



Anthropogenic influences on hurricane intensity: Implications from AOGCM simulations

[Causes of Warming in the Hurricane-Spawning Regions]

**Tom Wigley
NCAR, Boulder, CO, USA**

and

**Ben Santer,
PCMDI, LLNL, Livermore, CA, USA**

**Presented at the AMS Environmental Science Seminar on “Is
Global Warming Impacting, or Expected to Impact, Hurricanes”.
October 20, 2006**

With assistance from Peter Gleckler, Celine Bonfils, Mike Wehner, Krishna AchutaRao, Tim Barnett, Jim Boyle, Wolfgang Brüggemann, Mike Fiorino, Nathan Gillett, Jim Hansen, Phil Jones, Steve Klein, Jerry Meehl, Sarah Raper, Dick Reynolds, Karl Taylor and Warren Washington






Introduction

This work was prompted partly by statements made after hurricane Katrina by senior officials in NOAA that the observed trend in the intensity of Atlantic hurricanes was unrelated to anthropogenic forcing of the climate system.

We take it as proven (following, e.g., the work of Tom Knutson, Kerry Emanuel, Peter Webster and others) that the intensity of tropical storms in the Atlantic and North Pacific is significantly correlated with SSTs in specified cyclogenesis regions.

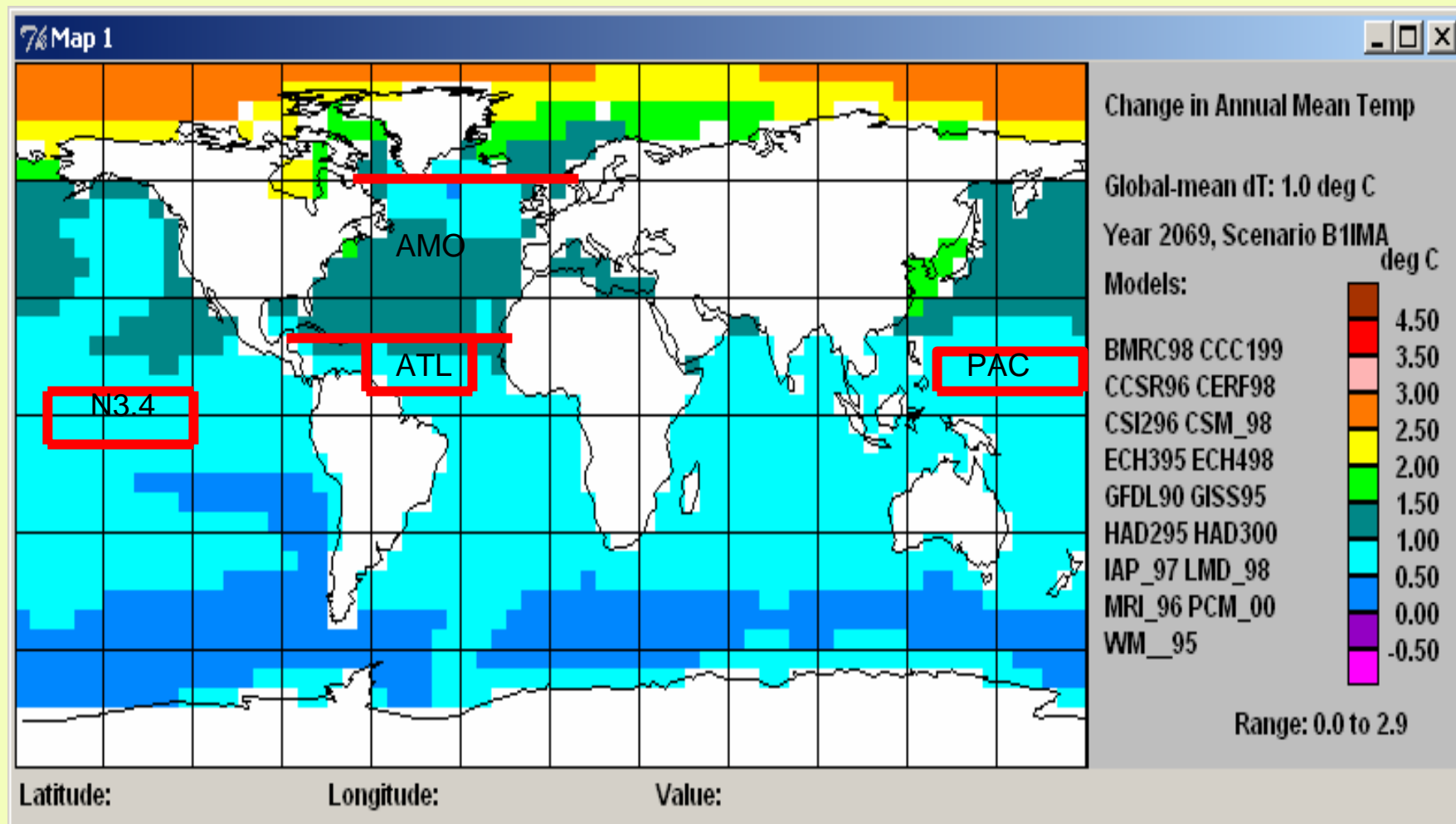
So the issue is whether or not there is an identifiable human influence on SSTs in these cyclogenesis regions.

