The Solar Cycle Influence: How TSI and Insolation Warm and Cool the Ocean

Abstract

LASP SORCE TSI, the CDR TSI, and Historical Solar

data were analyzed to determine that the increasing trend in solar irradiance over 400 years, from the sun's long low activity of the Maunder Minimum to it's equally long Modern Maximum 70-year high sunspot activity period, was *the primary source of energy responsible for the increase in ocean temperature* since the Little Ice Age.

Oceans Warm Under Rising & High Solar Activity or Insolation

over any duration- a week, month, year, solar cycle, or many strong cycles such as during the late 20th century historic warming and solar activity period.

Equatorial ocean heat content and temperatures are observed as sensitive to and *linear-lagged with daily TSI-insolation variation*, from upwelled heat accumulation of sub-surface solar penetration from prior clear sky high insolation *as observed in every* solar cycle onset El Nino event over solar cycles 19-24, and/or rising or high TSI.

Decadal scale ocean warming and post-solar maximum El Nino events are determined to occur after solar activity rises above a long-term average of 120 sfu F10.7cm, equivalent to 94 v2 SSN and 1361.25 W/m² SORCE TSI.

HadSST3 is found to be linearly sensitive to the *annual change* in SORCE TSI

at a nominal rate of 0.5°C/W/year, varying *with rate of TSI change, ie solar acceleration.*

An empirical F10.7-TSI-SST model was made combining a *F10.7cm-SORCE TSI correlation and regression model* and the *HadSST3-TSI sensitivity factor,* predicated on the SWPC Solar Cycle 24 panel 2016 F10.7cm flux forecast.

The author used this model in December of 2015 to *uniquely* and successfully predict the 2016 HadSST3 temperature fall to within 0.030°C, less than a 13% error.

Solar minimum La Nina events result from *insufficient TSI over time*, driving less equatorial evaporation, less cloud cover and precipitation, causing drought. Drought is now expected for the US 2018-20 from low solar minimum TSI.

The Solar Cycle Influence is the accumulated terrestrial temperature effect from all solar cycle activity, which varies with solar cycle magnetic field evolution, is herein found to be *the primary energy source* forcing net *ocean warming or cooling*, tropical evaporation, and subsequent extreme precipitation events or droughts.

Sun-warmed oceans drove 20th century climate change, driven by higher than average sunspot cycles and TSI, *higher than the determined 1361.25 W/m2 warming threshold.*

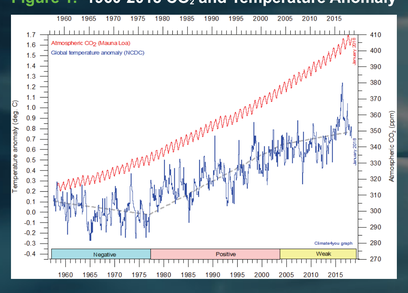
Background and Development

The IPCC AGW climate theory rests on a physical premise that CO_2 is the main temperature driver of the air and ocean via a changing air concentration, with internal variability making up the difference over a claimed very small direct solar TSI effect.

Carbon Dioxide warming theory physics has a 'positive' warming rate, but here the theory is truly challenged by three multi-decadal periods of three different temperature trend slope rates: negative, positive, and weak. Figure 1, *climate4you.com*

The three dissimilar trend rates since 1950 raises considerable doubt over claimed CO_2 warming.

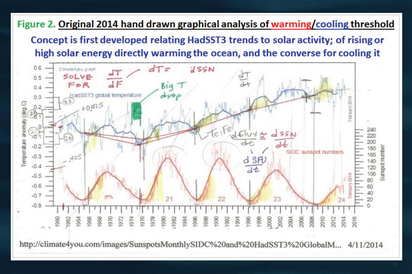
Figure 1. 1960-2018 CO_2 and Temperature Anomaly



In 2014, in lieu of uncertainty in CO_2 warming, and upon noticing a few apparent visual relationships in the MET HadSST3 and SIDC v1 sunspot series data, while the v2 SIDC sunspot numbers were being finalized, this investigation turned towards solar forcing.

The 2014 HadSST3-SIDC Figure 2, scanned from the author's original hand-drawn analysis, exhibits five visually distinct patterns that happened in every solar cycle shown here, covering solar cycles 20-24:

Figure 2. Original 2014 hand drawn graphical analysis of warming/cooling threshold



1) A large multi- year ENSO event observed at each solar minimum thru onset of cycle rising phase

2) Each solar cycle had maximums in smoothed HadSST3 at and after the solar cycle maximum

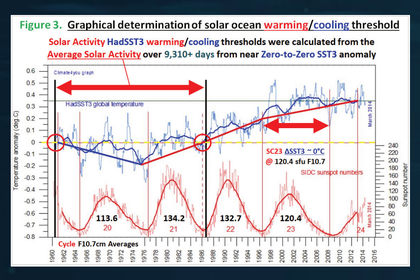
3) Higher sunspot cycles had net ocean warming

4) HadSST3 cooled going into every solar cycle minimum, including during net warming cycles

5) Very similar inter-cycle & similar multi-decadal HadSST3 warming and cooling trend rate slopes

