Solar Variability and Climate Change

K.K. Tung, M.W. Yau, K.F. Li, R.L. Shia, F. Li, D.E. Waliser, M.C. Liang, Y.L. Yung

Correspondence: tung@amath.washington.edu

Presented by: Albert (Man-Wai) Yau, CUHK

PRAGMA 14, Taichung, Taiwan, 2008

UNIVERSITY OF WASHINGTON

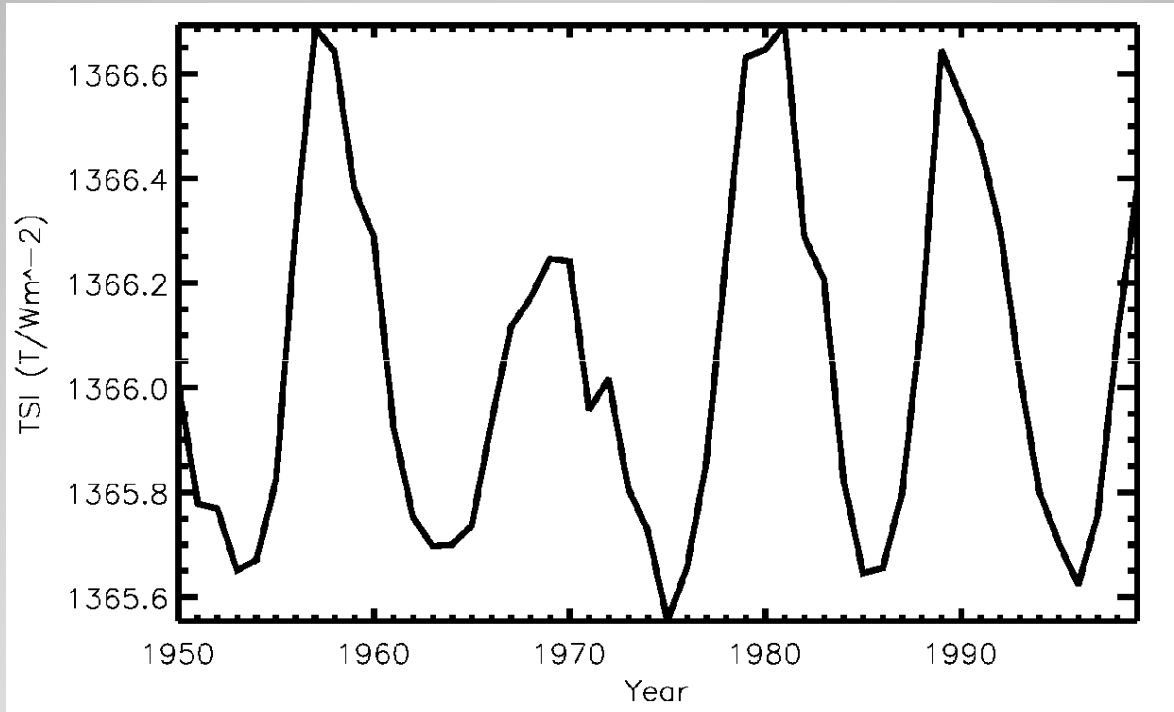
CALIFORNIA INSTITUTE OF TECHNOLOGY 1891

JPL

ACADEMIA SINICA 1928

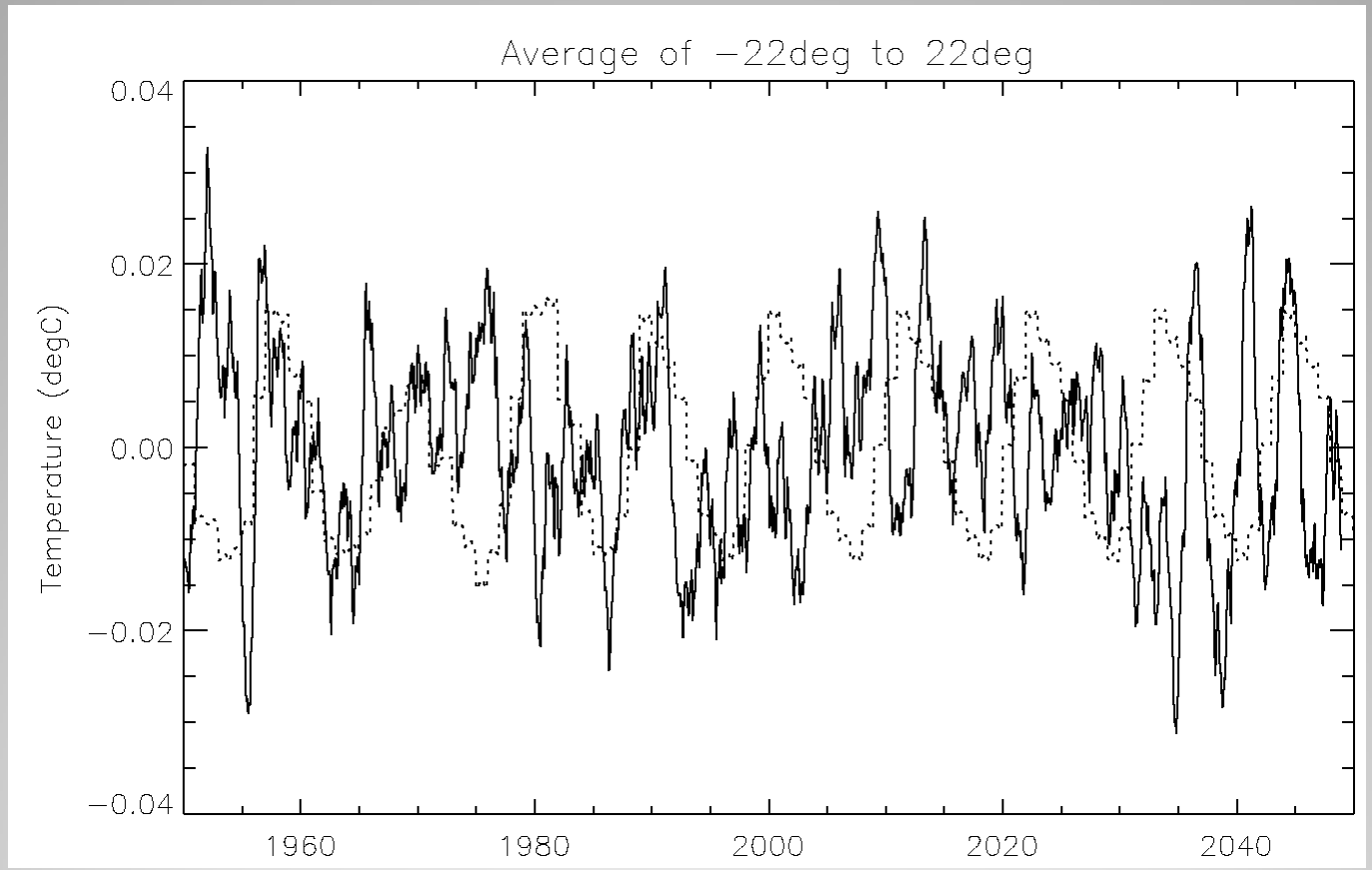
Introduction

- We want to study how does the climate system response to the variance in TSI (total solar irradiance)...



General Circulation Models

- ...using simulation results of GCMs (general circulation models).
  - The state-of-art GCMs incorporate coupled ocean and atmosphere.
- Major GCM models developed in the US:
  - NCAR
  - GISS
  - GFDL
  - ...etc



Average surface temperature from 22N to 22S (5 ensemble runs)

GISS Surface Temperature

IPCC AR4 Report

- IPCC (Intergovernmental Panel on Climate Change) released the Fourth Assessment Report in 2007
- IPCC has archive of GCM outputs of all working groups
- Nobel Peace Prize (2007) together with Al Gore!