This work has been published in: Santer, B.D., Wigley, T.M.L., Gleckler, P.J., Bonfils, C., Wehner, M.F., AchutaRao, K.M., Barnett, T.P., Boyle, J.S., Brüggemann, W., Fiorino, M., Gillett, N., Hansen, J.E., Jones, P.D., Klein, S.A., Meehl, G.A., Raper, S.C.B., Reynolds, R.W., Taylor, K.E. and Washington, W.M., 2006: Forced and unforced ocean temperature changes in the Atlantic and Pacific tropical cyclogenesis regions. *Proceedings of the National Academy of Sciences (PNAS)* **103**, 13905--13910.



Study regions plus normalized annual-mean warming

(i.e., warming per unit global-mean warming)





Background to the present study

1. Theory, observations and modeling provide evidence of a strong relationship between changes in SSTs and hurricane intensity
 2. *Emanuel* (2005) found that secular SST changes in Atlantic and Pacific tropical cyclogenesis regions were highly correlated with a measure of hurricane intensity based on maximum wind speeds
 3. Given the existence of a strong SST/hurricane intensity linkage, what are the causes of past SST changes in areas where hurricanes develop?
-



Some observational results






ENSO effects on SSTs in the Atlantic (ATL) cyclogenesis region

A common belief is that ENSO affects SSTs in this region. To test this we use N3.4 SSTs as an ENSO index.

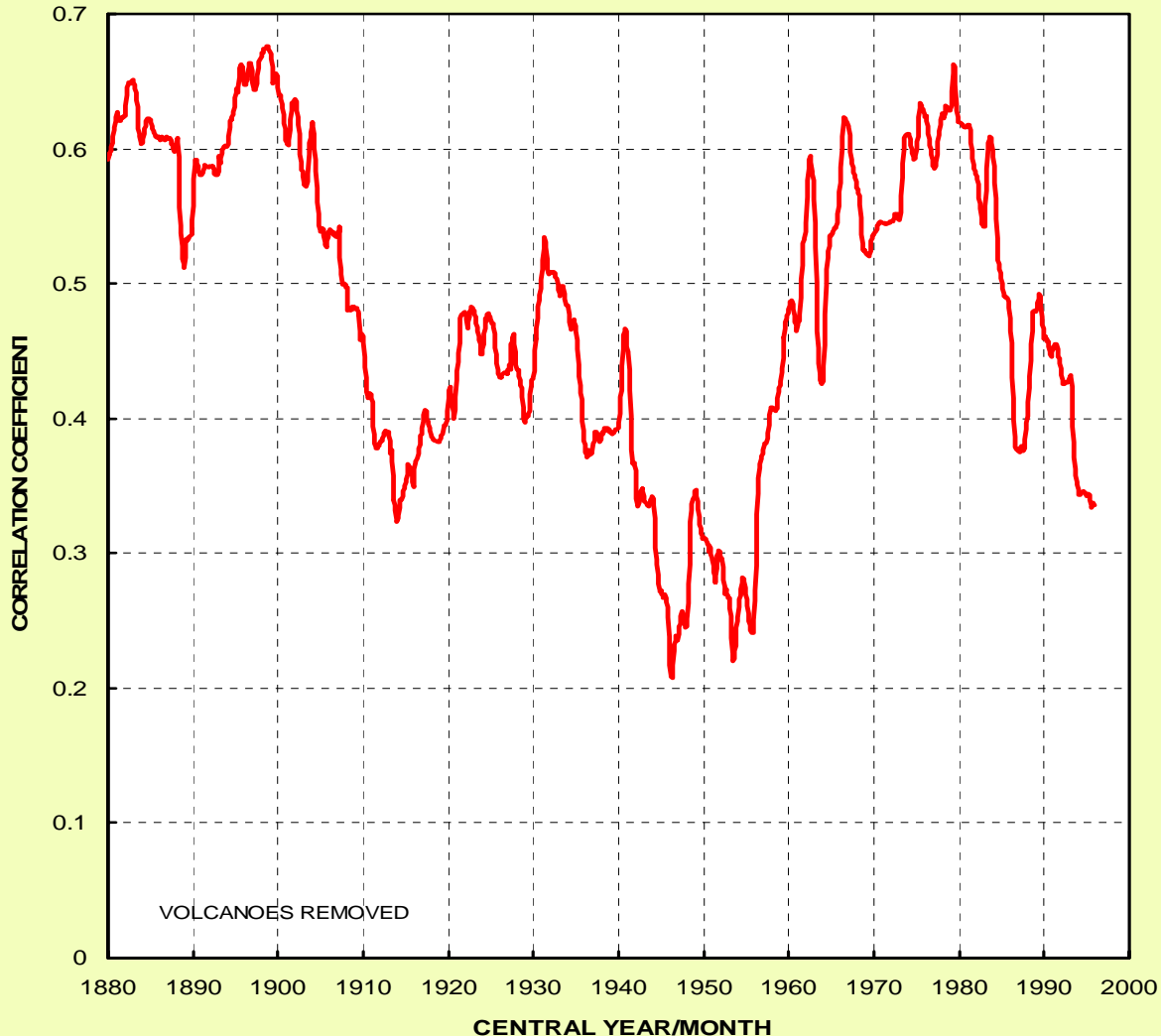
Conventional wisdom is that ENSO suppresses Atlantic hurricane activity.

