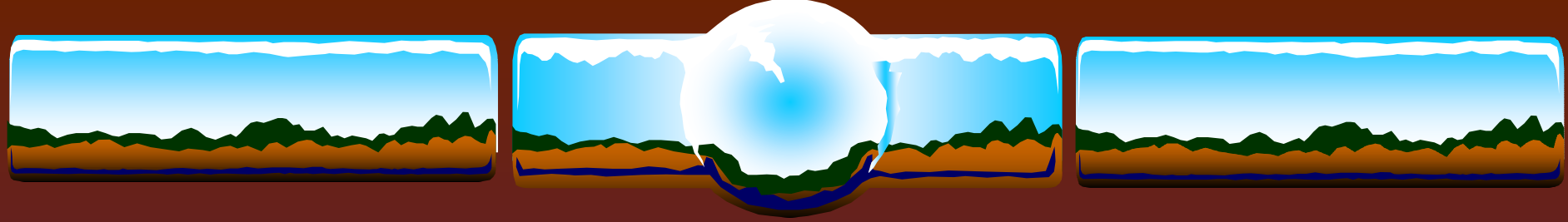


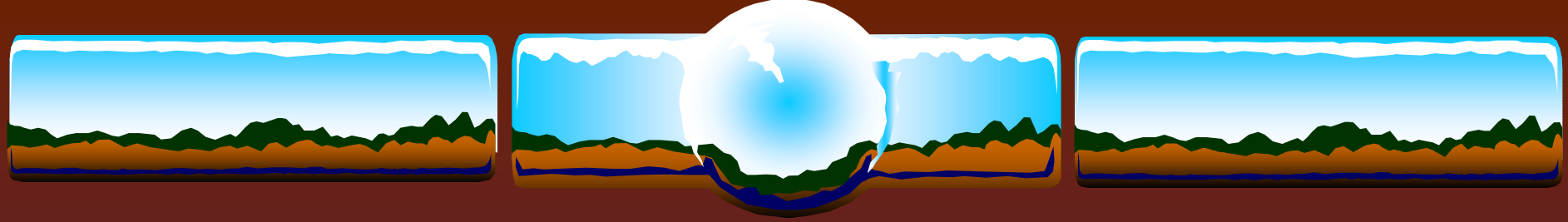
The Increasing Need for Research on Geoengineering Approaches to Reducing Potential Global Cooling

Presented at the Problems of Adaptation to Climate Change Conference

Moscow

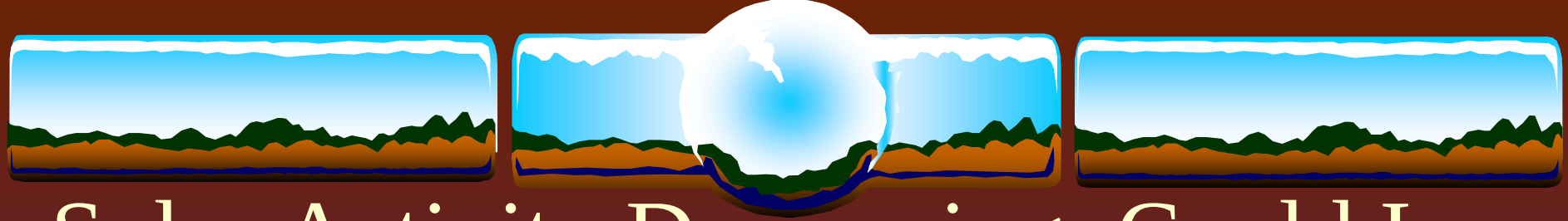
November 8, 2011

Alan Carlin



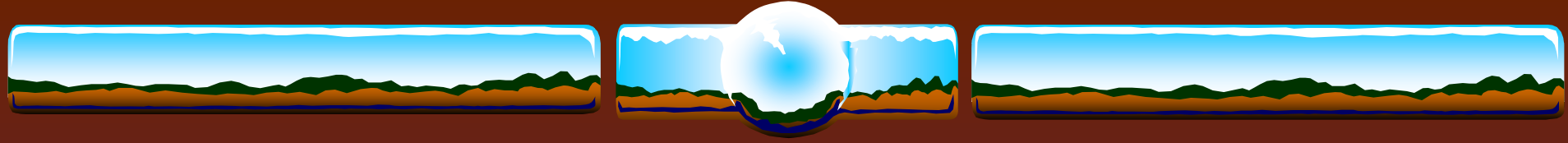
Purpose—to Answer These Questions

- Under what circumstances might geo be useful?
- How likely are these circumstances?
- Is geo the only approach that might be able to control Earth's climate under these circumstances?
- Is there a geo option that might work under these circumstances?
- What needs to be done?



Solar Activity Decreasing; Could Indicate Declining Global Temperatures

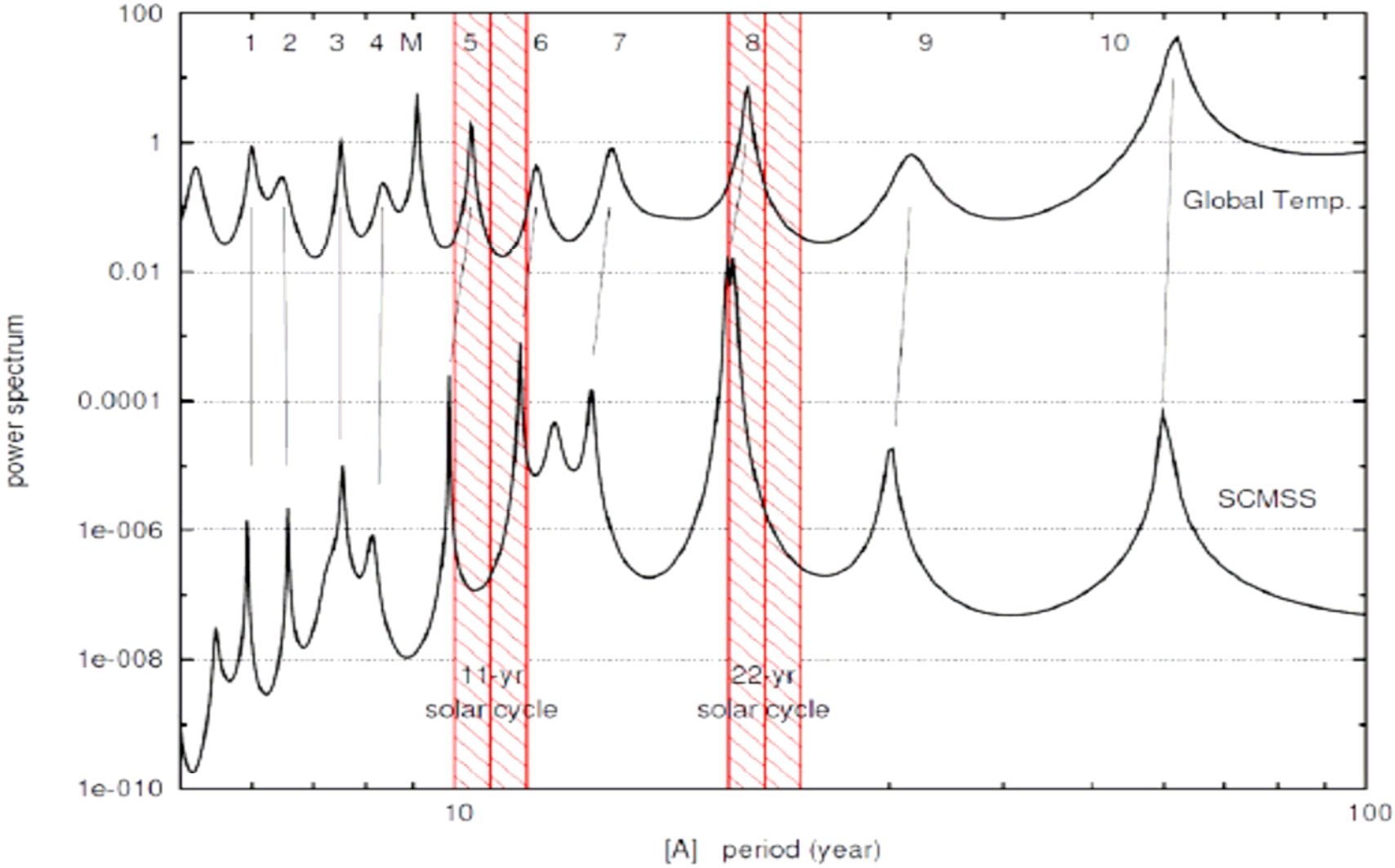
- Rapid fall in magnetic fields generating sunspots & other indicators of solar activity in recent years suggests possible onset of colder temperatures [AAS, 2011]
  - Precursors of Cycle 25 missing
  - Cycle expected to be greatly reduced or even not to appear at all
- Not included in atmospheric models results