Solar-cycle warming in IPCC models (Abstract #: GC43A-0935)

Ka-Kit Tung §, Man-Wai Yau ¶, King-Fai Li †, Run-Lie Shia †, Frank Li £, Duane E. Waliser £, Yuk L. Ling †

§ Department of Applied Mathematics, University of Washington, Seatle, USA

¶ Department of Physics, The Chinese University of Hong Kong, Shatin, Hong Kong

† Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA, USA

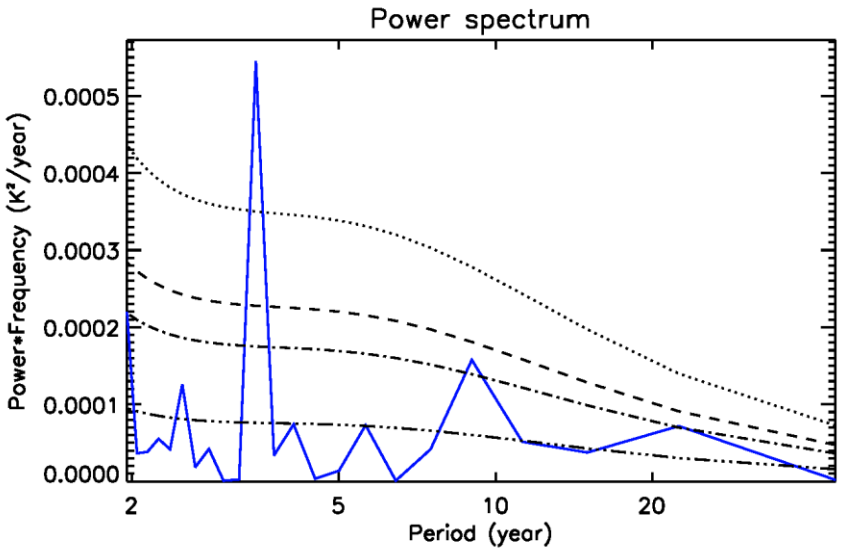
£ Science Team, NASA's Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA

AGU 2007 Fall Meeting

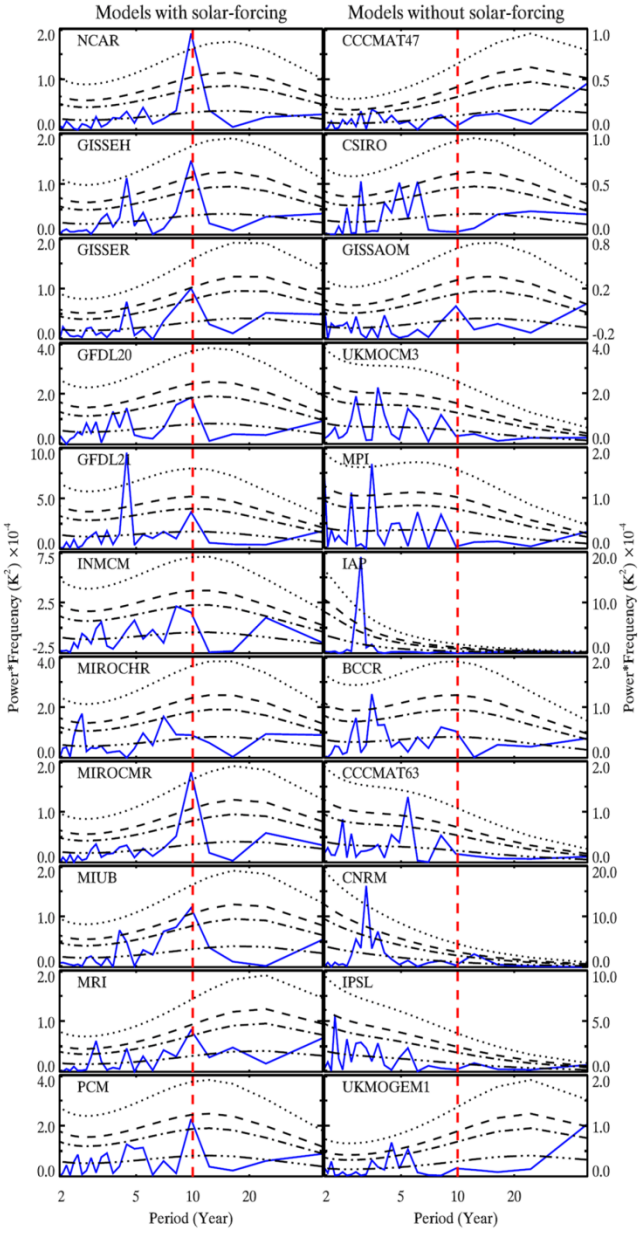
	Model	G	O	SD	SI	BC	OC	MD	SS	LU	SO	VL	Members
1	CCSM3	O	O	O	--	O	O	--	--	--	O	O	8
2	GFDL-CM2.0	O	O	O	--	O	O	--	--	O	O	O	3
3	GFDL-CM2.1	O	O	O	--	O	O	--	--	O	O	O	3
4	GISS-EH	O	O	O	O	O	O	O	O	O	O	O	5
5	GISS-ER	O	O	O	O	O	O	O	O	O	O	O	9
6	INM-CM3.0	O	--	O	--	--	--	--	--	--	O	--	1
7	MIROC3.2(medres)	O	O	O	?	O	O	O	O	O	O	O	3
8	MIROC3.2(hires)	O	O	O	?	O	O	O	O	O	O	O	1
9	MIUB/ECHO-G	O	--	O	O	--	--	--	--	--	O	O	5
10	MRI-CGCM2.3.2	O	--	O	--	--	--	--	--	--	O	O	5
11	PCM	O	O	O	--	--	--	--	--	--	O	O	4
1	BCCR-BCM2.0	O	--	O	--	--	--	--	--	--	--	--	1
2	CCCma-CGCM3.1(T47)	O	--	O	--	--	--	--	--	--	--	--	5
3	CCCma-CGCM3.1(T63)	O	--	O	--	--	--	--	--	--	--	--	1
4	CNRM-CM3	O	O	O	--	O	--	--	--	--	--	--	1
5	CSIRO-Mk3.0	O	--	O	--	?	?	?	?	?	--	--	3
6	ECHAM5/MPI-OM	O	O	O	O	--	--	--	--	--	--	--	4
7	FGOALS-g1.0	O	--	O	?	--	--	--	--	--	--	--	3
8	GISS-AOM	O	--	O	--	--	--	--	O	--	--	--	2
9	IPSL-CM4	O	--	O	O	--	--	--	--	--	--	--	2
10	UKMO-HadGEM1	O	O	O	O	O	O	--	--	O	--	O	1
11	UKMO-HadCM3	O	O	O	O	--	--	--	--	--	--	--	2

G = Well-mixed greenhouse gases
O = Tropospheric and stratospheric ozone
SD = Sulfate aerosol direct effects
SI = Sulfate aerosol indirect effects
BC = Black carbon
MD = Mineral dust
LU = Land use change
VL = Volcanic aerosols
OC = Organic carbon
SS = Sea salt
SO = Solar irradiance

