DECONSTRUCTING RECENT GLOBAL-MEAN TEMPERATURE CHANGES

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GOALS

(1) To unravel the primary causes of global-mean temperature changes since 1979

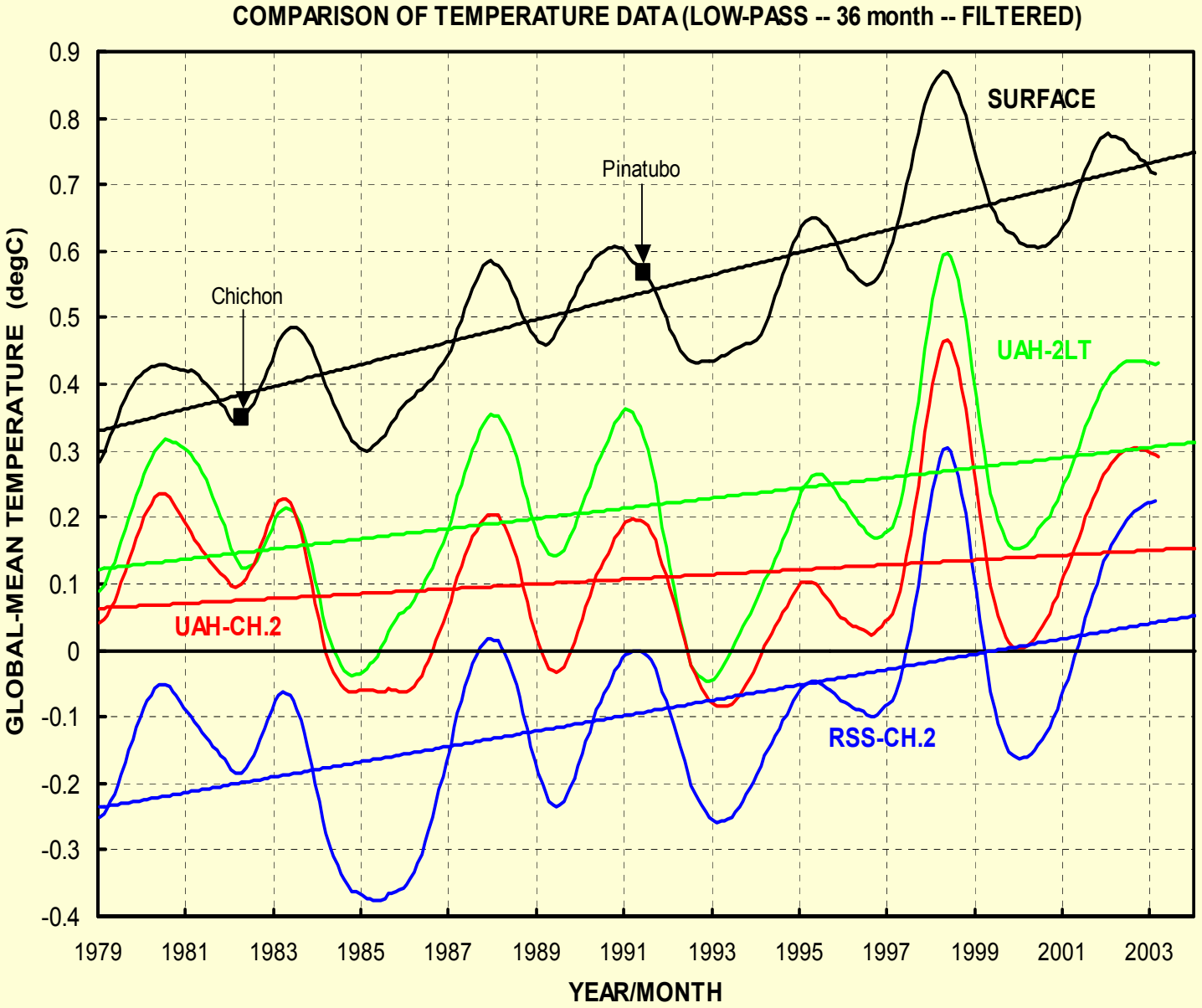
(2) To quantify the uncertainties associated with these causes, and with observational data uncertainties

OBSERVATIONAL DATA

(1) Surface temperature data (CRU, variance corrected)

(2) Microwave Sounding Unit (MSU) data

- MSU Channel 2 (UAH, version 5.1)
- MSU 2LT (UAH, version 5.1)
- RSS MSU Channel 2


COMPARISON OF TEMPERATURE DATA (LOW-PASS -- 36 month -- FILTERED)
GLOBAL-MEAN TEMPERATURE (degC)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
YEAR/MONTH
SURFACE
Pinatubo
Chichon
UAH-2LT
UAH-CH.2
RSS-CH.2

‘CAUSAL’ FACTORS

(1) internal variability [ENSO, NAO, etc.]

