightness solar cycles
- Modern Maximum had 2.4x # of months SN ≥95 than Cent. Min.

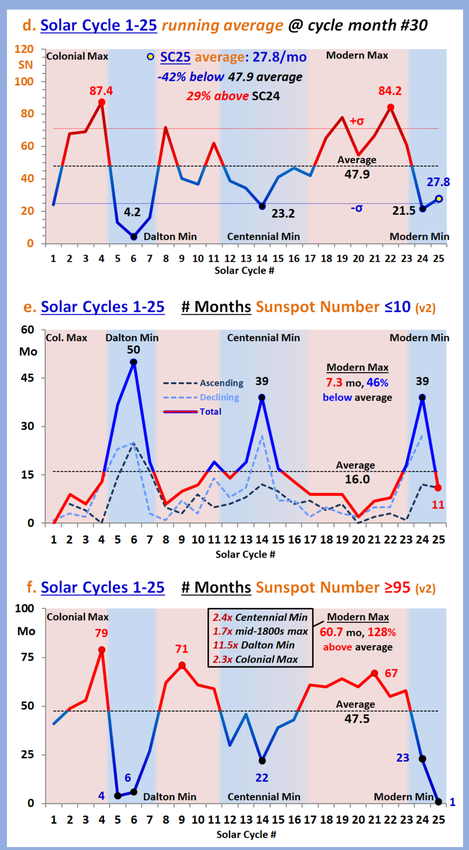

Figure 7d-f. Solar Cycles 1-25 Statistics

4 examples of Cumulative Departure from Average: CDA = idsmn[f(t)] = *integrated, detrended, subtracted mean, normalized [f(t)]*