The problem here is that ENSO/ATL SST correlations are not stable in time.



ATL: Optimum lagged correlations with N3.4 SSTs

RUNNING 241-MO CORRELS: N3.4 vs ATLANTIC CYCLOGENESIS REGION



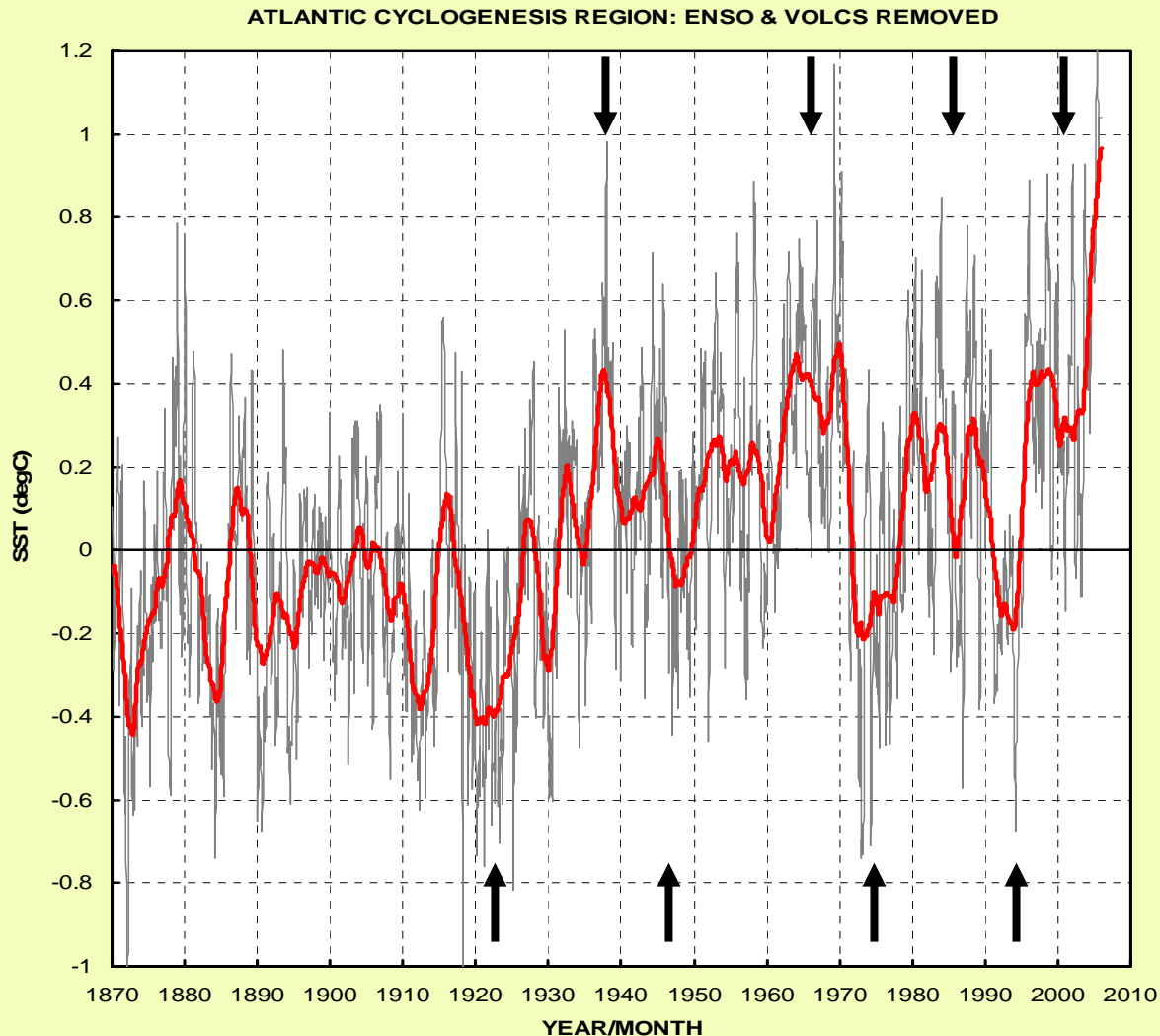
NOTE: The relationship between ENSO and ATL SSTs is clearly complex.