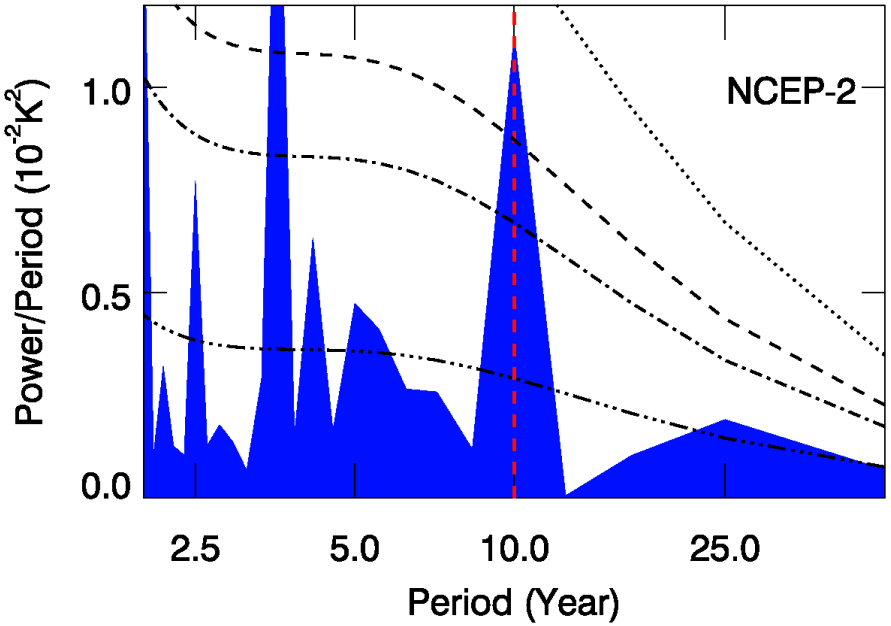
Forcing Used in IPCC Simulations



Observed Fourier Spectrum

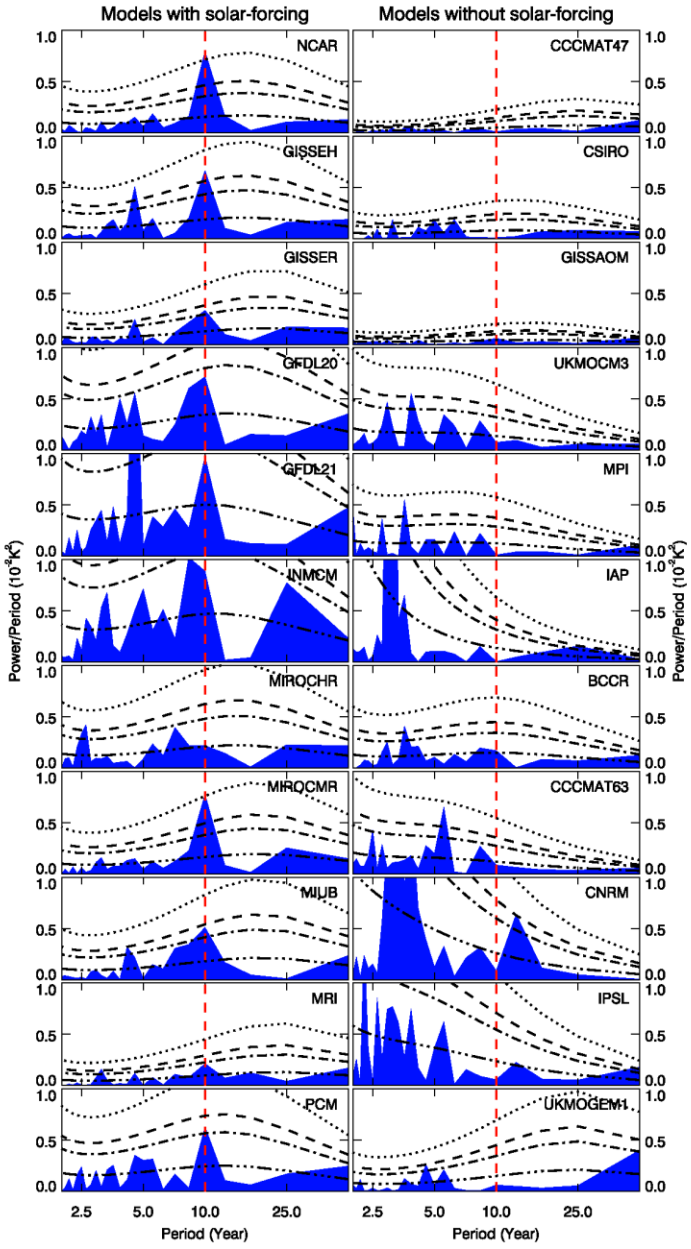


GCM Spectrum



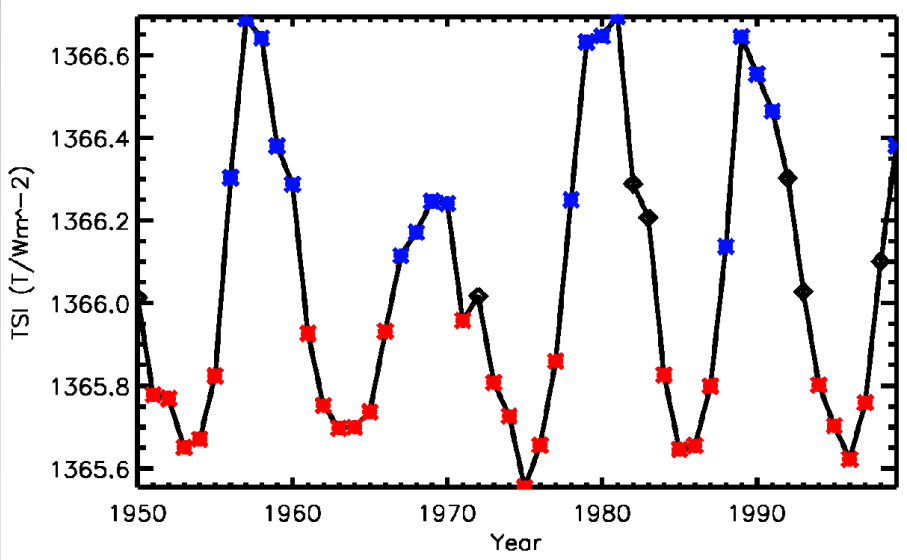
Observed Fourier Spectrum

Updated!