The apparent visual structure in the HadSST3 timeseries wrt sunspot activity led to the *basic assumption in this work*, that *maybe solar activity alone could be responsible for warming and cooling the ocean*. To test this idea, several secondary assumptions were developed during the Figure 3 graphical analysis:

Figure 3. Graphical determination of solar ocean warming/cooling threshold



- Solar cycles 20-23 F10.7cm flux averages were calculated; SC23 ΔSST3 ~ 0°C, F10.7cm @120.4
- The lower solar activity of solar cycle 20 was assumed responsible for cooling until 1976,
- after which higher solar activity cycles 21-23 were assumed responsible for net warming.
- A solar activity warming/cooling threshold, might possibly be determined by finding the *average solar activity* over a long time period from the onset of cooling, at the zero anomaly point, to zero again after a warming period.
- Zero anomaly crossover points in the monthly HadSST3 and the smoothed monthly HadSST3 global values were chosen to be as close to the zero anomaly as possible, red circled points, Figure 3 above.
- May 1960 was selected first as the best starting point in monthly HadSST3, at 0.001 °C; two alternative end points were chosen, Oct 1985 at 0.006 °C and Dec 1986 at -0.006 °C, and the results averaged.

Table 1. Estimated Solar Indice Warming/Cooling Threshold Determination

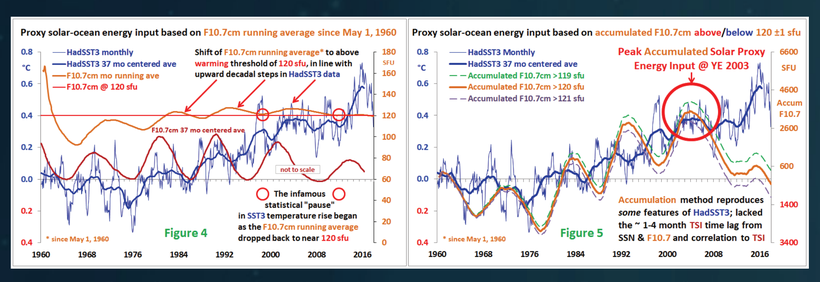
Test	Test Period		F10.7cm, sfu		SIDC v1 SSN		SIDC v2 SSN	
Start	5/1/1960	# days	sum	ave/day	sum	ave/day	sum	ave/day
End 1	10/31/1985	9,310	1,123,935	120.7	629,865	67.7	888,706	95.5
End 2	12/31/1986	9,736	1,155,503	118.7	635,764	65.3	895,122	91.9
Original Calculations			Average	119.7		66.5		93.7
Solar Warm/Cool thresholds:			F10.7cm	120	v1 SSN	66	v2 SSN	94

Table 1 Warming Threshold Calculations

The solar indice warming/cooling threshold(s) represent the long-term average solar activity level assumed necessary to just maintain the HadSST3 temperature anomaly at the same level over time, at zero anomaly in Figure 3.

Warming Threshold Tests

Two basic proxy solar-ocean energy input models were made with monthly F10.7cm solar radio flux data produced by DRAO, by creating a running average timeseries beginning with the test period start date of May 1, 1960, and secondly, a running sum of the accumulation or deficit in F10.7cm solar flux above or below 120 sfu. Other values were evaluated; all values over/under 120 ±0.25 sfu skewed series' tail ends.



Figures 4-5 Proxy Solar Energy Input Models based on simple running F10.7cm average & accumulation.

Figure 6. HadSST3 & Multivariate ENSO Index responsiveness to solar cycle rise and fall

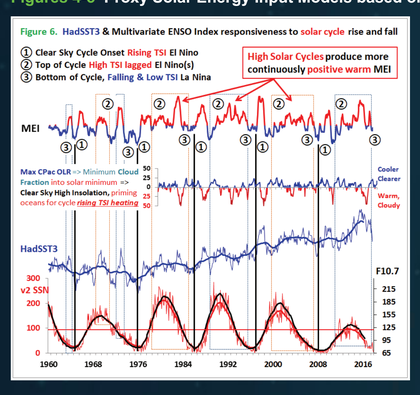


Figure 6. HadSST3 and Multivariate ENSO Index

1. El Nino at solar cycle onset under clear skies
2. Top of cycle heat accumulation El Nino(s)
3. Quick losses in SST after build-ups
4. La Nina occurs going into solar minimum

Central Pacific OLR (~ inverse Cloud Fraction)

1. Significantly less tropical evaporation occurs under low solar activity at the solar cycle heat depletion cycle end, with fewer clouds, higher insolation, leading to more solar energy uptake.
2. Spikes in warming/evaporation/clouds follow solar activity peaks consistently, indicating a direct solar forcing mechanism via insolation changes driven by daily total solar irradiance.

Solar Magnetic Mean Field drives TSI & TSI Threshold Found

Total solar irradiance at 1 A.U., the measure of heat energy from the sun, is herein found correlated to the solar magnetic field evolution, sunspot numbers, F10.7cm observed flux, from which the equivalent in LASP SORCE TSI to 120 sfu in DRAO F10.7cm radio flux, and to 94 in SIDC v2 sunspot number (Table 1), was determined to be 1361.25 W/m², the proposed multi-decadal scale solar warming/cooling threshold.