Further, ENSO warmth should lead to stronger hurricanes, at odds with "conventional wisdom".

This may be because of the influence of other factors, like changes in wind shear, which may offset the direct SST effect.

However, the ephemeral nature of the ENSO-SST link suggests that any ENSO-wind shear link may also be non-stationary.

SSTs in ATL after removing ENSO and volcanoes



Bell (NOAA): ... hurricanes ... are merely part of "the 20- to 30-year cycles that we've seen since 1950"

The possibility of such a cycle can be seen by the arrows.


This quasi-cyclic variability is referred to as the Tropical Multidecadal Mode (TMM).

There is a clear overall warming trend, but quantifying the relative importance of the trend and the TMM presents a challenge.



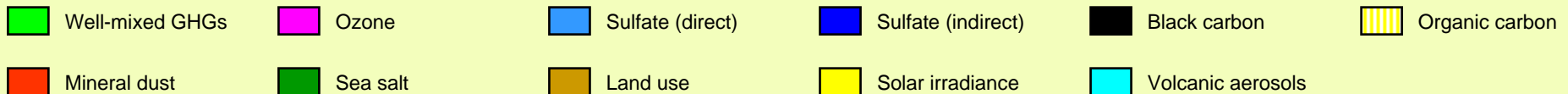
What do models (AOGCMs) tell us?

We use the results from simulations of 20th century climate carried out by a large number of modeling groups as input into the IPCC 4th Assessment (AR4).