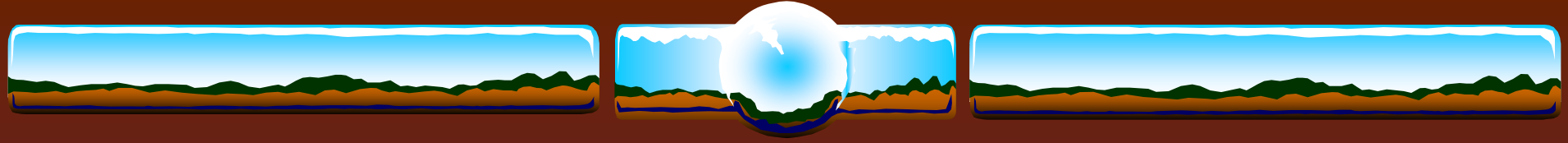


Sunspots, Oceans, & Temperature Have Similar Cycles

- Climate model results do not show effects of solar cycles on oceanic cycles and global temperatures but these cycles plainly exist—and have major similarities
  - Suggest astronomical origin of some temperature cycles
- Some solar/oceanic/temperature cycles
  - SCMSS cycles: 10, 20, 60 years
  - Sunspot cycles: 11, 22, 60, 85, 128 years
  - Oceanic cycles: ENSO; NAO & PDO 60-year cycles
  - Global temps: 9.1, 10.5, 21, 60, 200, 1000, 100000
- Vital to better understanding of climate change and choice of possible control systems—but still in its infancy

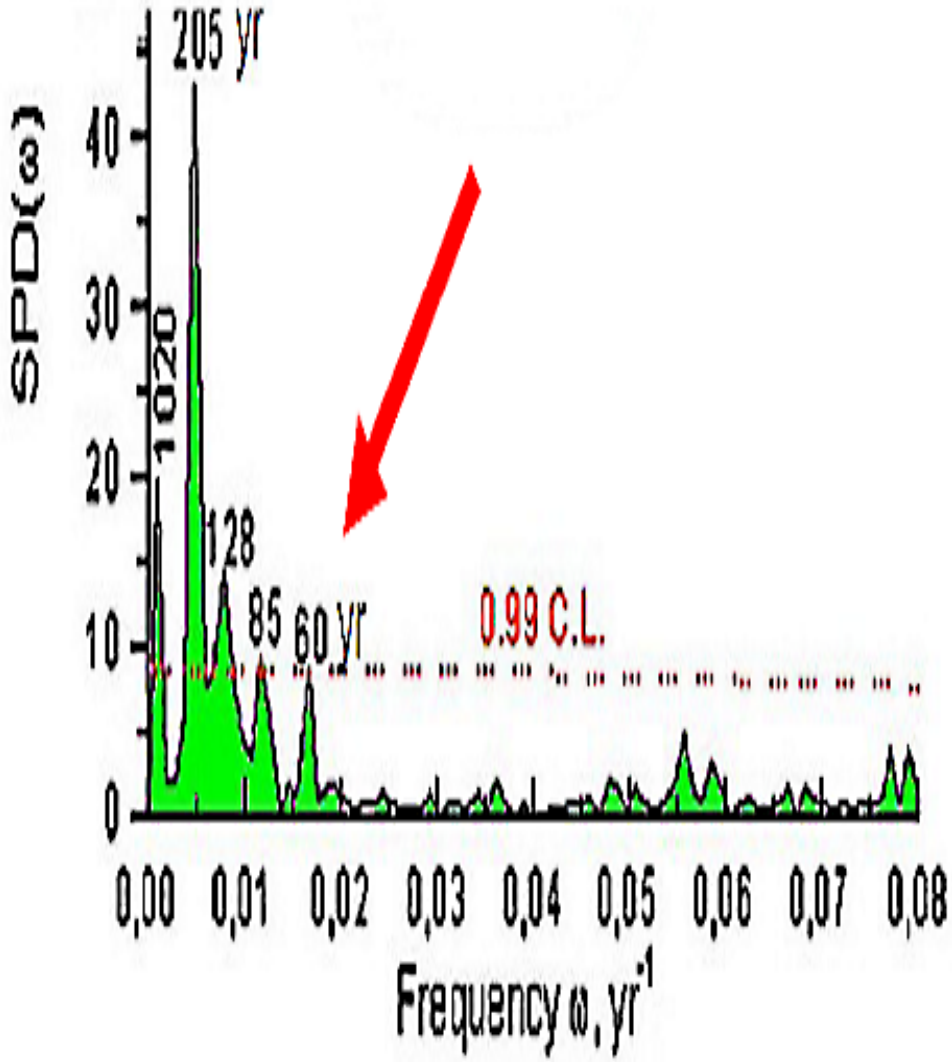
Spectral Analysis of Global Temperatures (1850 to 2009) and Speed of Sun wr/t CMSS [Scafetta, 2010]