Figures 7-8. Monthly CDR TSI change is bound and driven by monthly change in mean magnetic field

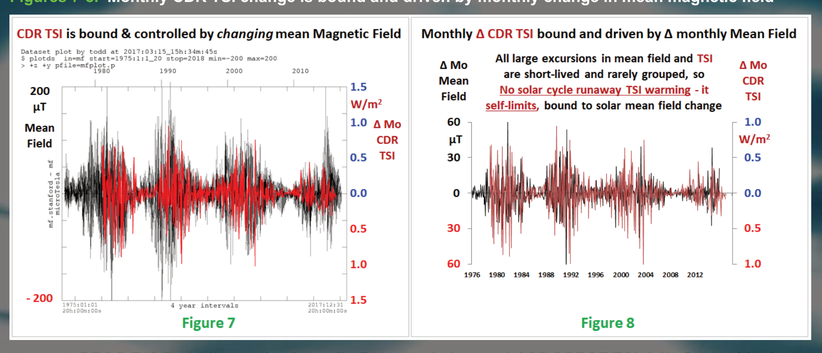
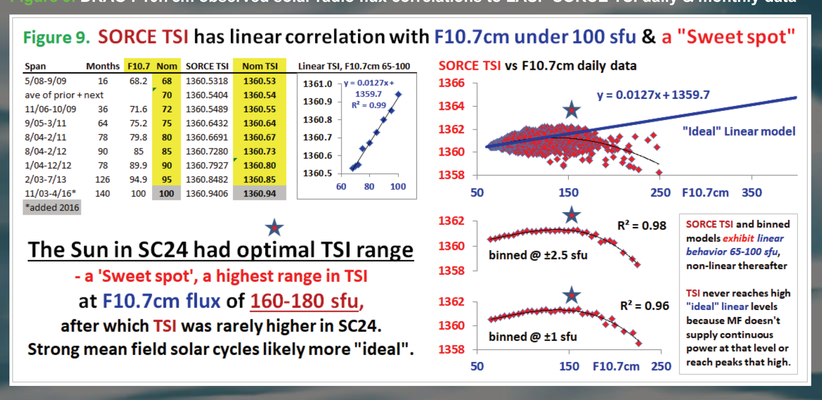


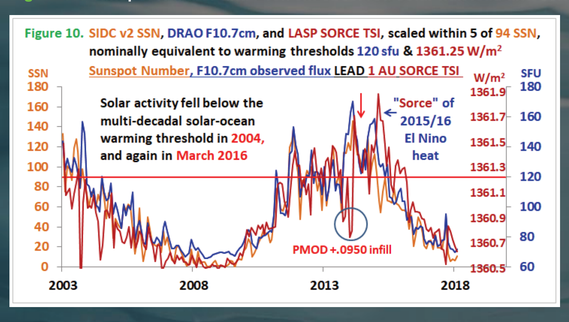
Figure 9. DRAO F10.7cm observed solar radio flux correlations to LASP SORCE TSI daily & monthly data



The proposed SORCE TSI equivalent multi-decadal HadSST3 warming/cooling threshold to F10.7cm observed flux at 120 ±0.25 sfu was estimated from three F10.7cm-SORCE TSI correlation and regression models; the linear model, and two binned samples of F10.7cm & TSI: the final value is 1361.25 ±0.05 W/m².

Solar Data from 2012 & 2013, averaged together and separately, grouped extremely well to the estimated equivalent solar-ocean warming thresholds: 89.6 v2 SSN, 121.3 sfu F10.7cm, and 1361.2658 W/m², a real-world validation thus far of the methods used to uncover the inherent correlative physical properties of the sun's magnetic field & indices. Thresholds were again real-world field-tested in 2015-16, after the 2014 solar cycle 24 sunspot maximum, discussed later.

Figure 10. Sunspot Number and F10.7cm observed solar flux *lead and correlate* to LASP SORCE 1 AU TSI



"The 2014/15 El Niño – Part 11 – Is the El Niño Dying?" WUWT At red arrow in Figure 10, this author said clearly using a full knowledge and appreciation of all things posted here thus far, June 23, 2014 10:15am comment:

"Solar activity ramped up late last year and has since tapered off. The "recharge" of the oceans from that rampup is now dissipating. If and only if there is another spike in solar activity this year will there be an El Nino." - Bob Weber

It happened, the rest is history.

Ocean supersensitive to Solar Mean Field, CDR TSI change

Figure 11. HadSST3 spikes *correspond* to solar Mean Field spikes

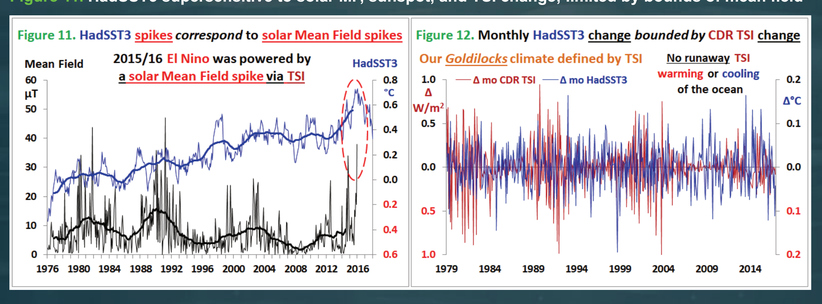
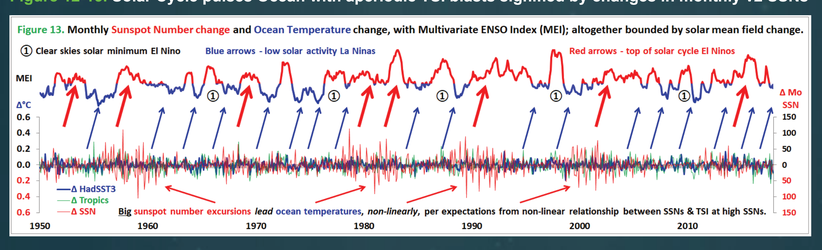