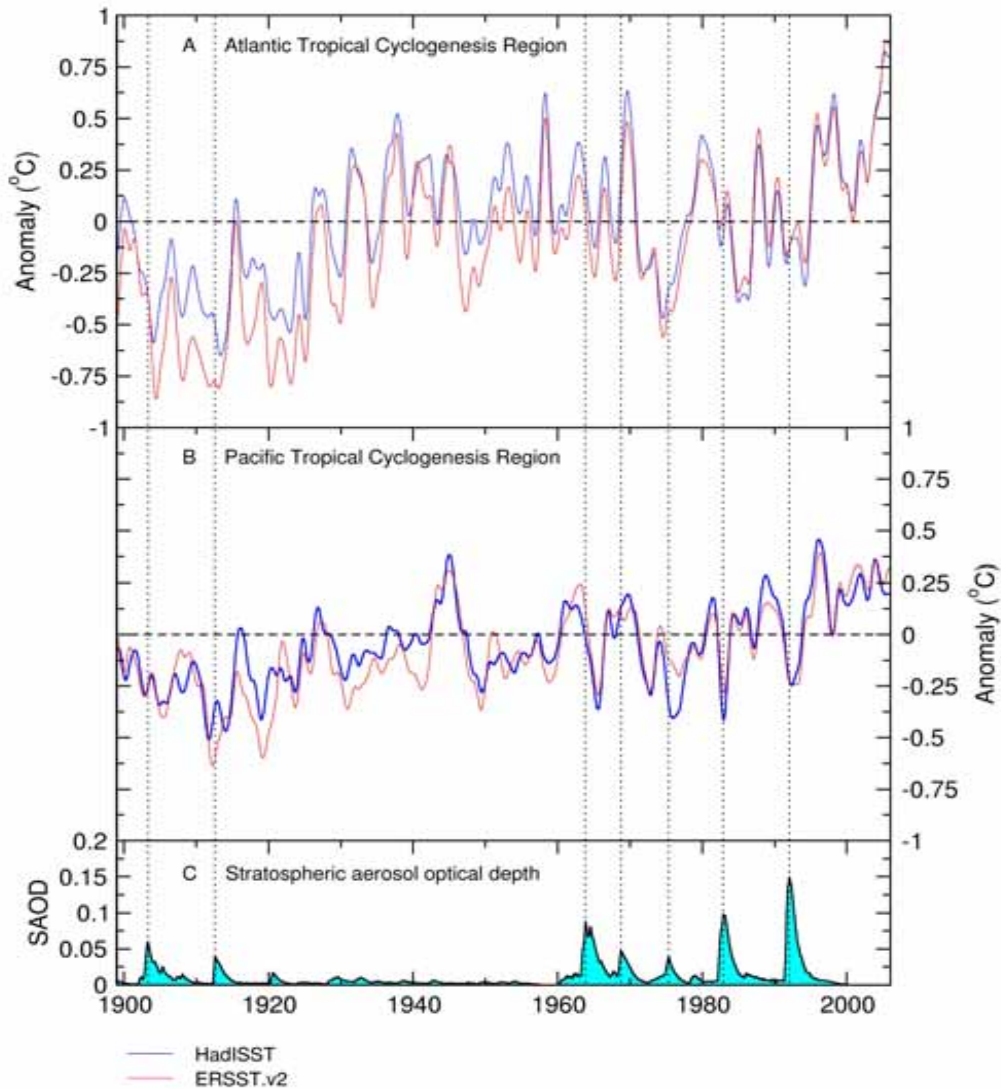


Forcings used in IPCC AR4 “20th century” simulations

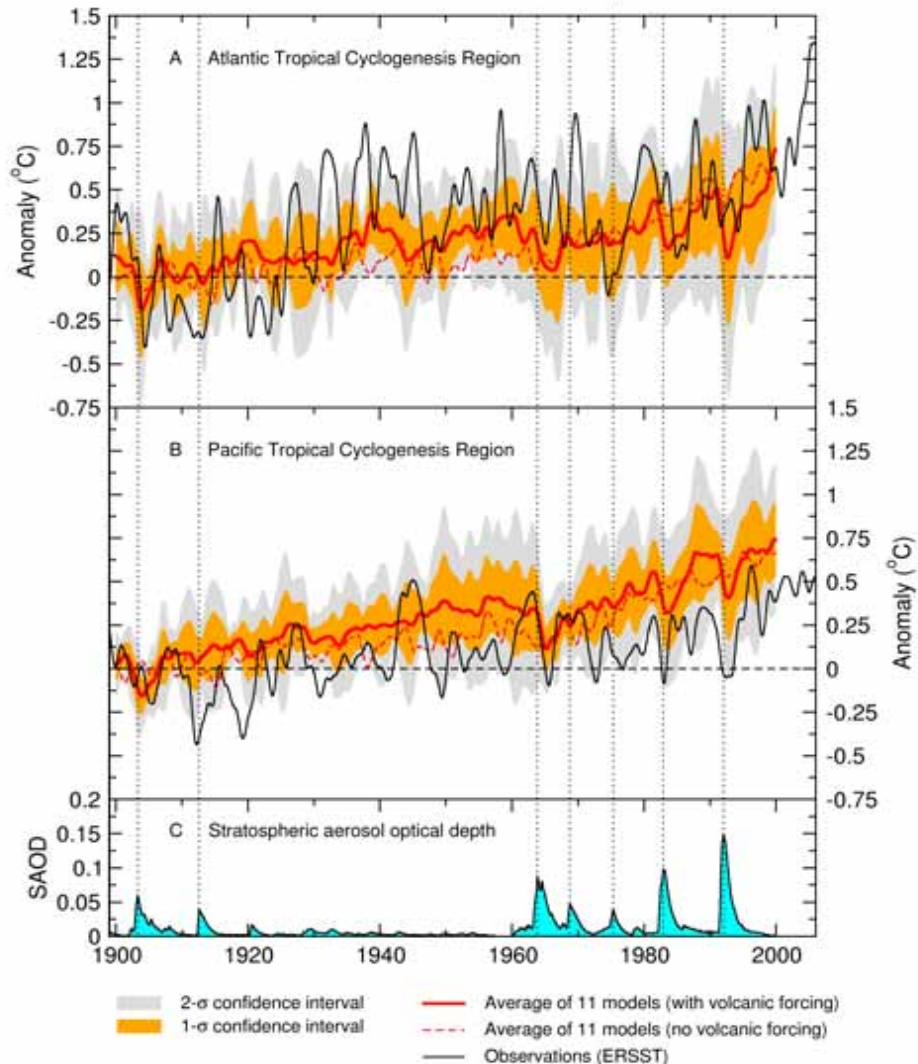
	Model	G	O	SD	SI	BC	OC	MD	SS	LU	SO	V
1	CCCma-CGCM3.1(T47)	Well-mixed GHGs		Sulfate (direct)								
2	CCSM3	Well-mixed GHGs	Ozone	Sulfate (direct)		Black carbon	Organic carbon				Solar irradiance	Volcanic aerosols
3	CNRM-CM3	Well-mixed GHGs	Ozone	Sulfate (direct)		Black carbon						
4	CSIRO-Mk3.0	Well-mixed GHGs		Sulfate (direct)								
5	ECHAM5/MPI-OM	Well-mixed GHGs	Ozone	Sulfate (direct)	Sulfate (indirect)							
6	FGOALS-g1.0	Well-mixed GHGs		Sulfate (direct)								
7	GFDL-CM2.0	Well-mixed GHGs	Ozone	Sulfate (direct)		Black carbon	Organic carbon			Land use	Solar irradiance	Volcanic aerosols
8	GFDL-CM2.1	Well-mixed GHGs	Ozone	Sulfate (direct)		Black carbon	Organic carbon			Land use	Solar irradiance	Volcanic aerosols
9	GISS-AOM	Well-mixed GHGs		Sulfate (direct)				Mineral dust	Sea salt			
10	GISS-EH	Well-mixed GHGs	Ozone	Sulfate (direct)	Sulfate (indirect)	Black carbon	Organic carbon	Mineral dust	Sea salt	Land use	Solar irradiance	Volcanic aerosols
11	GISS-ER	Well-mixed GHGs	Ozone	Sulfate (direct)	Sulfate (indirect)	Black carbon	Organic carbon	Mineral dust	Sea salt	Land use	Solar irradiance	Volcanic aerosols
12	INM-CM3.0	Well-mixed GHGs		Sulfate (direct)							Solar irradiance	
13	IPSL-CM4	Well-mixed GHGs		Sulfate (direct)	Sulfate (indirect)							
14	MIROC3.2(medres)	Well-mixed GHGs	Ozone	Sulfate (direct)		Black carbon	Organic carbon	Mineral dust	Sea salt	Land use	Solar irradiance	Volcanic aerosols
15	MIROC3.2(hires)	Well-mixed GHGs	Ozone	Sulfate (direct)		Black carbon	Organic carbon	Mineral dust	Sea salt	Land use	Solar irradiance	Volcanic aerosols
16	MRI-CGCM2.3.2	Well-mixed GHGs		Sulfate (direct)							Solar irradiance	
17	PCM	Well-mixed GHGs	Ozone	Sulfate (direct)							Solar irradiance	Volcanic aerosols
18	UKMO-HadCM3	Well-mixed GHGs	Ozone	Sulfate (direct)	Sulfate (indirect)							
19	UKMO-HadGEM1	Well-mixed GHGs	Ozone	Sulfate (direct)	Sulfate (indirect)	Black carbon	Organic carbon			Land use	Solar irradiance	Volcanic aerosols