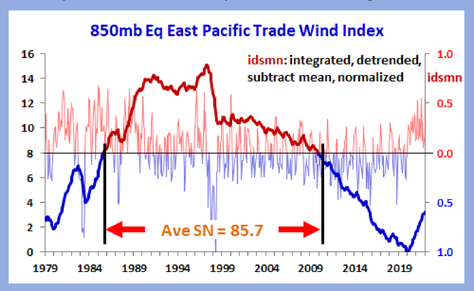

Figure 8. East Pacific Trade Wind Index and CDA function

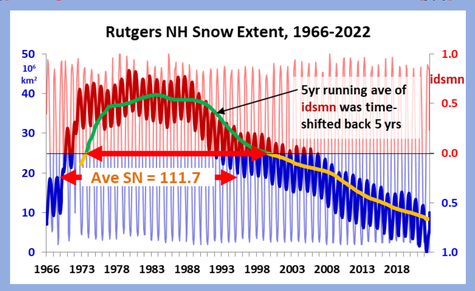

Figure 10. Rutgers NH Snow Extent and CDA function

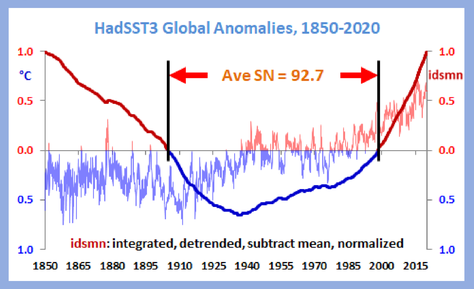

Figure 9. HadSST3 Global SST Anomalies and CDA function

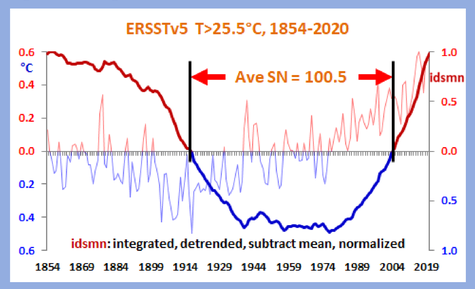

Figure 11. Ocean Temp >25.5C and CDA function

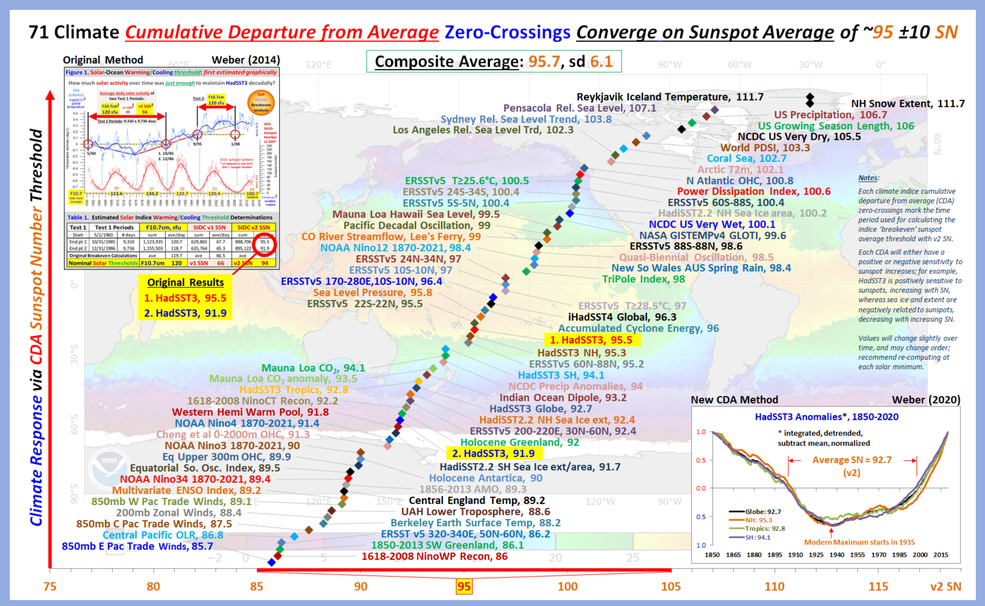

Figure 12. Climate Indices w/CDA Sunspot Number Thresholds

Holocene T's, Multi-Messenger SN confirm threshold theory

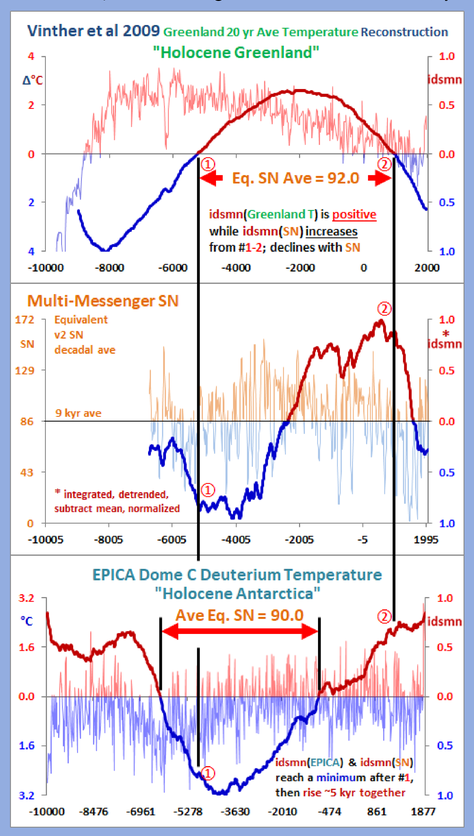

Figure 13. Holocene Temperatures and Multi-Messenger SN

The sun-ocean warming threshold works as far back as the mid-late Holocene using the Multi-Messenger SN developed by Leif Svalgaard, [Up to Nine Millennia of Multimessenger Solar Activity) based on Wu et al (2018) multi-proxy reconstruction of solar activity over the last 9000 years and the Vinther etal (2009) & Jouzel et al (2007) reconstructions.

Greenland, the Antarctica, and the Sahara all responded to civilization-crushing low Holocene solar & orbital induced climate changes 6-8 kya; the Sahara dried up from less tropical evaporation induced droughts.

Conclusion

CO2 can't force ocean temperatures *it lags*; the Sun does it!