Notes on Spectral Analysis Chart

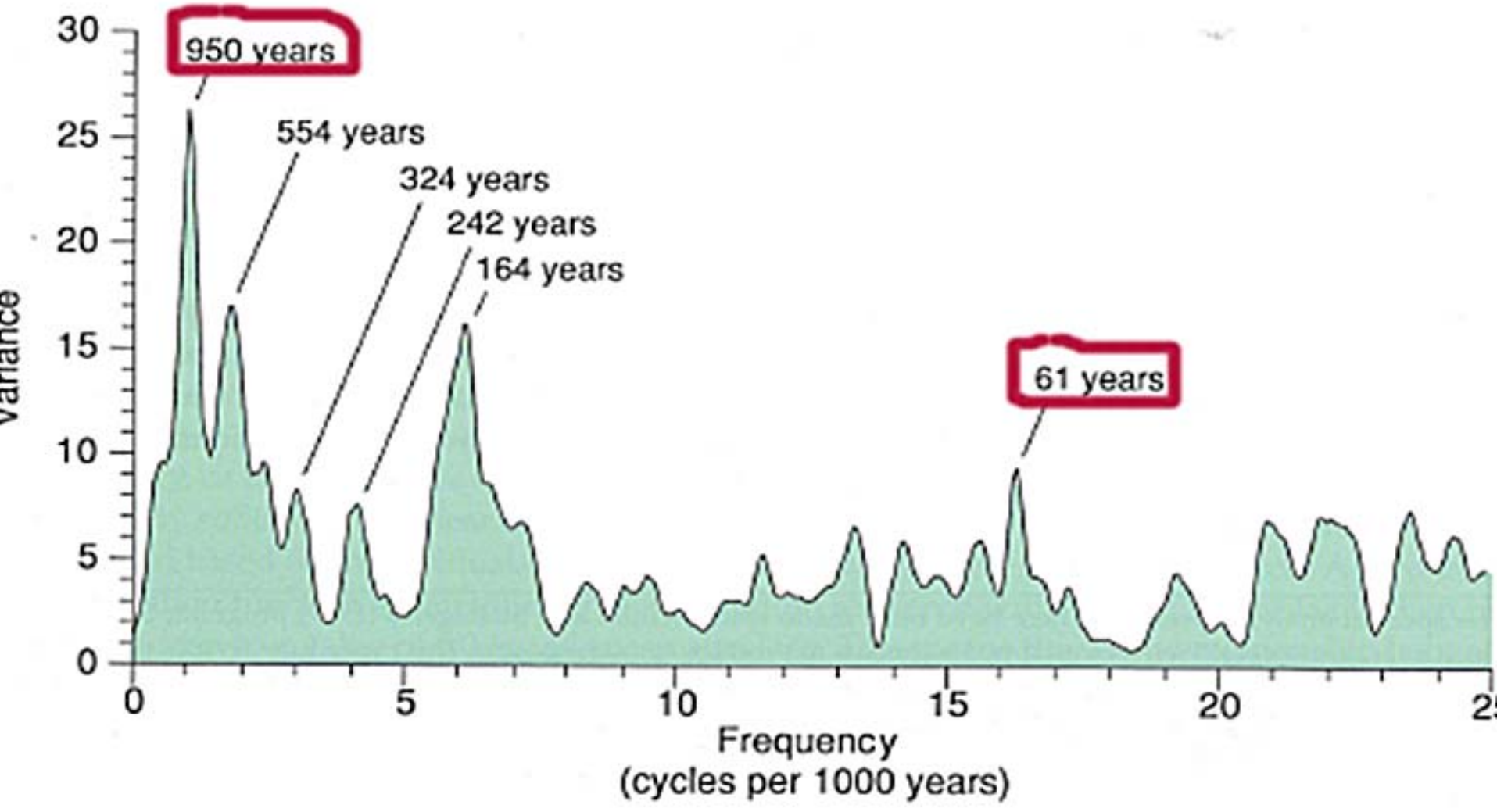
- Speed of sun relative to CMSS depends on the orbits of the planets
- All temperature cyclic peaks correspond with similar small offset to SCMSS peaks except peak M
- But peak M happens to correspond to a solar/lunar tidal cycle of 9.1 years
- Peaks 5 and 8 are close to the 11±1 and 22 ±2 solar sunspot cycles
- Conclusion: Amazing similarity; possible cause & effect?

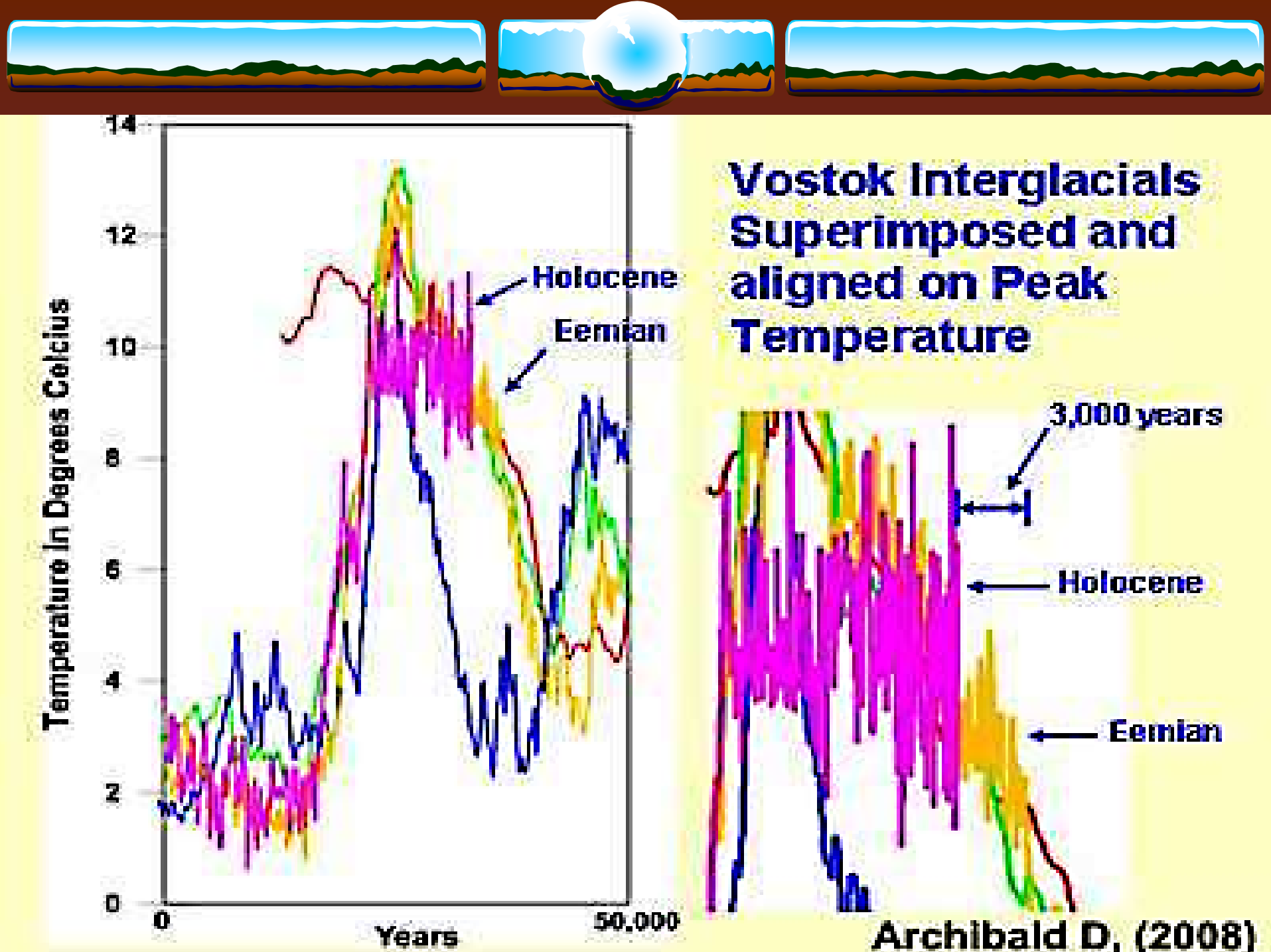


Fourier Spectrum Density of Wolf Numbers reconstructed by Nagovitsyn. Dotted line: 0.99 c.l. (red noise factor 0.3). Significant cycles at 60, 85, 128, 205 yr.