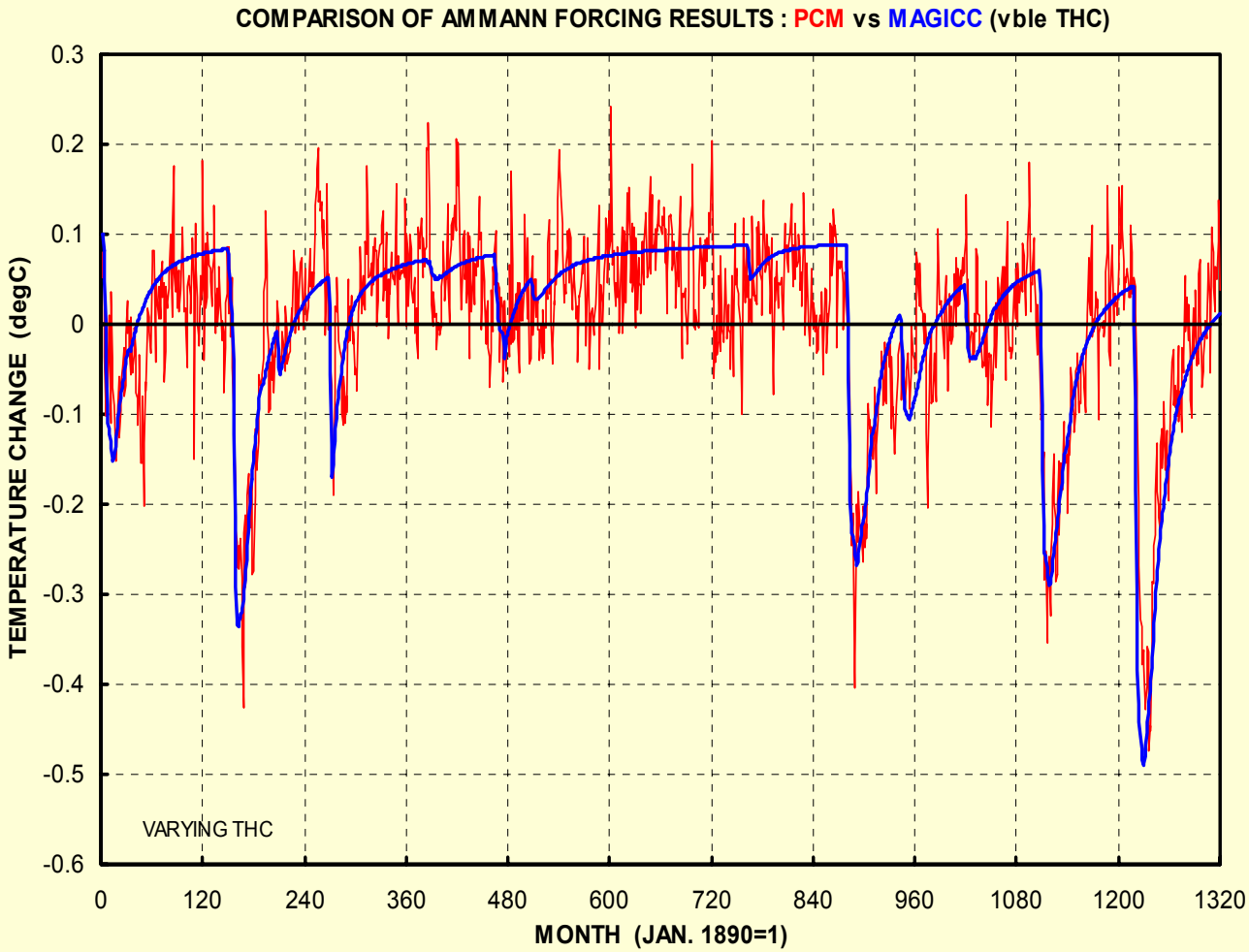
(2) volcanic eruptions

(3) solar irradiance changes

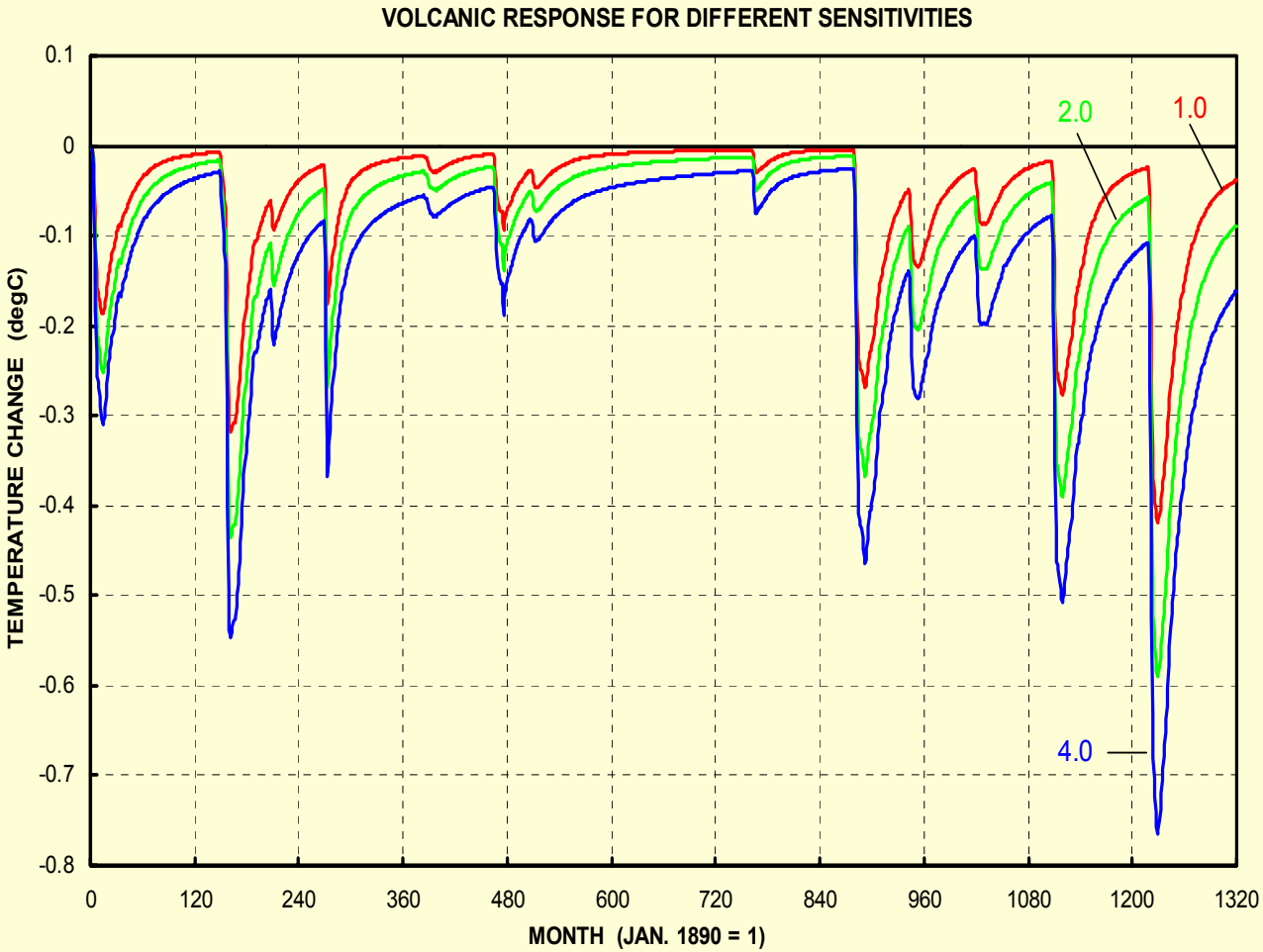