Observed SST changes in cyclogenesis regions



Observed (ERSST v.2) and modeled SST variations




NOTE:

The observed variability is much larger than the model variability. This is because there is only a single realization of the observations, while the model results are a 22-member ensemble average.




Could the observed and model SST trends be the result of internally generated variability?

In other words, are these trends significantly different from trends expected in the absence of external forcing?

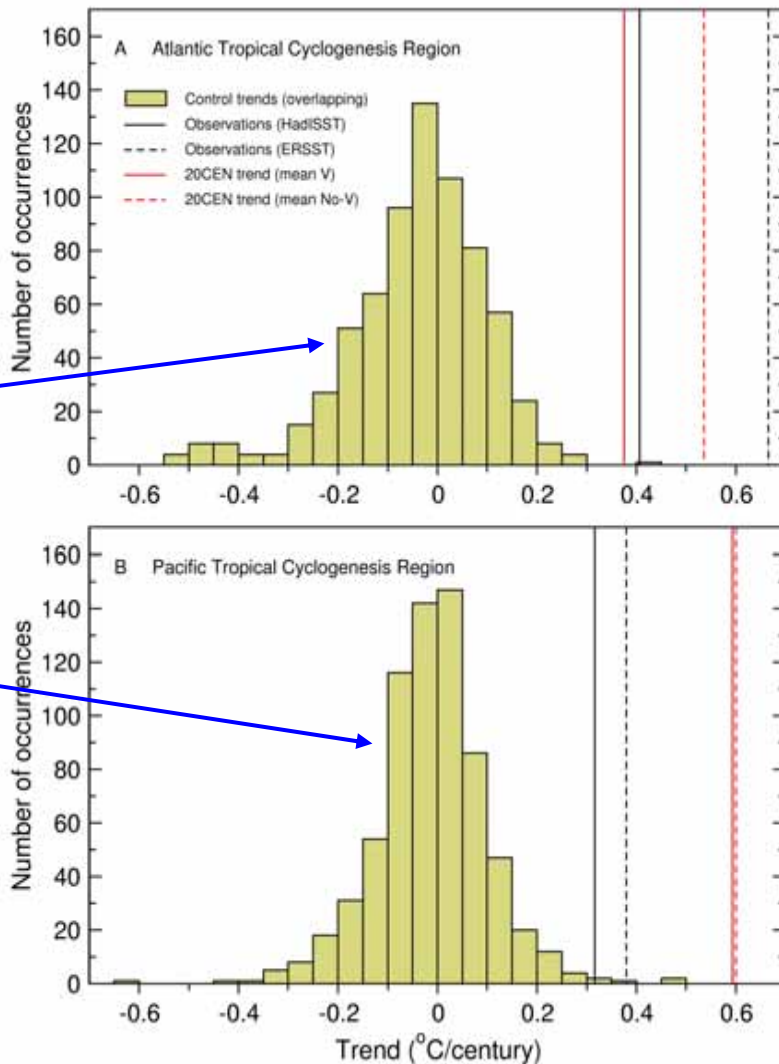




Trend significance testing

1. To characterize trends that are expected in the absence of external forcing, we use AOGCM control runs, of length 100 to 1,000 years, from 22 climate models
 2. For each control run, least-squares linear trends are estimated from successive 100-year segments of ACR and PCR SST time series
 3. Results from all 22 models were then combined to obtain “multi-model” sampling distributions of unforced SST trends
 4. These ‘null’ distributions are then compared with observed and model-simulated SST trends over the 20th century
- 

Unforced vs forced SST variations



Distributions of 100-yr trends in the absence of external forcing.