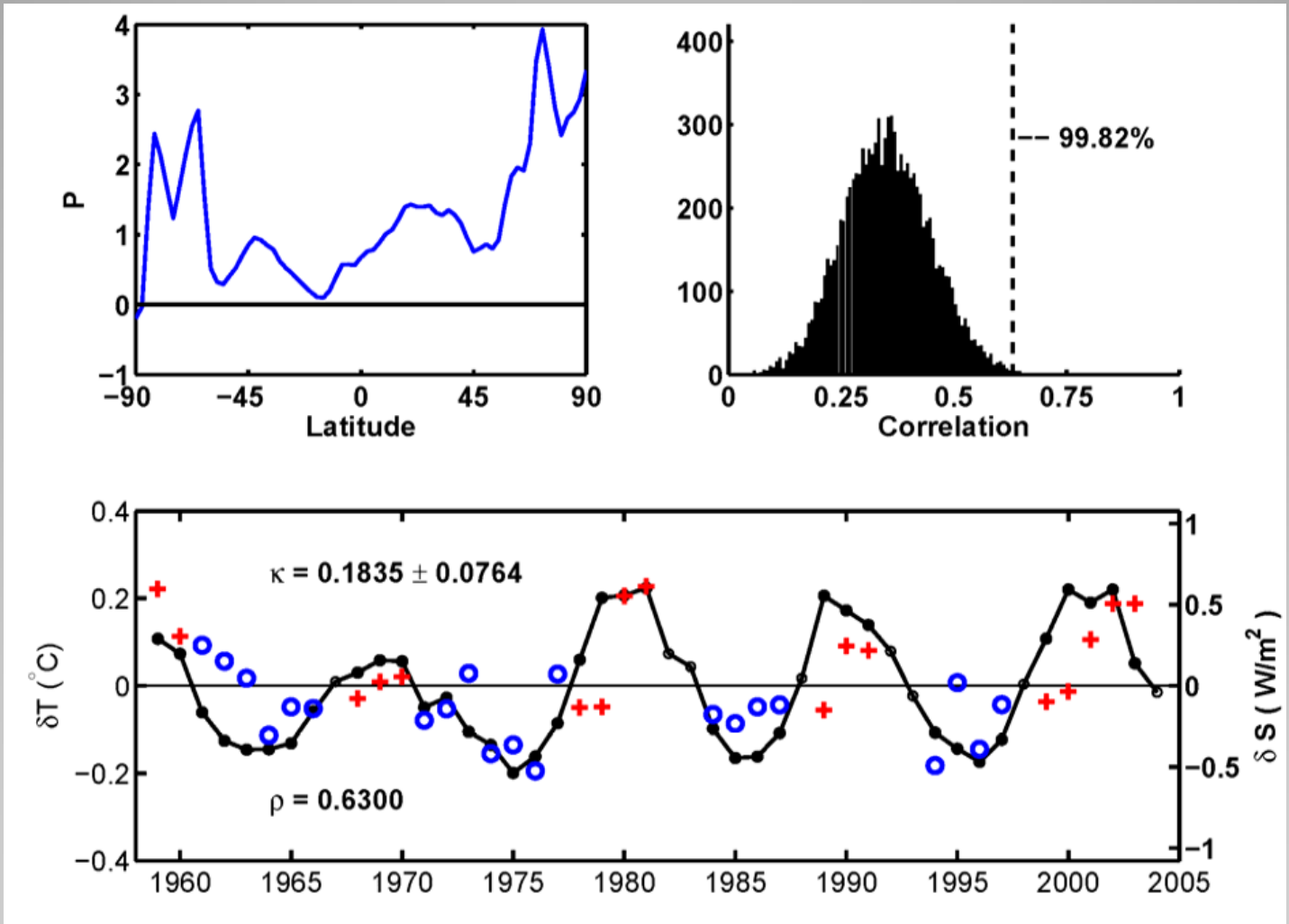


GCM Spectrum

- Camp and Tung (2007) in Geophysical Research Letters:
  - "Surface warming by the solar cycle as revealed by the composite mean difference projection"