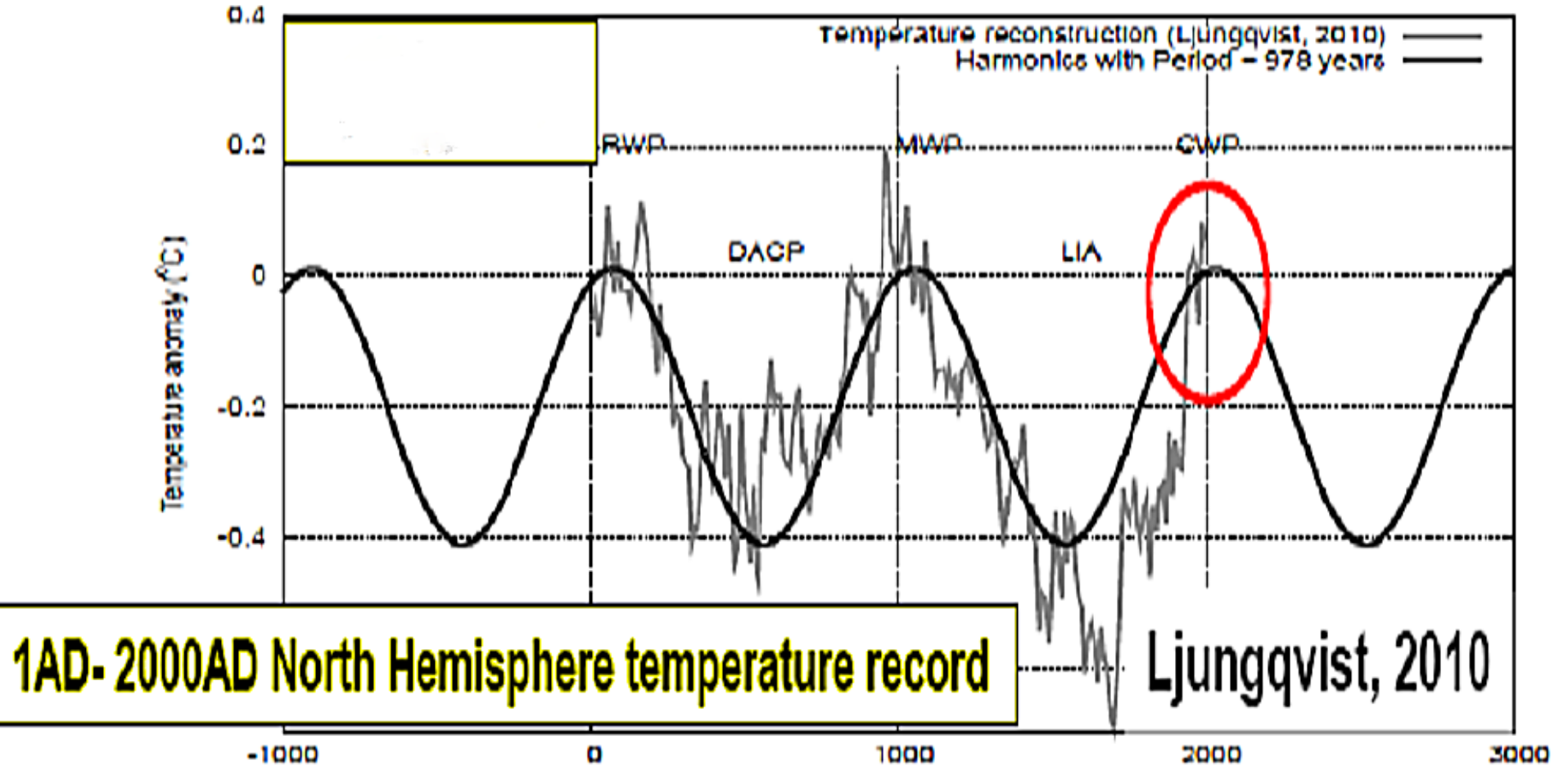
Ogurtsov et al., Solar Physics, 2002

Power Spectrum $\delta^{18}O$ Ratios for Holocene Portion of GISP2 Ice Core [Davis & Bohling, 2001]

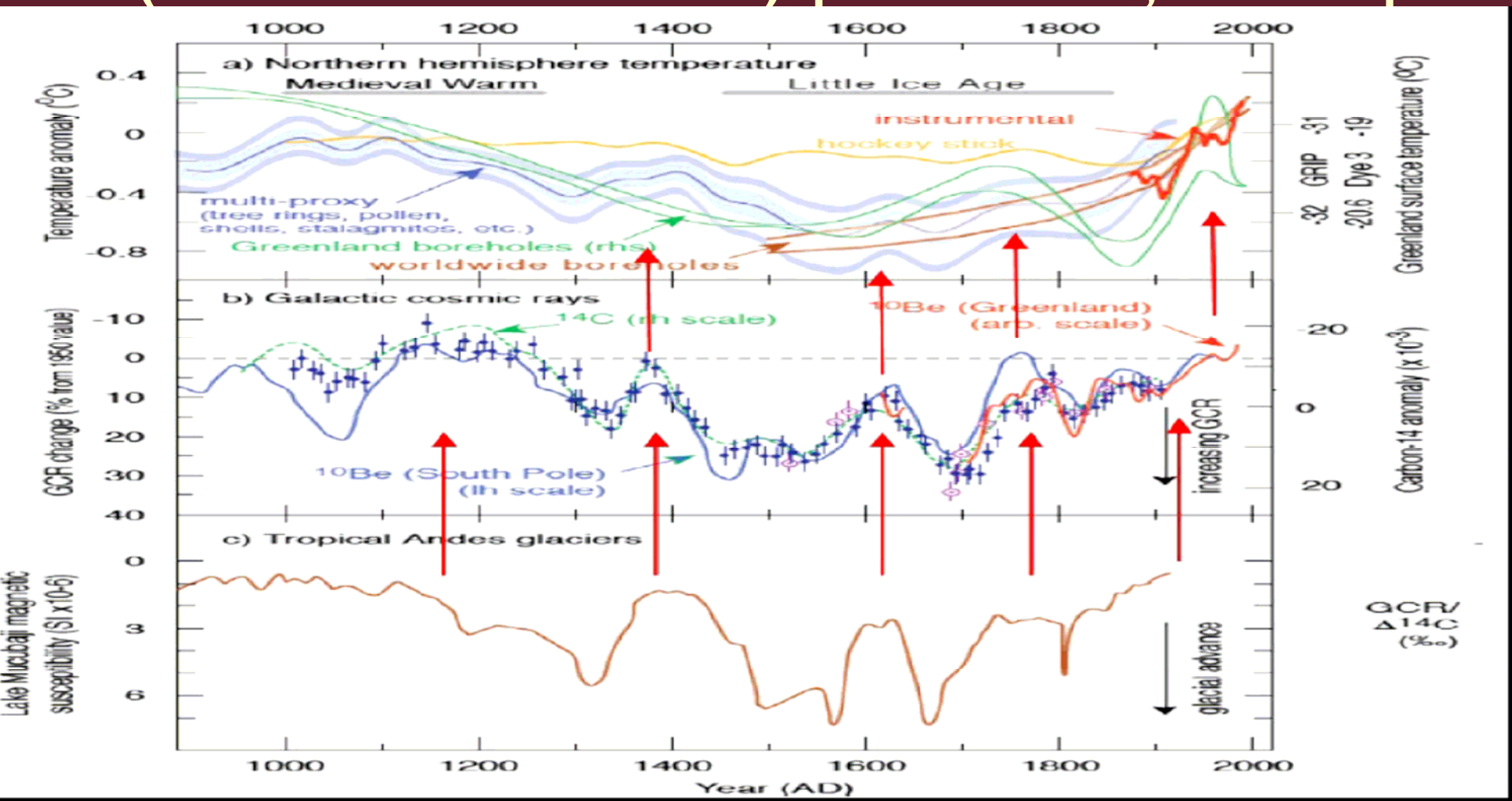



Vostok Interglacials Superimposed and aligned on Peak Temperature
Temperature in Degrees Celcius
14
12
10
8
6
4
2
0
0
Years
50,000
Holocene
Eemian
3,000 years
Holocene
Eemian
Archibald D. (2008)