ATL: Model trend similar to HadISST trend, but smaller than ERSST trend. No overlap between model or observed trend and internally generated trend.

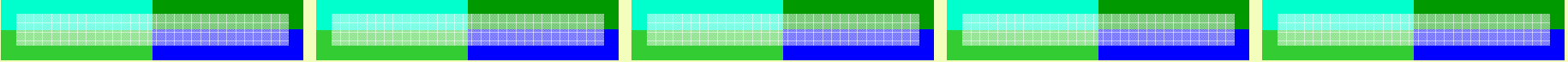
PAC: Model trend considerably larger than HadISST or ERSST trend. No overlap between model trend and internally generated trend. Minimal overlap between observed trend and internally generated trend.



First conclusion

It is extremely unlikely that the 20th century SST trends in ATL or PAC could be due to internally generated variability, provided that the internal variability of the models (as defined by model control runs) is a reasonable estimate of real world internal variability.





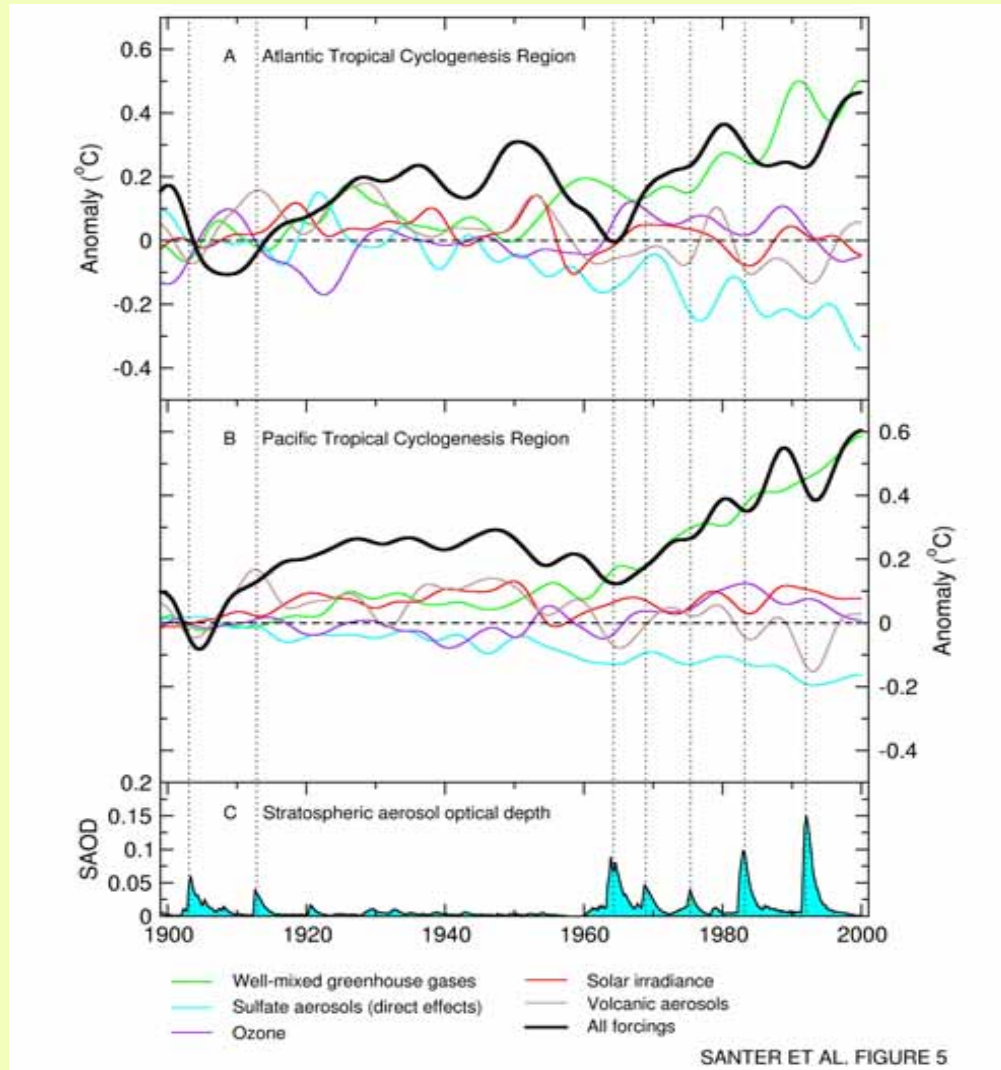
Leading question

If the observed and model trends in SSTs are not due to internal variability alone, what is the primary external forcing factor that has caused these trends?