(4) anthropogenic factors

EFFECT OF VOLCANIC ERUPTIONS

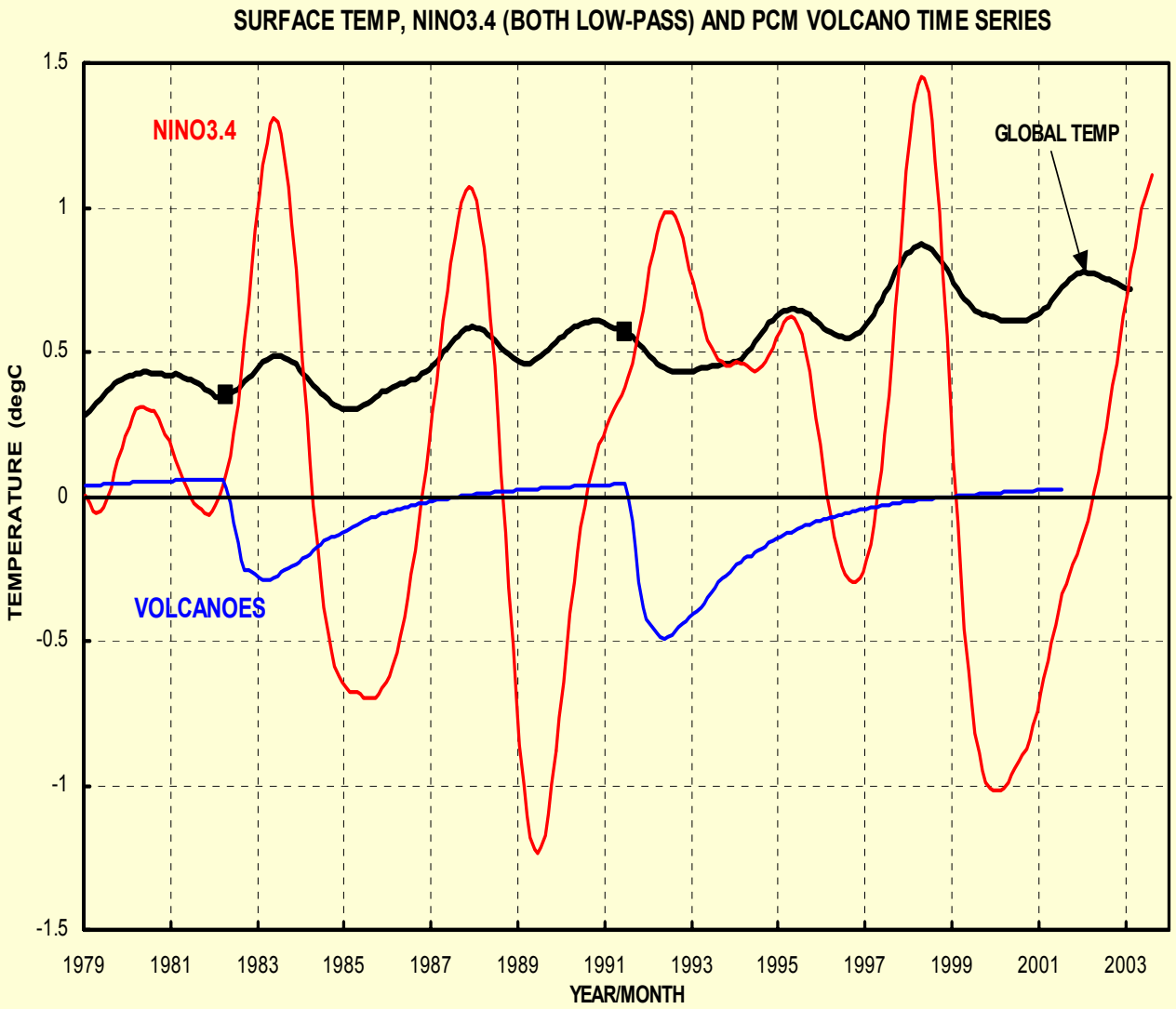
16-member ensemble-mean from PCM [signal plus noise] compared with simulation using the simple UD EBM 'MAGICC' [pure signal].