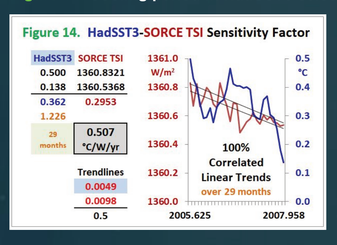
Figure 12-13. Solar Cycle pulses Ocean with aperiodic TSI blasts signified by changes in monthly v2 SSNs

Figure 13. Monthly Sunspot Number change and Ocean Temperature change, with Multivariate ENSO Index (MEI); altogether bounded by solar mean field change.



The HadSST3 inter-cycle warming and cooling slopes appear similar in slope rate but oppositely signed. The change in sea surface temperature appears to correlate *at times* to the change in 1 AU TSI, possibly indicating a simple relationship, with a lag, which results from upwelling time from TSI warming at depth.

Figure 14. Cooling period in HadSST3 selected for testing, sensitivity factor established with SORCE TSI



- HadSST3 and SORCE TSI monthly data were used to establish the *HadSST3-TSI sensitivity factor*, by dividing the change in HadSST3 by the change in SORCE TSI over the test period, divided by the number of months in the test period, and divided by 12 for months per year.
- A sole time period in both datasets was tested: August, 2005 to December, 2007, because the 29 months of data had 100% correlated trends.
- The nominal *HadSST3-TSI sensitivity factor* is computed to be 0.5°C/W/year. The lag is estimated at a year from annual insolation, registered at every calender year end.

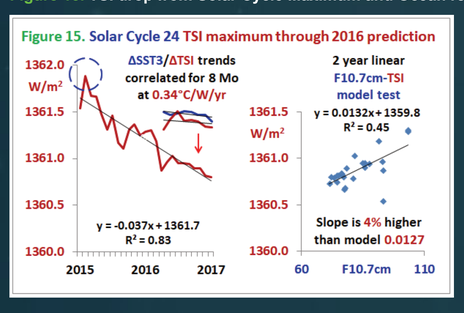
2015 '16 predictions based on typical solar cycle TSI change

The first sunspot peak of SC24, in February 2014, was followed by a peak in December, making 2014 the smoothed maximum year in SIDC v2 SSN for solar cycle 24. Climate scientists and others were predicting by November and December that 2016 would be another record temperature year. This investigator looked at it and had a different take, and said so December 6, 2015 10:44pm in a blog comment from "2015 will be the 3rd Warmest Year in the Satellite Record", December 3rd, 2015 (on Dr. Roy Spencer's blog):

"It was TSI in 2015…. 2016 will NOT be a record year as there will be no long outstanding solar cycle TSI peak like Feb 2015. Enjoy it while lasts, solar minimum is on the way…" - Bob Weber

2016 HadSST3 ended well below the maximum 2016 record temperature, but it was a record year after all. The sun-ocean model developed here forecasted a drop from a typical fall in solar activity from the solar maximum, Too bad for this prognostication, as it was not as completely specified then as it was modelled: "*NOT at record temperatures by year end*". 2016 had no long outstanding TSI spike, so… "2/3 ain't bad".

Figure 15. TSI drop from Solar Cycle Maximum and Ocean response; 2 year real-time F10.7-TSI model test



- Fig 15. blue circle Feb-Mar 2015 TSI peak powered record-setting 2015/16 El Nino
- TSI barely changed from 4/16 to 11/16, 8 months that averaged 1360.9377 W/m², see flattish areas in Fig 15. under arrow.
- TSI drop into 2016 year-end was slowed as a result, leading to SSTs holding on until December bigger drop, busting the annual SST3 change part of prediction
- Fix: Author's next solar model revision will incorporate a time-weighted TSI function favoring year-end solar activity, and evaluate registering model in Jan.

TSI and Sea Surface Temperature forecasting application

The 2016 HadSST3 temperature drop per the now combined F10.7cm-TSI-SST3 model was predicated on the monthly Predicted_Sunspot_Numbers_and_Radio_Flux: Predict.txt data from NOAA Space Weather Prediction Center (SWPC) that is issued in the first week of the month, projecting the solar cycle to 2020. The SWPC NOAA SSN and F10.7cm data is divided into "low", "predicted", and "high" range categories.

The key to the forecast method involves converting the SWPC predicted 12 month change in F10.7cm flux to an expected correlated change in SORCE TSI with the use of the simple linear F10.7cm-TSI model. The linear model as described in Figure 9 is usefully applicable in the low range of F10.7cm flux of 65-100 sfu, the range of the SWPC F10.7cm forecast for 2016. The SWPC in Dec 2015 predicted a large 20-30 sfu drop in F10.7cm flux, high to low range, from Dec 2015 to Dec 2016.