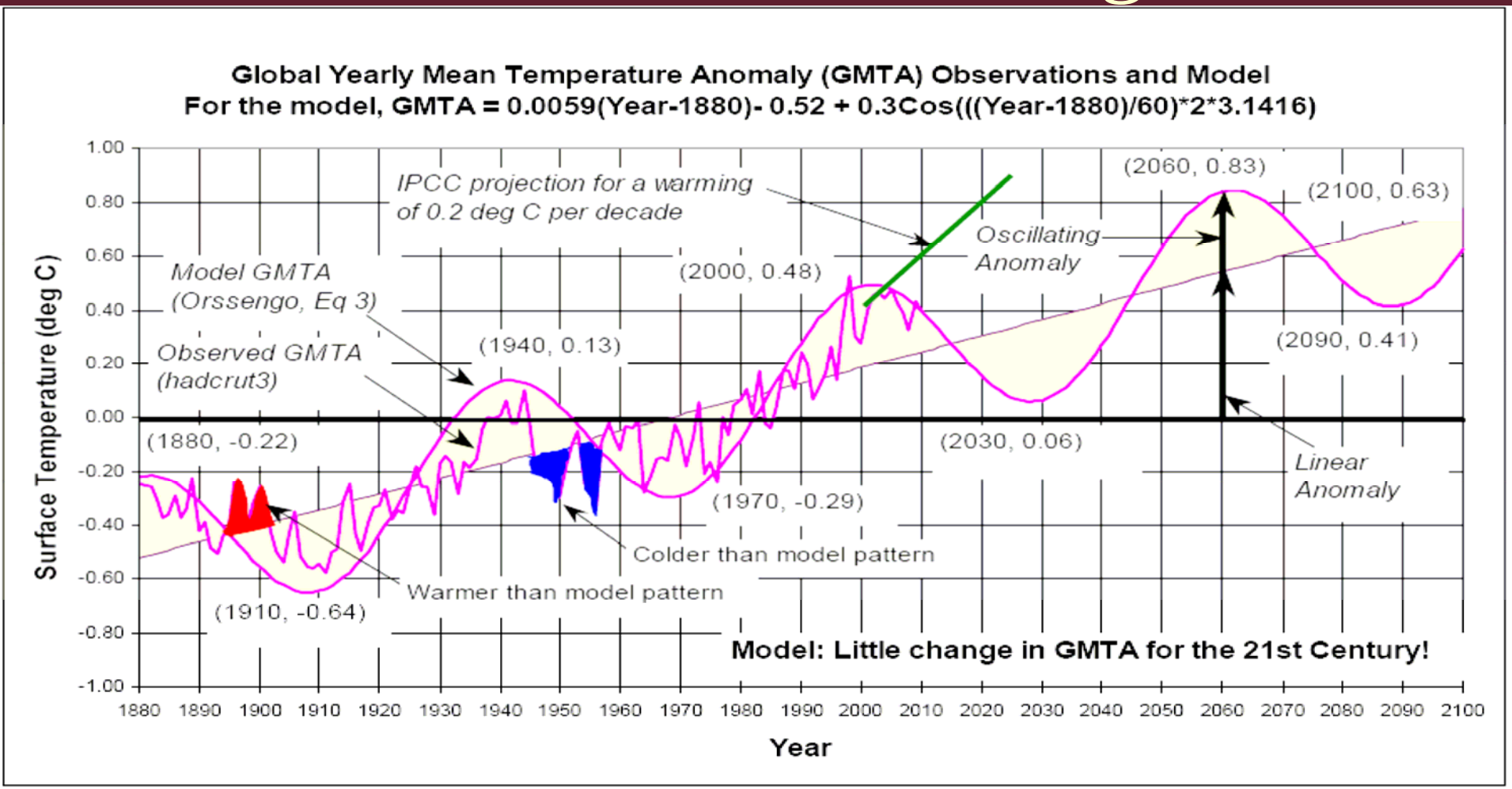
Likely ~1000 Year Temperature Cycle [Scafetta, 2011]



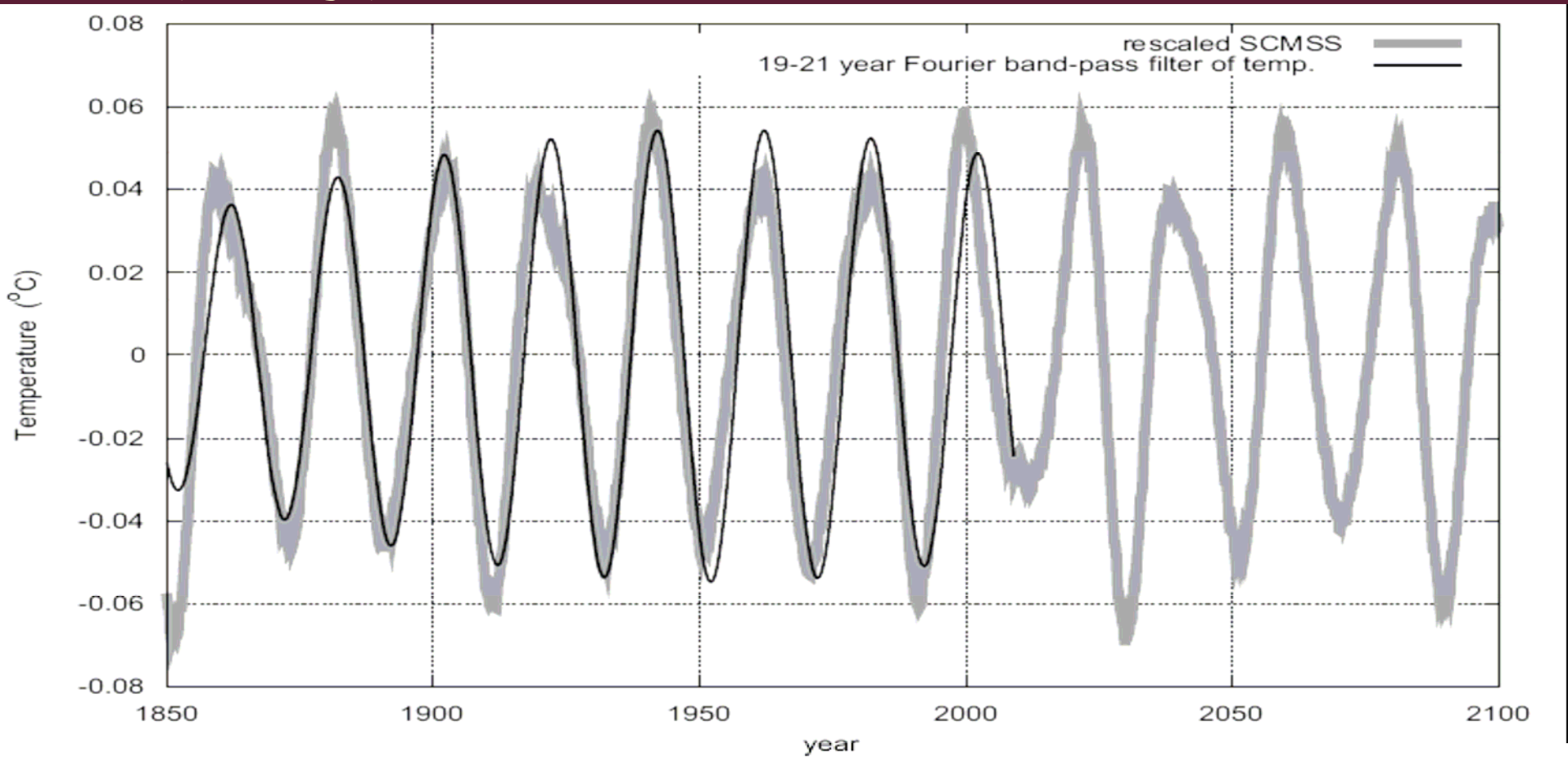
Possible ~200 Year Temperature Cycle (More Uncertain) [Scafetta, 2011]