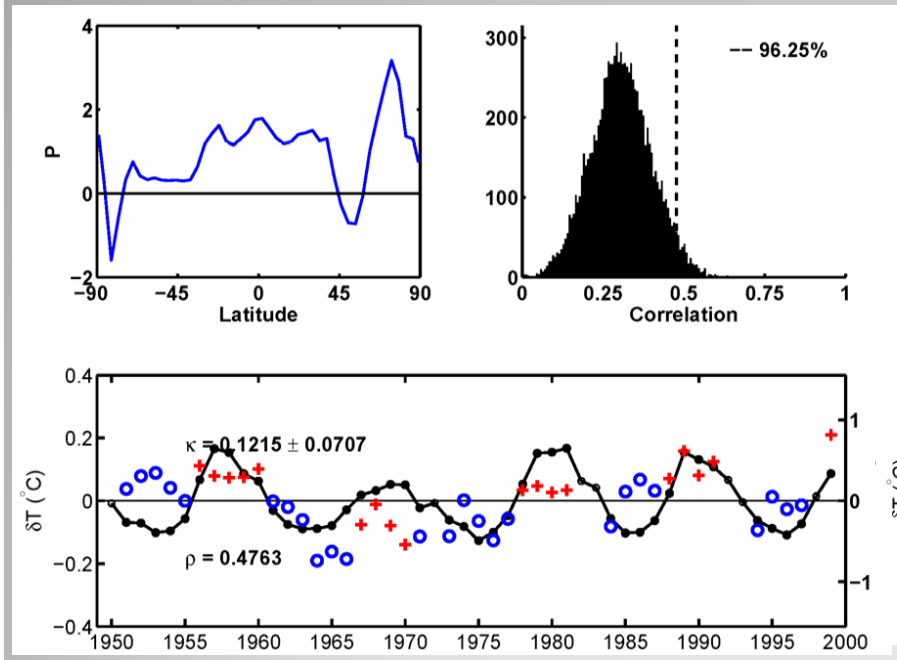


CMD Projection



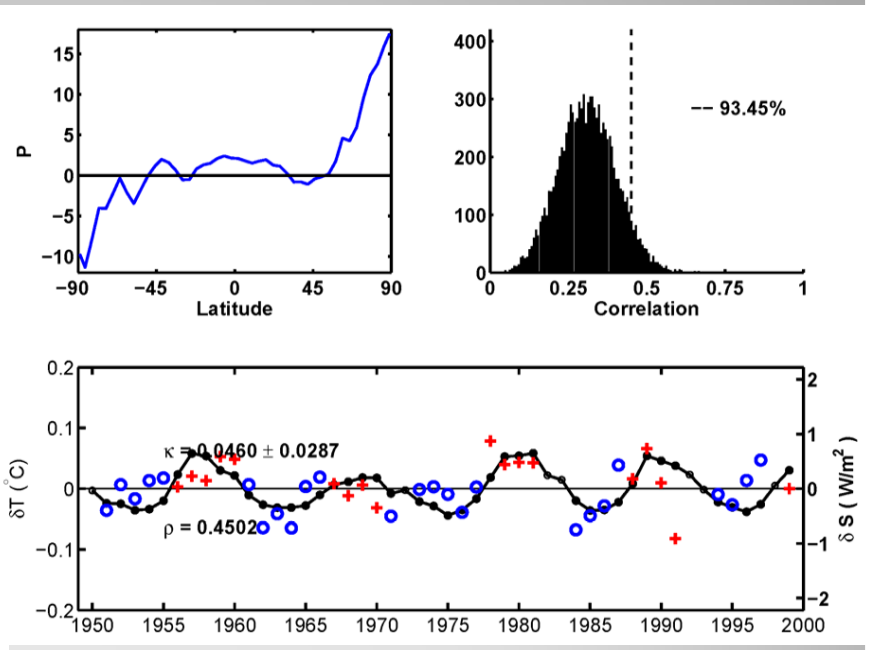
NCEP-2 Reanalysis (Camp & Tung, 2007)

GISS-EH



κ = 0.12+/-0.07 K m^2 W^{-1}

GISS-ER



κ = 0.05+/-0.03 K m^2 W^{-1}

GISS-EH & GISS-ER

- Live (almost) from AGU–Dispatch #6
  - http://www.realclimate.org/index.php/archives/2007/12/live-almost-from-agu%e2%80%93dispatch-6/
  - The next part is the really interesting and most important part. In poster by Tung, Yau, Li, Shia, Li, Waliser and Yung (GC43A-0935) the authors look at 22 IPCC models from the AR4 archive used in the Fourth Assessment report. 11 of these models include solar cycle forcing by irradiance variations, and the other 11 use a constant solar irradiance. All of these models have a fully dynamic ocean. The latter, as expected, do not show any significant 11 year cycle in surface temperature. However, all of the 11 models with solar variability show a significant solar cycle in temperature. Some models have a weaker response than others, and all are somewhat weaker than the observed cycle. The NCAR model has the highest amplitude cycle. An ensemble of 10 runs gives an amplitude of about .10K in surface temperature, but one of the individual runs of the ensemble has an amplitude of .14K, only slightly less than the observations. That says that the high amplitude of the observed cycle could be just a matter of natural variability of the response. Even more important, the spatial pattern of the response is similar between models and observations.

RealClimate.org

Future Works