Table 2. The performance of the F10.7cm-TSI -SST model: actual TSI change vs model change tested

Table 2. The BEST FIT MODEL yields Dec 2016 temperature within 0.030°C, 12.7% error @ uncertainty upper limit

Model ΔTSI = 0.0127*ΔF10 — Model ΔSST = 0.507*ΔTSI

Exact Value 0.507	Actual F10.7cm	Modelled ΔTSI '15-'16	Actual SORCE TSI	Model Error	YE Low F10.7cm	HadSST3 °C	Modelled ΔSST '15-'16	SST Error	Model Error
2015	117.8		1361.4321		112.5	0.592			
2016	88.8		1361.0073		81.2	0.613			bust
Δ	29	0.3683	0.4248	-13.3%	31.3	0.021	0.1867	0.2077	-88.8%
					SWPC				
Dec-15	112.5		1361.2527		Modelled	0.717	The BEST FIT MODEL		
Dec-16	75.3		1360.8154		ΔTSI	0.447	at uncertainty limit		
Δ	37.2	0.4724	0.4373	8.0%	0.3975	0.270	0.2395	0.030	12.7%
					-0.0335	20%			
	Ave of two:	0.4204	0.4310	-2.5%	-7.8%	0.64	0.2131	0.057	26.7%

Year end 2016 HadSST3 @ 0.447°C was below year 2014 @ 0.477°C, an impressive drop. HadSST3 uncertainty: 0.02 - 0.03 °C

The TSI model error of the "Ave of two" was -2.5%. The Dec-Dec model had 8% error, within 0.05 W/m² of the actual annual SORCE TSI change. The SWPC F10-TSI model was within 0.03 W/m² of actual @ -7.8% error. The actual 2016 ΔSST/ΔTSI was 0.64, 20% higher than 0.507. The ΔSST/ΔTSI actual was 0.34 for 8 months in 2016, 33% less than 0.507 (see Fig 15). Although the trends correlated over time linearly, the ΔSST3/ΔTSI rates changed, controlled by the rate of solar TSI change rate, over the course of two years..

Table 3. Forecast data updated w/daily TSI and monthly SWPC. Compact current solar-SST forecast table

Present SWPC prediction-based forecast for ΔSST by expected end of solar cycle 24 (December 2019).

The least likely scenario is the SWPC "high" range, due to the nature of the present low solar activity.

Based on the yearly average change method
The expected 2018-2019 change in HadSST3 based on SWPC "low" & "predicted" ranges is between -0.176°C and -0.100°C.

Based on Dec-Dec annual change, table not shown
The expected 2018-2019 change in HadSST3 based on SWPC "low" & "predicted" ranges is between -0.155°C and -0.146°C.

Table 3. Forecast updated monthly w/ytd & SWPC data

	Year	to YE	Δ TSI	Δ SST
	1360.6200	1360.6296	-0.1293	-0.0646
	2018 Low	1360.5630	-0.1864	-0.095
	Predicted	1360.6560	-0.0935	-0.047
	High	1360.7521	0.0027	0.001
	Alt - Linear	1360.6225	-0.1270	-0.064
	2019 Low	1360.4620	-0.1605	-0.081
updated	Predicted	1360.5187	-0.1038	-0.053
4/9/2018	High	1360.6330	0.0105	0.005
	Alt - Linear	1360.5269	-0.0956	-0.048
2018-19	Low	Predict	High	Alt-Lin
net Δ SST	-0.176	-0.100	0.007	-0.113

The Solar Cycle Influence on Sea Surface Temperatures

Figure 16. The Solar Cycle Influence on Sea Surface Temperature

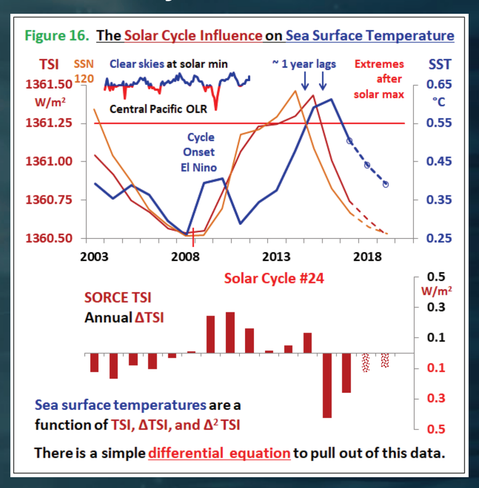


Figure 16. The Solar Cycle Influence

- Previous solar cycle OHC drops into minimum, clearing skies via less cloud cover, increasing tropical insolation for more rapid recharge just before highest new cycle TSI yr change rates
- Cycle onset TSI energy ENSO-depleted
- Solar cycle increase in MF & TSI adds more energy into the ocean through to solar maximum, after which depletion takes over again after peak upwelling
- Ocean Heat Content accumulates from higher net solar cycle TSI energy over the threshold; and conversely, cools
- <12mo lag at sun from ΔMF to max TSI
- 1-12mo ΔSST3 lag from solar changes
- Min to max, SC24 raised HadSST3 by 0.355°C (yearly data) @ 0.1°C/W/year, 0.488°C monthly. 0.596°C 1-'08 to 1-'16