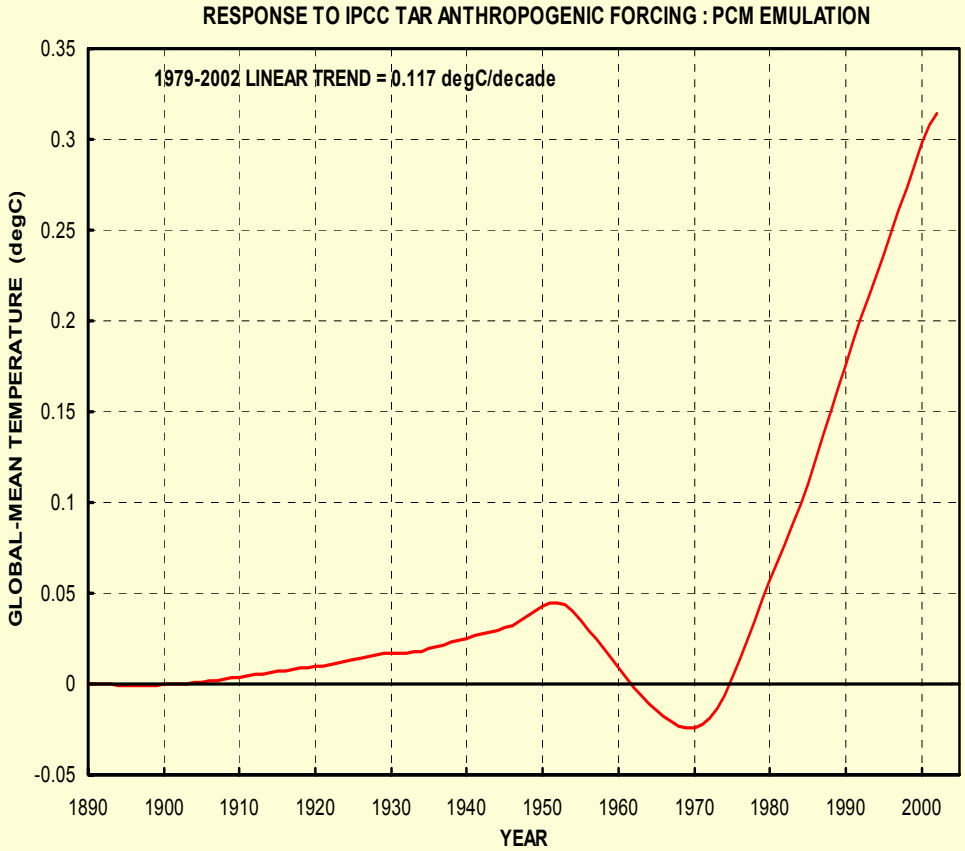
EFFECT OF CLIMATE SENSITIVITY ON THE RESPONSE TO VOLCANIC FORCING



GLOBAL-MEAN TEMPERATURE COMPARED WITH ENSO INDEX (Nino3.4 SSTs, leading by 6 months) AND VOLCANO RESPONSE