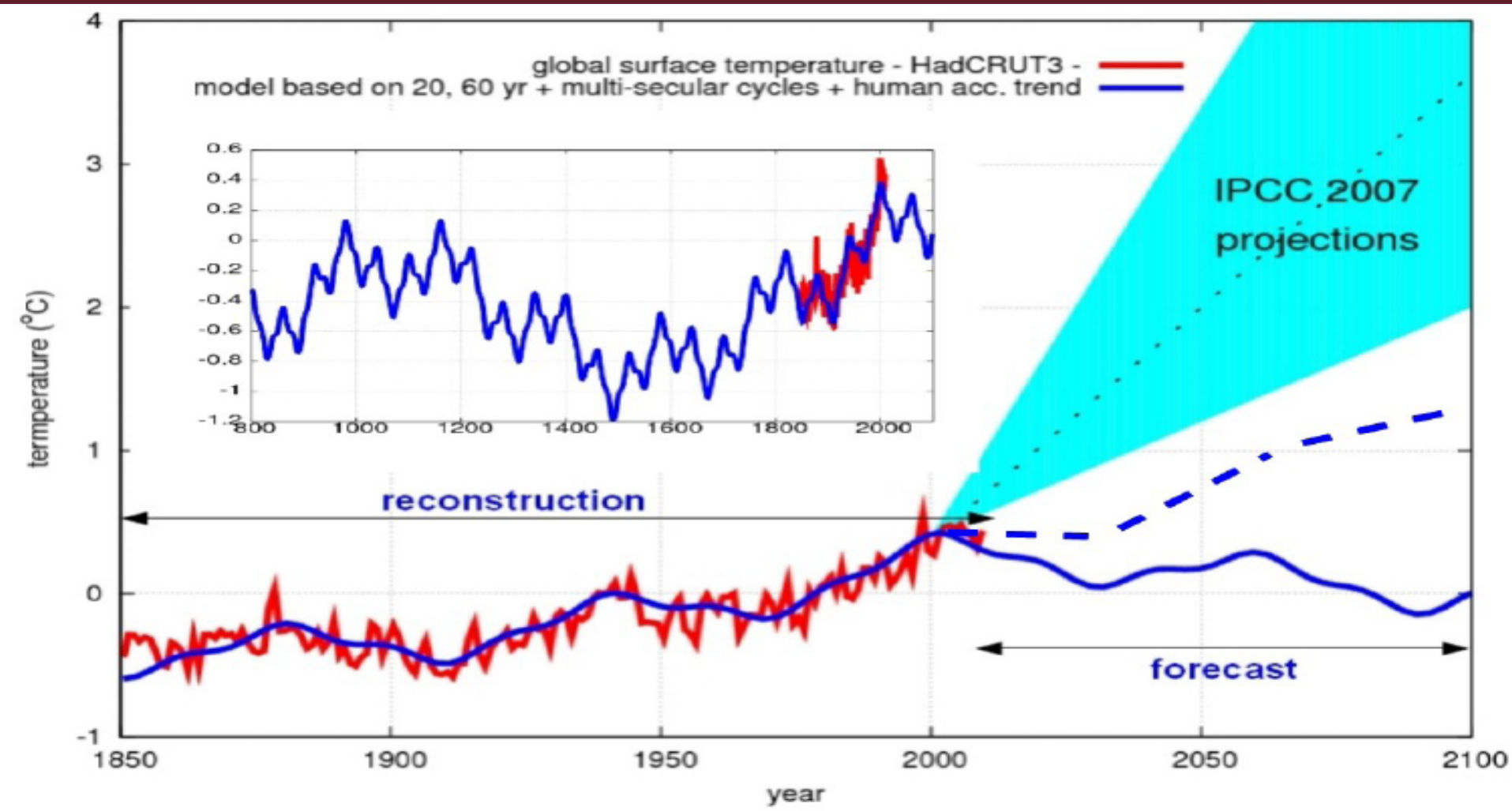
60 Year Cyclical Envelope Model that Fits Last 130 Years [Orssengo, 2010]

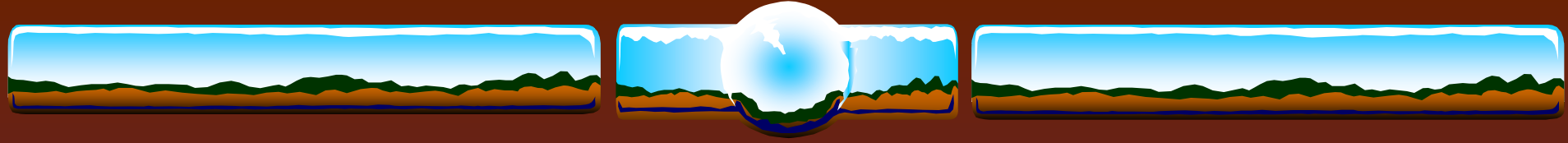


20-year Oscillation of CRU Temperature (Black) Against Rescaled Speed (Gray) of CMSS [Scafetta, 2010a]



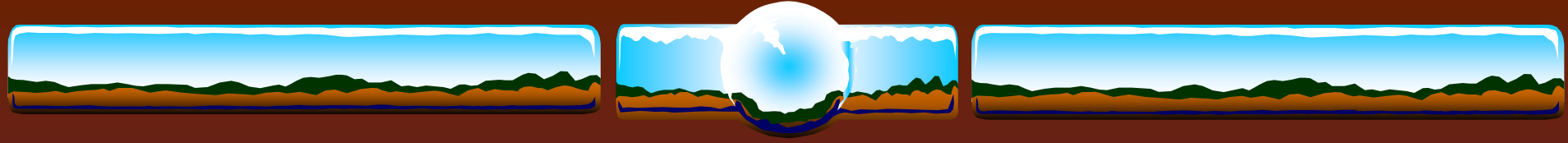
Global Temperature Projections Based on Cycles & a Little AGW [Scafetta, 2011]





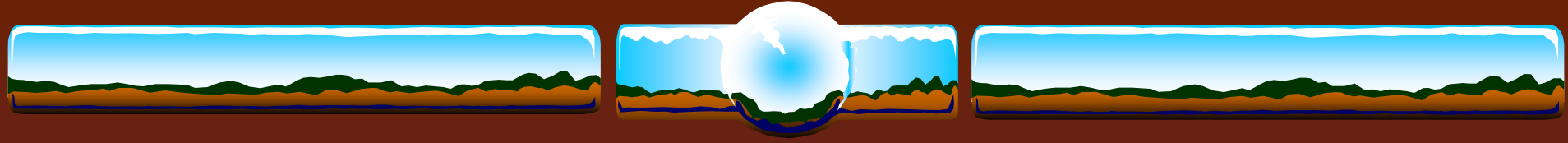
Some Significant Global Temperature Cycles and Geo Implications

Years	Ampli-tude °C	Estimated Present Position in Cycle	Need for Geo to Avoid?
100,000 (ice age)	~10	Passed peak--<~3,000 yrs. to Holocene end?	Yes, particularly for high latitudes. New ice age catastrophic
1,000/950	~0.4	Peak ~2000 to 2060	Not individually, but combination might. But next full combination valley ~500 yrs.?
200/210	~0.4	Peak ~2007	
60	~0.3	Peak ~2002	
20	~0.1	Valley ~2011?	Only cycle pushing up?