Figure 17. The Extremes driven by the Solar Cycle 24 TSI Peak: Kelvin Waves, MJO, El Nino, Atm. Rivers

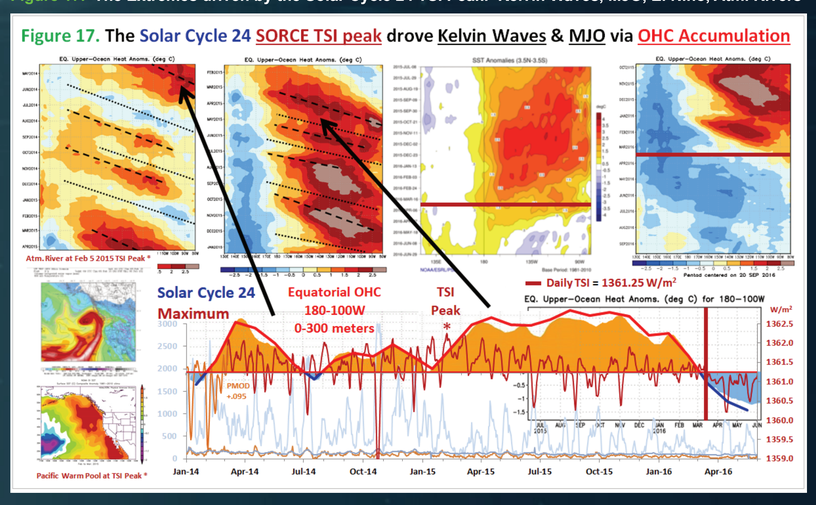


Figure 18. Solar Cycle Influence via TSI driven OHC accumulation is evident in 18 ocean climate indices

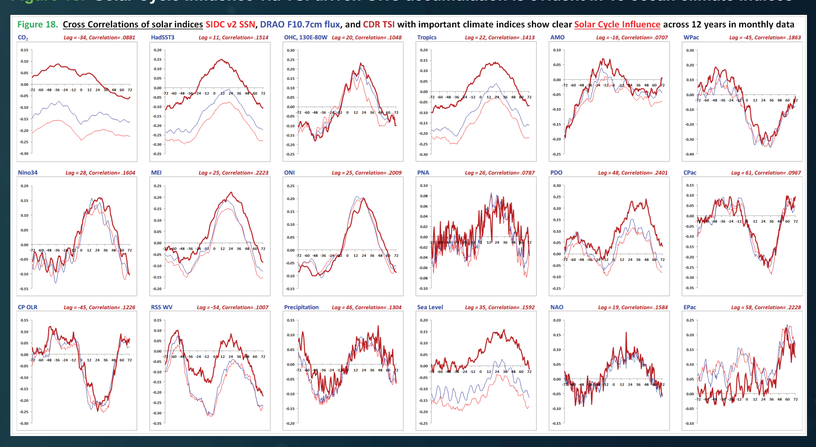


Figure 19. A *more active* 20th century Sun produced *more heat* that *warmed & accumulated* in the Ocean

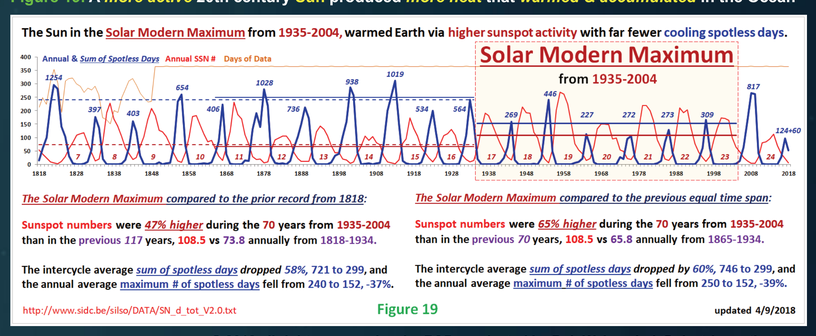


Figure 19

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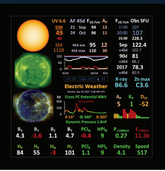
Acknowledgements:
MET, NOAA, NASA, WSO, SIDC, LASP, DRAO, RSS, SWPC, PMOD, UW, ESRL

The Sun causes warming, cooling, and extreme events, not CO_2!



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Supplemental

Figure 9.1. Real example of Fig. 9 "Ideal" linear SSN-TSI model is PMOD from solar cycle 22. (d)