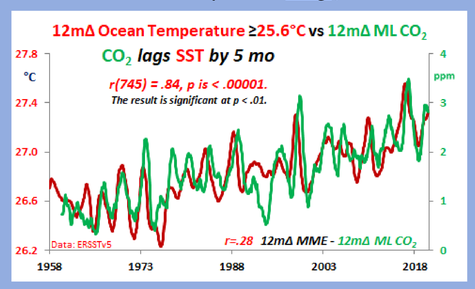

Figure 14. Ocean Temperature >25.5 leads ML CO2 by 5 month

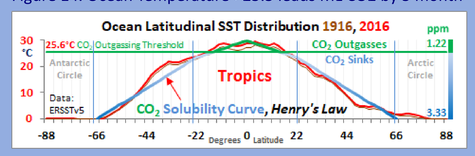

Figure 15. Ocean entirely conforms to CO2 solubility curve

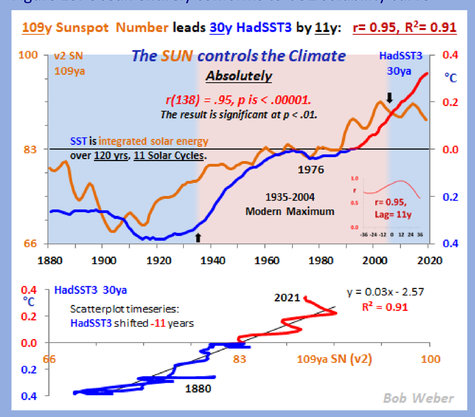

Figure 16. The Sun, not CO2, controls the climate, *absolutely*.

This is overwhelming evidence the climate is solar-driven and organized around the 95±10 SN sun-ocean warming threshold, *the true climate tipping point*, starting with tropical trade winds, extending to all parts of the hydrological system including clouds, precipitation, and even carbon dioxide, well-regulated by variable solar activity and the ocean.

*Climate change to 2100 depends entirely on **unknown** sunspot activity.*

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The Sun drives warming, cooling, extreme events, and CO2.

Author conducted & funded research presented May'22 in Madison, WI

Climate change is fundamentally reducible to sunshine, not CO2.

bob@electricweather.com

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by Robert Weber
Orcid# 0000 0002 4394 5317

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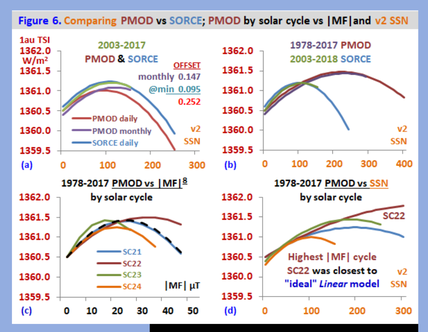
http://climexp.knmi.nl/data/iersstv5_0-360E_-5-5N_n.dat
http://climexp.knmi.nl/data/iersstv5_0-360E_-10-10N_n.dat

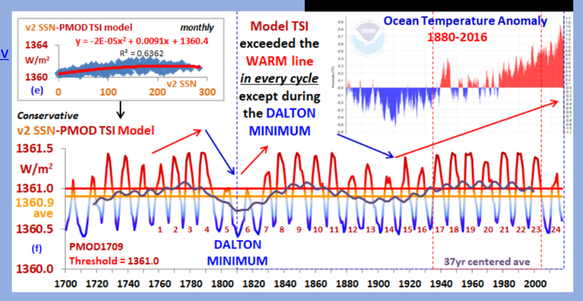


From author's 2018 AGU Poster,

"Extreme Weather Events and Climate Extremes are Limited by the Duration of Solar Cycle Irradiance Extremes"

Fig. 6 (above): Monthly TSI is non-linear with high sunspot number, degree of non-linearity depends on MF strength.

Fig. 17 e,f (below): SN-PMOD TSI Model made by the author for the 2018 AGU poster was used in this poster because it gave the closest result to the actual temperature change using the SB equation, versus *all* linear SN-TSI models.



Odds of 9 Tropical Step-up/downs with 9 Solar Cycles:

Odds = Probability event will occur / Probability event won't occur

Probability event will occur

One year out of average 11.1 years for solar minimum.
Four years out of remaining 10.1 years for solar max.
9 solar cycles for each occurrence.

(1/11.1)9 x (4/10.1)9 = 9.37x10-14

Probability event will not occur

Ten years out of 11.1 years other than solar minimum.
Seven years out of remaining 10.1 years not solar max.
9 solar cycles for each occurrence.