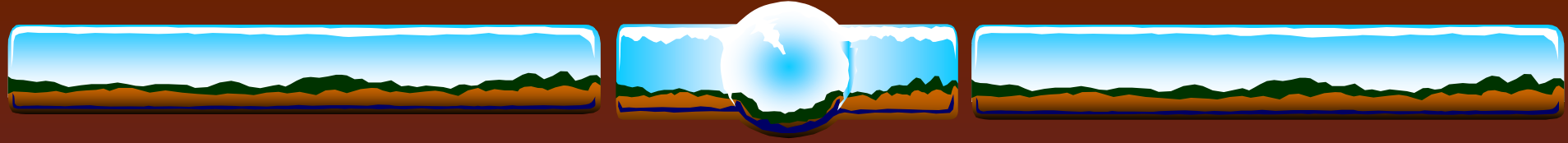
There is a Mechanism for Significant Solar Influence on Climate

- Some solar variability may be due to planetary orbits, particularly Jupiter and Saturn (60 year repetition of combined orbits!), the two largest
- Svensmark hypothesis explains one way solar variability may influence climate
- Possible mechanism recently confirmed by CERN experiments



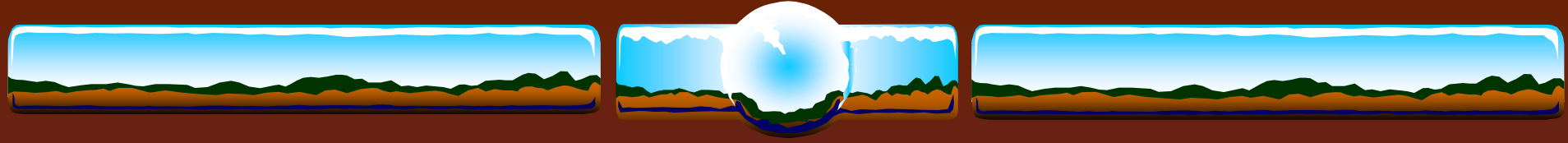
Why Geo Is the Only Realistic Possibility to Prevent Major Temp Changes

- Climate is a very complicated system, but limited observational evidence suggests global temperatures may be headed down—and sooner or later way down
- To avoid future climate changes by adjusting CO_2 emissions we would have to accurately predict changes far in advance since ambient CO_2 levels change slowly and uncertainly. Cooling control would require *increasing* GHG emissions. Major uncertainties:
  - Climate sensitivity, implementation, CO_2 residence time, fuel
- Need capability to respond rapidly (maybe as little as 1 year) to real threat of major adverse change as long as future uncertain
- Geo offers only real opportunity for this despite problems



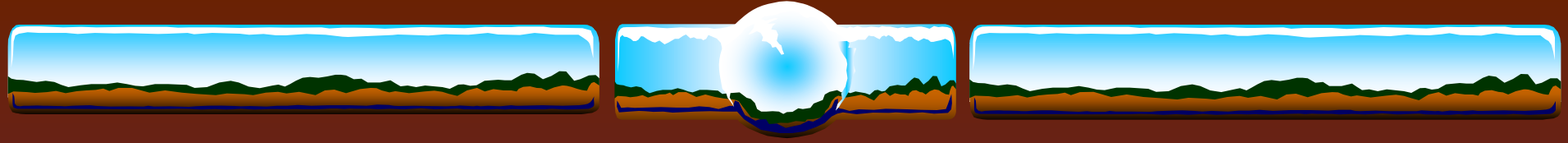
SRM Is Interesting Geo Option

- SRM using insertion of particles in stratosphere could rapidly increase or decrease global temperatures as needed—clearly what is needed
- Very much more effective & efficient compared to CO_2 reductions to bring about global cooling
  - By ~4-5 orders of magnitude in terms of cost-effectiveness in marginal cost /tonCeq. using IPCC assumptions concerning CSF and CO_2 residence times
  - By ~6-7 orders using observation-based CSF and CO_2 residence times
  - So IF controlling warming, MUCH better economically to use SRM
- CO_2 increases probably hopeless to bring about warming
- SRM has numerous problems/risks of course
- Should be presumed priority for research and construction of international system to implement
- High latitude countries have a self-interest in spearheading effort to prevent cooling since cooling will hit them most and with greater effect



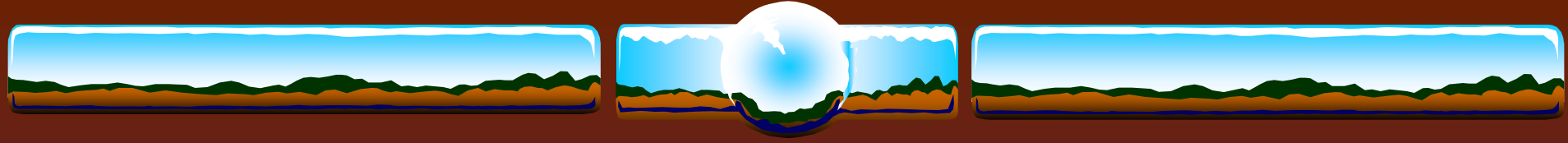
When Should Geo Be Considered for Preventing Cooling?

- Only for potentially catastrophic changes (not AGW)
- Possibly to prevent a new little ice age
- When new ice age (IA) starts, given huge costs of major temperature fall—but can we tell when it starts and would geo be sufficient to avoid it?
  - If IAs are in considerable part a result of the ice albedo effect there might be hope—by decreasing the ice build up very early in the process
  - How much of a cyclical decrease in temps needed to initiate IA?
  - But would require very rapid & insightful response
  - If due primarily to other factors IA prevention may require more than geo can deliver



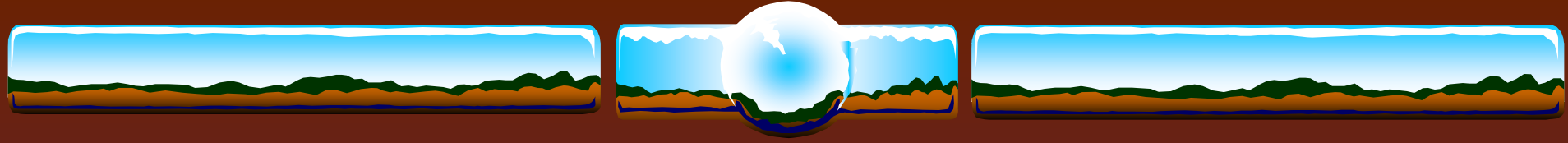
Answers to Original Questions

- Under what circumstances might geo be useful? Avoiding new ice age; possibly combination of other cooling cycles
- How likely are these circumstances? Almost certain
- Is geo the only approach that might be able to control Earth's climate under these circumstances? Yes
- Is there a geo option that might work under these circumstances? Yes, SRM



What Is Needed

1. Better understanding of cosmoclimatology & ice age initiation to better predict future
2. Detailed laboratory/computer studies to determine the best means, environmental effects, and detailed costs to implement an optimum geo approach such as SRM.
3. Very limited testing of the optimum approach to verify its key parameters without endangering the Earth's environment.
   - ❖ Started by Institute of Global Climate and Ecology, 2008/9
4. Development of an international understanding and mechanism for quickly implementing the optimum approach when and if determined to be actually needed to avoid very adverse climate changes (not normal or minor variability).
   - ❖ Unknown when needed, but may take a long time to develop.



For More Details and New Developments

- Carlin Economics and Science website at http://www.carlineconomics.com
- Links to my published articles on geoengineering and climate change: http://www.carlineconomics.com/publications

Notes/references by chart page

1. Email comments by Nicola Scafetta on an earlier draft are gratefully acknowledged.

3. [AAS, 2011]: Press release on three papers presented at American Astronomical Association Solar Physics Division's Conference on June 14, 2011 in Las Cruces, NM, USA, available online at http://www.boulder.swri.edu/~deforest/SPD-sunspot-release/SPD_solar_cycle_release.txt
Here are the abstracts of the three studies referred to in the release:

P16.10
Large-scale Zonal Flows During the Solar Minimum — Where Is Cycle 25?13
Frank Hill, R. Howe, R. Komm, J. Christensen-Dalsgaard, T. P. Larson, J. Schou, M. J. Thompson
The so-called torsional oscillation is a pattern of migrating zonal flow bands that move from midlatitudes towards the equator and poles as the magnetic cycle progresses. Helioseismology allows us to probe these flows below the solar surface. The prolonged solar minimum following Cycle 23 was accompanied by a delay of 1.5 to 2 years in the migration of bands of faster rotation towards the equator. During the rising phase of Cycle 24, while the lower-level bands match those seen in the rising phase of Cycle 23, the rotation rate at middle and higher latitudes remains slower than it was at the corresponding phase in earlier cycles, perhaps reflecting the weakness of the polar fields. In addition, there is no evidence of the poleward flow associated with Cycle 25. We will present the latest results based on nearly sixteen years of global helioseismic observations from GONG and MDI, with recent results from HMI, and discuss the implications for the development of Cycle 25.