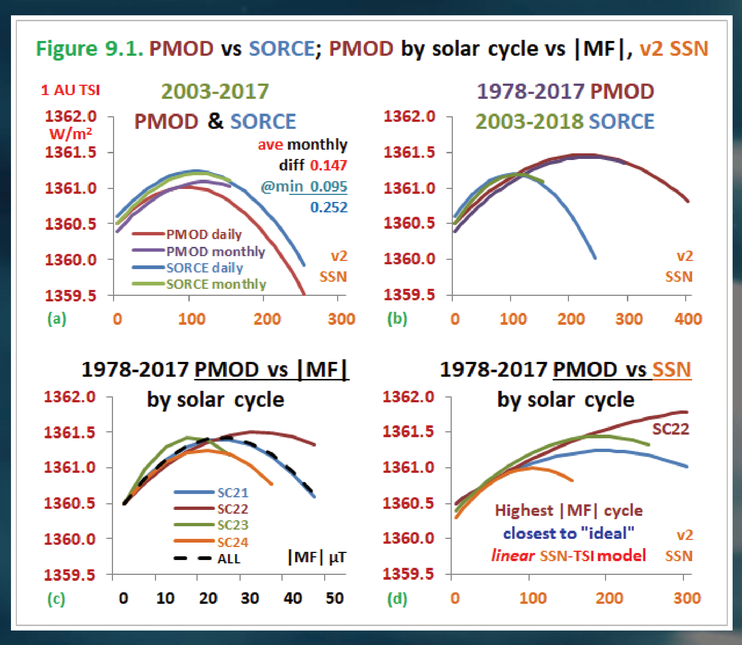


Figure 17.1. Clear skies high insolation warms Eq C. Pacific *before* SC24 TSI energy heats it up.

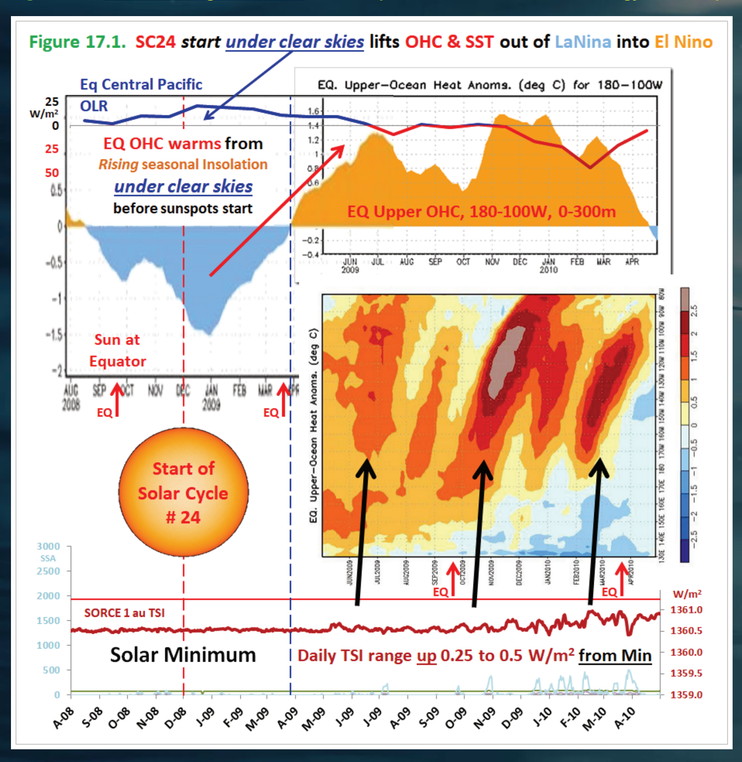
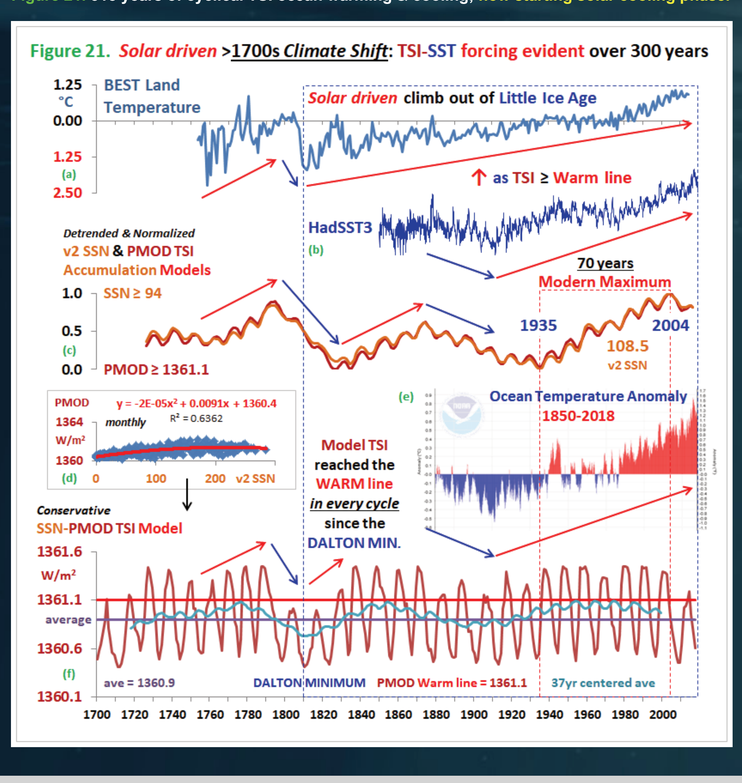
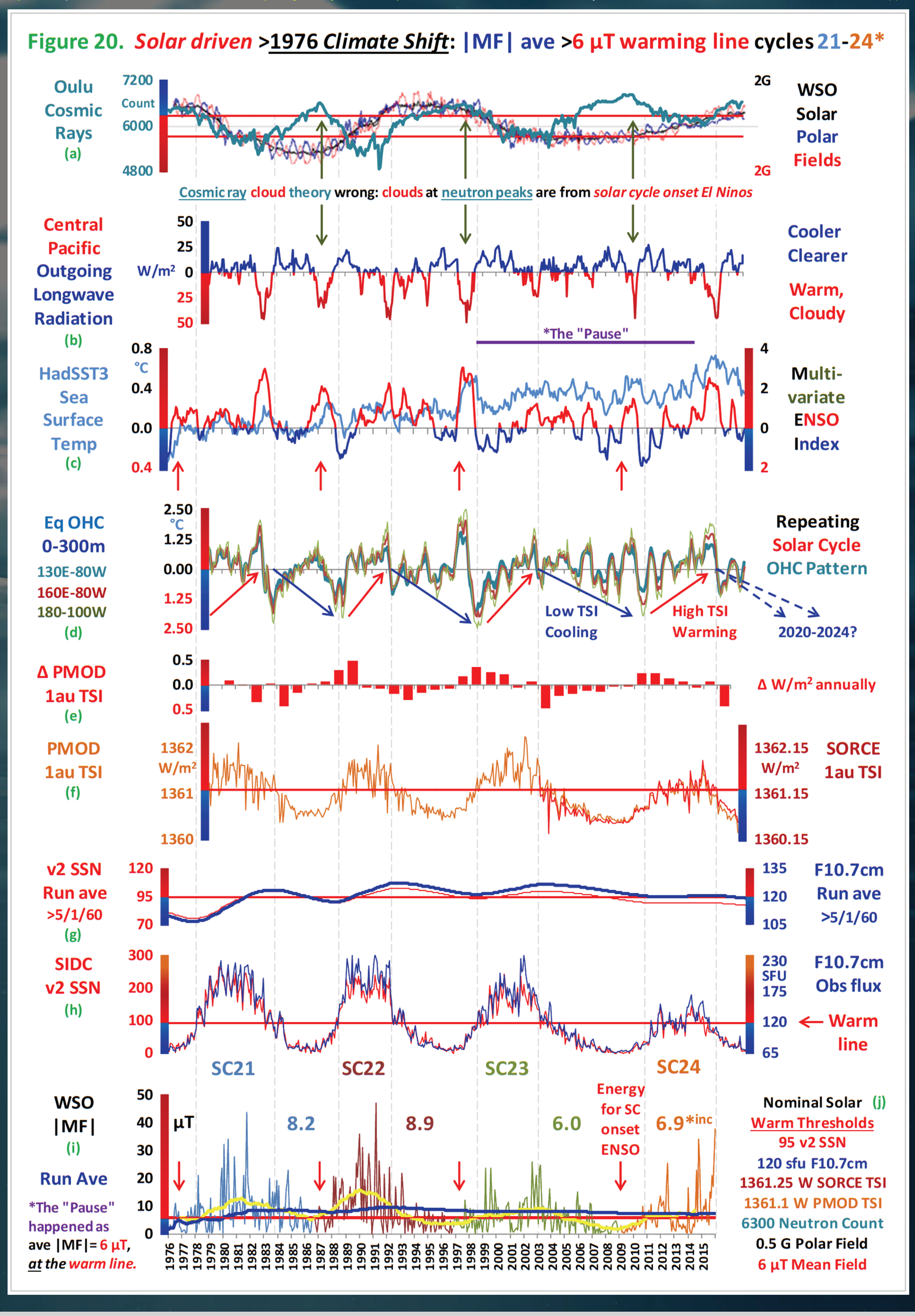