(10/11.1)9 x (7.1/10.1)9 = 1.78x10-2

Odds = 5.27x10-12 ; Odds = 1 : 1.9x1011

http://climexp.knmi.nl/data/iersstv5_0-360E_-22-22N_n.dat
http://climexp.knmi.nl/data/iersstv5_0-360E_-24--34N_n.dat
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http://climexp.knmi.nl/data/iersstv5_zonalmean_0-360E_-88-88N_n.dat
http://climexp.knmi.nl/data/iersstv5_1_mean_gt25.5_0-358E_-60-60N_n.dat
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https://psl.noaa.gov/cgi-bin/data/composites/comp.pl?var=NOAA+Extended+SST+V5+%28ERSST%29&level=Surface&mon1=0&mon2=11&iy=&iy=1928&iy=1937&iy=1947&iy=1957&iy=1970&iy=1979&iy=1990&iy=2002&iy=2015&iy=&iy=-1923&iy=-1933&iy=-1944&iy=-1954&iy=-1964&iy=-1975&iy=-1985&iy=-1996&iy=-2008&ipos%5B1%5D=&ipos%5B2%5D=&ineg%5B1%5D=&ineg%5B2%5D=&timefile0=&tstype=0&timefile1=&value=&typeval=1&compval=1&lag=0&labelcolor=Color&labelshaded=Shaded&type=2&scale=100&contourlabel=1&switch=0&cint=.1&lowr=-1&highr=1&proj=ALL&xlat1=0&xlat2=90&xlon1=0&xlon2=360&custproj=Northern+Hemisphere+Polar+Stereographic&level1=1000mb&level2=10mb&Submit=Create+Plot

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https://psl.noaa.gov/cgi-bin/data/composites/comp.pl?var=NOAA+Extended+SST+V5+%28ERSST%29&level=Surface&mon1=0&mon2=11&iy=&iy=&iy=&iy=&iy=&iy=&iy=&iy=&iy=&iy=2020&iy=&iy=-2015&iy=&iy=&iy=&iy=&iy=&iy=&iy=&iy=&ipos%5B1%5D=&ipos%5B2%5D=&ineg%5B1%5D=&ineg%5B2%5D=&timefile0=&tstype=0&timefile1=&value=&typeval=1&compval=1&lag=0&labelcolor=Color&labelshaded=Shaded&type=2&scale=100&contourlabel=1&switch=0&cint=.1&lowr=-1&highr=1&proj=ALL&xlat1=0&xlat2=90&xlon1=0&xlon2=360&custproj=Northern+Hemisphere+Polar+Stereographic&level1=1000mb&level2=10mb&Submit=Create+Plot