P17.21
A Decade of Diminishing Sunspot Vigor
W. C. Livingston, M. Penn, L. Svalgaard
s Convention Center
Sunspots are small dark areas on the solar disk where internal magnetism, 1500 to 3500 Gauss, has been
buoyed to the surface. (Spot life times are the order of one day to a couple of weeks or more. They are thought to be dark because convection inhibits the outward transport of energy there). Their "vigor" can be described by spot area, spot brightness intensity, and magnetic field. From 2001 to 2011 we have measured field strength and brightness at the darkest position in umbrae of 1750 spots using the Zeeman splitting of the Fe 1564.8 nm line. Only one observation per spot per day is carried out during our monthly telescope time of 3-4 days average. Over this interval the temporal mean magnetic field has declined about 500 Gauss and mean spot intensity has risen about 20%. We do not understand the physical mechanism behind these changes or the effect, if any, it will have on the Earth environment.

P18.04
Whither goes Cycle 24? A View from the Fe XIV Corona
Richard C. Altrock
Solar Cycle 24 had a historically prolonged and weak start. Observations of the Fe XIV

corona from the Sacramento Peak site of the National Solar Observatory showed an abnormal pattern of emission compared to observations of Cycles 21, 22, and 23 from the same instrument. The previous three cycles had a strong, rapid "Rush to the Poles" in Fe XIV. Cycle 24 displays a delayed, weak, intermittent, and slow "Rush" that is mainly apparent in the northern hemisphere. If this Rush persists at its current rate, evidence from previous cycles indicates that solar maximum will occur in approximately early 2013. At lower latitudes, solar maximum previously occurred when the greatest number of Fe XIV emission regions* first reached approximately 20° latitude. Currently, the value of this parameter at 20° is approximately 0.15. Previous behavior of this parameter indicates that solar maximum should occur in approximately two years, or 2013. Thus, both techniques yield an expected time of solar maximum in early 2013.

____

*Annual average number of Fe XIV emission features per day greater than 0.19

4. Acronyms:
SCMSS: Speed of sun relative to the Center of Mass of the Solar System
ENSO: El Nino Southern Oscillation
NAO: North Atlantic Oscillation; see Mazzarella and Scafetta, Evidences for a quasi 60-year North Atlantic Oscillation since 1700 and its meaning for global climate change, *Theoretical and Applied Climatology*, 2011.
PDO: Pacific Decadal Oscillation

5. [Scaffeta, 2010]: Nicola Scafetta, Climate Change And Its Causes A Discussion About Some Key Issues**,** SPPI, March 18, 2010, available online at http://scienceandpublicpolicy.org/images/stories/papers/originals/climate_change_cause.pdf

6. Peak M should be related to half of the Saros cycle (18.06 years) and half of the nodal cycle (18.6 years)—Scafetta Email to author

7. From Scafetta, 2011, available online at http://www.scribd.com/doc/60571419/Nicola-Scafetta-ICCC6-PPT

8. [Davis and Bohling, 2001] Image from:
http://i90.photobucket.com/albums/k247/dhm1353/DavisandBohlingFig7a.png
Found in Davis J.C., and Bohling G., The Search for Patterns in Ice-Core Temperature Curves: in Gerhard, Lee C., William E. Harrison, and Bernold M. Hanson, eds., *Geological Perspectives of Global Climate Change*, 213-230 (2001); available online at http://onlinelibrary.wiley.com/doi/10.1046/j.1526-0984.2000.74003-3.x/abstract

9. From http://www.seafriends.org.nz/issues/global/climate2.htm
The source notes that from the Vostok (Antarctica) ice core, which goes back for 4 ice ages, it can be seen that the temperature goes through very similar swings. In this graph, the five interglacials have been superimposed, aligned by their maximum temperatures. The magenta-coloured squiggle is our present interglacial warm period, which has been remarkably level over

time. It has lasted now for over 6 millennia and the next ice age can begin any time soon (give and take a millennium). The Eemian is the previous warm period, some 110,000 years ago.

10. [Scafetta. 2011]: Available online at http://www.scribd.com/doc/60571419/Nicola-Scafetta-ICCC6-PPT
Ljungvist, 2010: Fredrik Charpentier Ljungqvist, A New Reconstruction of Temperature Variability in the Extra-tropical Northern Hemisphere During the Last Two Millennia, Geografiska Annaler: Series A, 2010, pp. 339-50, available online at http://agbjarn.blog.is/users/fa/agbjarn/files/ljungquist-temp-reconstruction-2000-years.pdf

11. [Scafetta. 2011]: Available online at http://www.scribd.com/doc/60571419/Nicola-Scafetta-ICCC6-PPT

12. Orssengo, 2010: Orssengo, G., Predictions of Global Mean Temperatures & IPCC Projections. *Icecap*, April 2010. Available online at http://wattsupwiththat.files.wordpress.com/2010/04/predictions-of-gmt.pdf

13. [Scaffeta, 2010a]: Available online at http://www.fel.duke.edu/~scafetta/pdf/scafetta-JSTP2.pdf

14. [Scafetta. 2011]: Available online at http://www.scribd.com/doc/60571419/Nicola-Scafetta-ICCC6-PPT
The blue lines show a reconstruction of global temperatures since the year 800 using 20, 60, multi-secular cycles plus a little AGW. The red lines show actual HadCRUT3 surface temperature data. The dotted blue line shows what might happen if temperatures continued to follow the same cycles after year 2000 as before, as illustrated in Chart 12. The solid blue line on the right side shows the forecast if most of the solar cycles enter a down phase after about the year 2000.

15. Sources:
1000-year cycle amplitude: Chart 10 above.

1000-year peak: Chart 10 and Email from N. Scafetta. Note that this is of considerable importance to the analysis. My analysis assumes that the 1000-year peak has already passed. Scafetta, however, believes that it is in the range of year 2000 to 2060. If the peak has not yet passed, the forecast for the remainder of this Century would be different. Time did not allow discussion of this assumption.

200/210-year cycle peak: See Figure 5 of O. I. Shumilov Physical Interpretation of Solar Cycle Length Connection to Global Surface Temperatures, *The solar cycle and terrestrial climate, Solar and space weather Euroconference* (1 : 2000 : Santa Cruz de Tenerife, Tenerife, Spain), *Proceedings of the 1st Solar and Space Weather Euroconference*, 25-29 September 2000, Santa Cruz de Tenerife, Tenerife, Spain. Edited by A. Wilson. Noordwijk, Netherlands: ESA Publications Division, 2000 xi, 680 p. ESA SP, Vol. 463, p.521, available online at http://adsabs.harvard.edu/full/2000ESASP.463..521S

In addition, David Archibald says the De Vries cycle (210 years) “current minimum started right on schedule” [in 2008]; see http://wattsupwiththat.com/2010/10/06/archibald-on-dr-hathaway%E2%80%99s-most-recent-solar-cycle-24-prediction/

60-year peak: Pierre Corbyn, available online at http://www.weatheraction.com/pages/data/WAclimatechange.ppt

20-year valley: Chart 13 above.