- We want to run our own GCM at the Research Center for Environmental Changes in Academia Sinica
  - Candidate: GISS-EH
- Hardware specs of the cluster in RCEC:
  - 32 nodes of Core 2 Duo @2GHz
  - 2GB RAM per node
  - MPICH, MPICH2
  - Torque
- 100-year of simulation: ~1 month

What Do We Need

- The urge of computing power
  - The current GCMs are very CPU intensive
  - The GCMs require multiple ensemble runs to make sure the results are trustworthy
  - The scalability of different GCMs vary
- Will grid computing help promoting the usage GCM models?
  - The need of running GCMs among different institutions around the world cannot be under-estimated

References

- IPCC Fourth Assessment Report (AR4)
- Camp, C. D., and K. K. Tung (2007), Surface warming by the solar cycle as revealed by the composite mean difference projection, Geophys. Res. Lett., 34, L14703, doi:10.1029/2007GL030207

Questions?

Contacts

- Ka-Kit Tung
  - Department of Applied Mathematics, University of Washington
  - Email: tung@amath.washington.edu
  - Webpage: http://www.amath.washington.edu/people/faculty/tung/
- Albert Yau
  - Department of Physics, The Chinese University of Hong Kong
  - Email: mwy@gps.caltech.edu / cnam@cuhk.edu.hk
  - Webpage: http:/www.gps.caltech.edu/~mwy/
- Danie Liang (梁茂昌)
  - Research Center for Environmental Changes, Academia Sinica
  - Email: mcl@rcec.sinica.edu.tw
  - Webpage: http://www.rcec.sinica.edu.tw/~mcl/
- Yuk L. Yung
  - Division of Geological and Planetary Sciences, California Institute of Technology
  - Email: yly@gps.caltech.edu