Breakdown of contributions to SST changes

(based on single forcing experiments using PCM)






Conclusions (1)

Current model estimates of internal climate variability cannot explain 20th century SST increases in either the ACR or PCR

- Conclusion is insensitive to existing uncertainties in model physics and parameterizations
- Insensitive to details of significance testing procedure

Experiments with PCM suggest that forcing by well-mixed greenhouse gases has been the main influence on century-timescale SST increases

There is clear evidence of a volcanic influence on observed SST variability in the ACR and PCR






Conclusions (2)

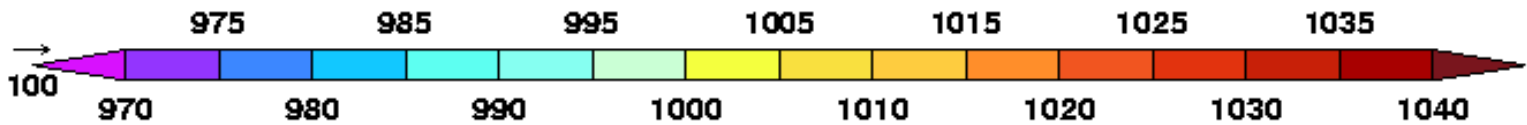
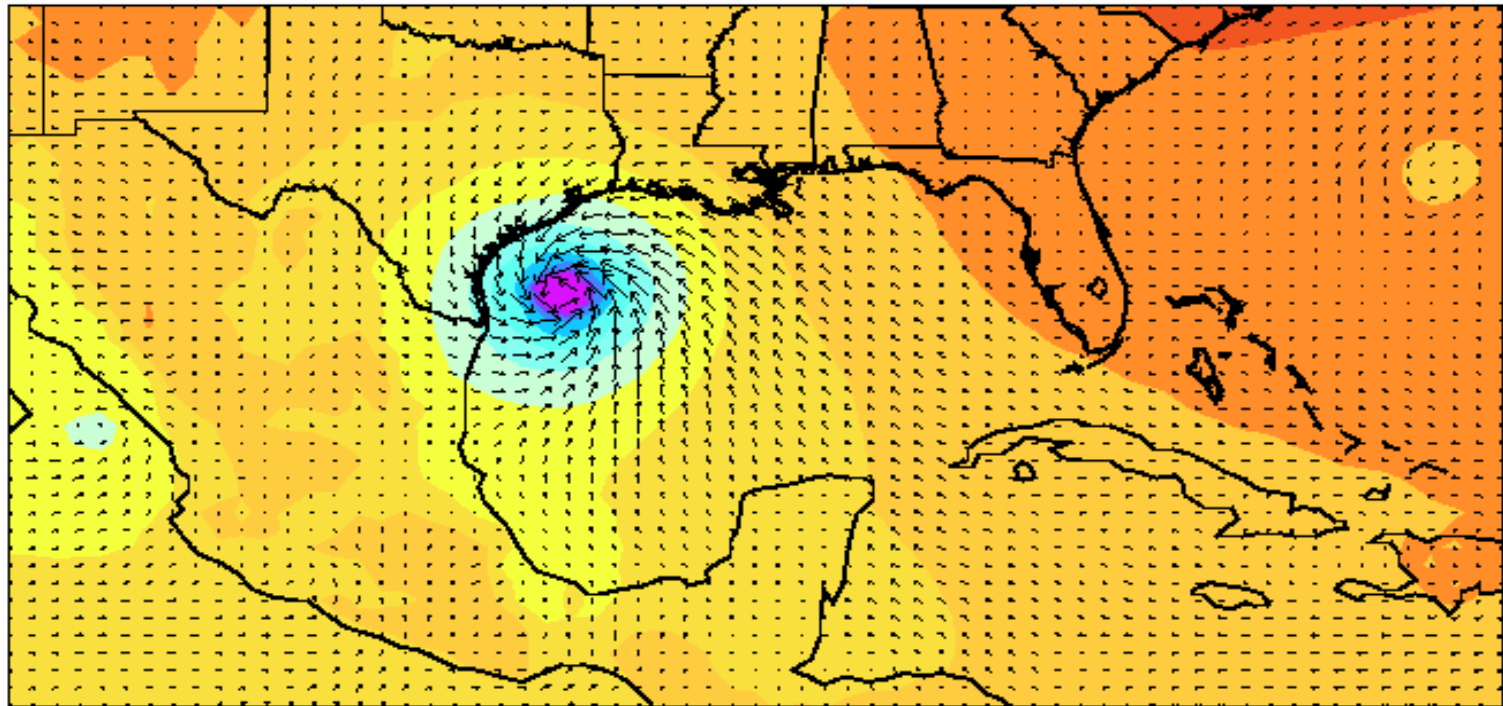
On decadal timescales, most current climate models

- Underestimate SST variability in the ACR
- Overestimate variability in the PCR

Even if variability biases of similar magnitude are applied on century timescales, it is highly unlikely that climate noise alone could fully explain SST trends in either the ACR or PCR



Unforced simulation with a high-resolution (T239; approx 0.5° by 0.75°) climate model



Max. surface wind speed: 134 mph. Min. surface pressure: 946 mb.
LLNL, and Mike Wehner, LBNL

Courtesy Bala Govindasamy.

END