VBA Code for idsmn() function:

```
Sub idsmn()
 Application.ScreenUpdating = False
 Application.CutCopyMode = False

 Dim arr, t As Variant
 Dim lower, upper, n, rAve, rMax, rMin, rDiff As Integer
 Dim i, gap, step, dAve, cMax, cMin, Max, oMax, oAve, oMin, Diff As Double
 Dim all, start, finish, counted, nCt, nFin, first, last, a, b, c As String
 Dim answer, Data, place, d1, d2, dates, d, e, f As String
 Dim aCell, dRng, dRng, pRng As Range
 Dim cht As Chart

'Plots the integrated, detrended, subtracted mean, and normalized f(t), and f(t)
'With time index one cell to the left, put cursor in first data cell, run sub
 Set aCell = Application.ActiveCell
 start = aCell.Address
 finish = aCell.Offset(10000, 0).Address
 all = start & ":" & finish
 Set dRng = Range(all)
 n = WorksheetFunction.Count(dRng)

 nFin = aCell.Offset(n - 1, 0).Address
 counted = start & ":" & nFin
 first = aCell.Offset(0, 1).Address
 last = aCell.Offset(n - 1, 1).Address
 answer = first & ":" & last
 d1 = aCell.Offset(0, -1).Address
 d2 = aCell.Offset(n - 1, -1).Address
 dates = d1 & ":" & d2
 Set dRng = Range(dates)

'Calculate Data Max, Ave, Min
 oMax = Application.Max(Range(counted))
 oAve = Application.Average(Range(counted))
 oMin = Application.Min(Range(counted))
 aCell.Offset(-4, 0) = oMax
 aCell.Offset(-3, 0) = oAve
 aCell.Offset(-2, 0) = oMin
 Diff = oMax - oAve
 If Diff > 10 Then
   rDiff = Application.RoundUp(Diff, -1)
 Else
   rDiff = Application.RoundUp(Diff, 0)
 End If
 rAve = Round(oAve, 0)
 rMax = rDiff + rAve
 rMin = rMax - 2 * rDiff

'Integrate

 arr = Range(counted).Value
 lower = LBound(arr)
 upper = UBound(arr)

 For i = lower + 1 To upper
  arr(i, 1) = arr(i - 1, 1) + arr(i, 1)
 Next i
 gap = arr(upper - 1, 1)
 step = gap / upper
 Range(answer).Value = arr
 a = aCell.Offset(0, 1).Address
 b = aCell.Offset(n - 2, 1).Address
 c = a & ":" & b
 Range(c).Copy
 aCell.Offset(1, 1).PasteSpecial Paste:=xlPasteValues
 aCell.Offset(0, 1) = 0
 aCell.Offset(0, 1).Select

'Detrend

 Set aCell = Application.ActiveCell
 arr = Range(answer).Value

 For i = lower + 1 To upper
  arr(i, 1) = arr(i, 1) - step * (i - 1)
 Next i

 Range(answer).Value = arr

 dAve = Application.Average(Range(answer))

'Subtract Mean

 arr = Range(answer).Value

 For i = lower To upper
  arr(i, 1) = arr(i, 1) - dAve
 Next i

 Range(answer).Value = arr
 cMax = Application.Max(Range(answer))
 cMin = Abs(Application.Min(Range(answer)))

 If cMax > cMin Then
   Max = cMax
 Else
   Max = cMin
 End If

'Normalize

 arr = Range(answer).Value

 For i = lower To upper
  arr(i, 1) = arr(i, 1) / Max
 Next i

 Range(answer).Value = arr

'Make Chart

 Data = start & ":" & last
 place = aCell.Offset(1, -5).Address
 Set pRng = Range(place)

 ActiveCell.Range(Data).Select
 ActiveSheet.Shapes.AddChart.Select
 Set cht = ActiveChart

'Must first make a chart template called CDA or comment out  .ApplyChartTemplate
'CDA chart has +1 and -1 secondary axis
 With cht
   .ChartType = xlLine
   .SetSourceData Source:=Range(Data)
   .ApplyChartTemplate ( _
     "C:\Users\User\AppData\Roaming\Microsoft\Templates\Charts\CDA.crtx")
   .SeriesCollection(1).XValues = dRng
   .SeriesCollection(2).XValues = dRng

   .Axes(xlValue).Select
   .Axes(xlValue).MaximumScale = rMax
   .Axes(xlValue).MinimumScale = rMin
   If rMax > 10 Then
     .Axes(xlValue).TickLabels.NumberFormat = "[Red]0;[Blue]0"
   Else
     .Axes(xlValue).TickLabels.NumberFormat = "[Red]0.0;[Blue]0.0"
   End If
   .Axes(xlValue).MajorUnit = (rMax - rMin) / 4
   .Axes(xlValue, xlSecondary).MajorUnit = 0.2
   .Axes(xlValue, xlSecondary).MajorUnit = 0.5
   If rMax + rMin = 0 Then
     .Axes(xlCategory).Format.Line.Visible = msoTrue
   Else
     .Axes(xlCategory).Format.Line.Visible = msoFalse
   End If
   .Axes(xlCategory).TickMarkSpacing = 12
   .Axes(xlCategory).TickLabelSpacing = 120

   .Parent.Top = pRng.Top
   .Parent.Left = pRng.Left
 End With

 d = aCell.Offset(-2, -1).Address
 e = aCell.Offset(-4, -1).Address
 f = d & ":" & e
 aCell.Offset(0, -1).Copy
 Range(f).PasteSpecial Paste:=xlPasteFormats
 Application.CutCopyMode = False

 Range(answer).Select
 Selection.NumberFormat = "0.00"

  aCell.Offset(0, -1).Select
End Sub
```

Data Acknowledgements: SIDC, NOAA, NASA, ESRL, WSO, UW, BOM, MET, PSL, SWPC, LASP, PMOD, KNMI

The Sun drives warming, cooling, extreme events, and CO2.

Author conducted & funded research presented May'22 in Madison, WI

Climate change is fundamentally reducible to sunshine, not CO2.

bob@electricweather.com