Figure 21. 318 years of cyclical TSI ocean warming & cooling; now starting solar cooling phase.



The Solar Cycle Influence: *solar-ocean supersensitivity* graphically depicted with TSI warming/cooling of OHC/SST.

Figure 20. Top to bottom solar influence on climate has *repeating* solar cycle-OHC/SST pattern. Sun's mean field drives solar activity indices. Net OHC warmth accumulates via TSI warmed El Ninos. (c)



DATA Sources

Figure 1

http://climate4you.com/images/NCDC%20GlobalMonthlyTempSince1958%20AndCO2.gif

http://aftp.cmdl.noaa.gov/products/trends/co2/co2_mm_mlo.txt

http://www.ncdc.noaa.gov/oa/climate/research/ghcn/ghcn.html

Figure 2, 3

http--climate4you.com-images-SunspotsMonthlySIDC%20and%20HadSST3%20GlobalMonthlyTempSince1960%20WithSunspotPeriodNumber.gif

Table 1, 2, 3; Figure 3, 13, 4, 5, 6, 9, 9.1, 10, 19, 20, 21

http://www.sidc.be/silso/DATA/SN_d_tot_V2.0.txt

http://www.sidc.be/silso/DATA/SN_m_tot_V2.0.txt

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Figure 7, 12, 21

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Figure 7, 8, 11, 12, 20

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Figure 12-14, Figure 16, 20, 21

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Figure 9, 10, 14, 15, 16, 17; Table 2

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Figure 9.1, 20, 21

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Figure 17, 17.1, 20

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Figure 6, 13, 16, 17.1, 18, 20, 21

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Figure 19

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Figure 20

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Figure 21

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Climate change is fundamentally reducible to daily TSI, not CO_2!