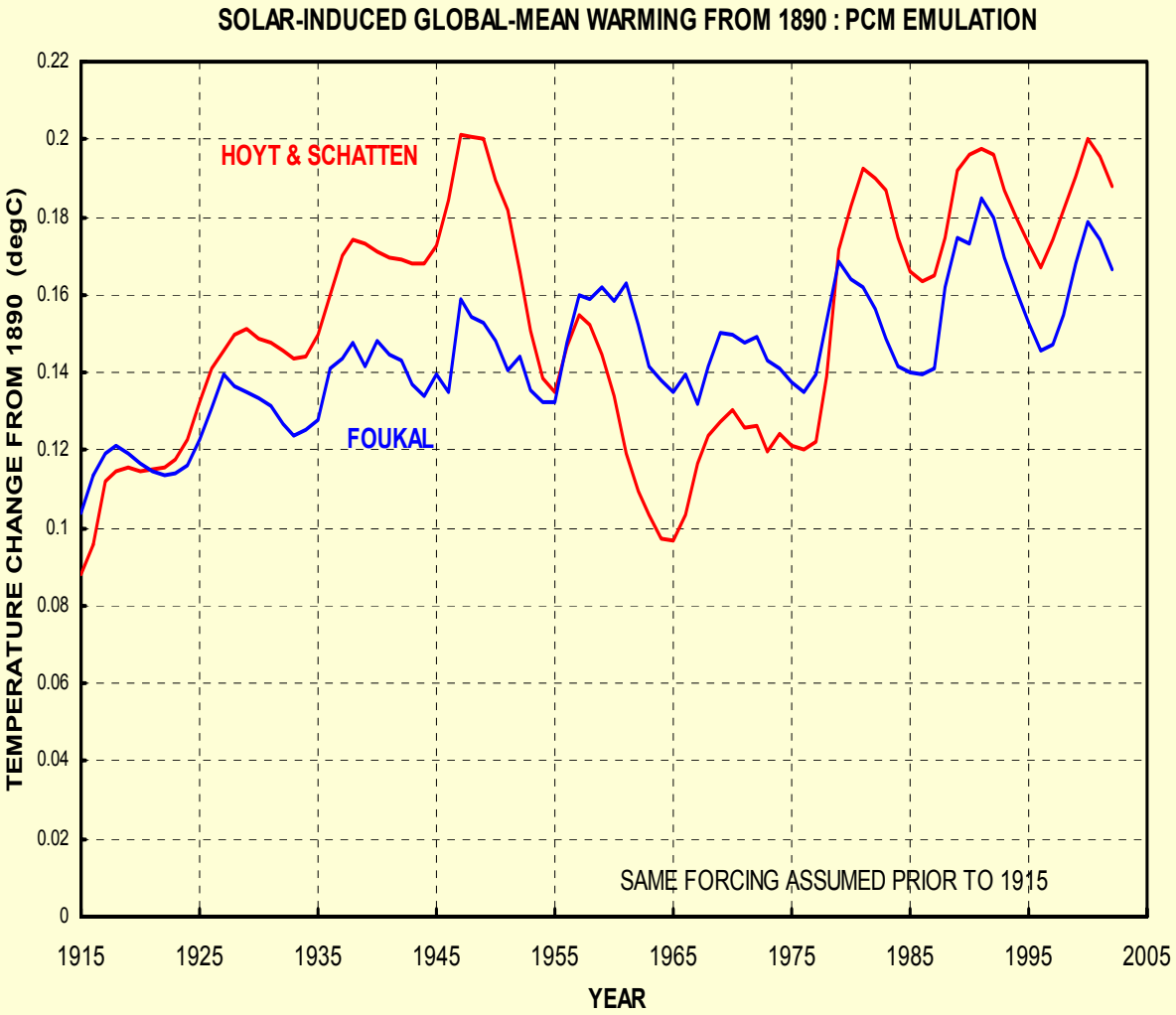


RESPONSE TO ANTHROPOGENIC FORCING
(GHGs & Aerosols)



- NOTE: Linear trend over 1979-2002 is 0.121degC/decade, but this result is specific to the assumed forcing and to the use of PCM. In reality, the specific trend is uncertain.

RESPONSE TO SOLAR FORCING
Comparison for two different forcing reconstructions



STATISTICAL MODEL (1)

$$T(t) = V(t) + a\,E(t - a_1) + b\,A(t) + c\,S(t) + \varepsilon(t)$$

where

T(t) = global-mean temperature

V(t) = response to volcanic forcing
[= $f(\Delta T_{chichon}, \Delta T_{pinatubo}, \tau)$]

E(t) = ENSO index; Nino3.4 SSTs
[a_1 = lag of global-mean temp behind index]

A(t) = response to anthropogenic forcing

S(t) = response to solar forcing
[or d $F(t - a_2)$, where F = solar forcing]

{parameters to fit are in blue}

STATISTICAL MODEL (2)

$T(t) = V(t) + a\,E(t - a_1) + b\,A(t) + c\,S(t) + \varepsilon(t)$

NOTE: This is not a simple regression analysis because

(1) $V(t) = f(\Delta T_{chichon}, \Delta T_{pinatubo}, \tau)$ is nonlinear

(2) $\Delta T_{chichon}$, $\Delta T_{pinatubo}$, τ, a, b, c and a_1 are not independent

(3) the predictors are collinear

(4) the predictors are strongly autocorrelated

(5) the predictors may be physically related (e.g. E(t) may be influenced by V(t)), so that interaction terms may be needed

FITTING THE MODEL : (1) BRUTE FORCE

$T(t) = V(t) + a\ E(t - a_1) + b\ A(t) + c\ S(t) + \varepsilon(t) = T_{est}(t) + \varepsilon(t)$

- Calculate $T_{est}(t)$ for many values of the parameters and minimize some function (such as $\Sigma(T_{est} - T)^2$) that characterizes the goodness of fit.

- Problem 1: How to define goodness of fit?

- Problem 2: The optimization surface is quite flat over a wide range of parameter values, so there are many suboptimal solutions that provide good fits. Subjective judgment is needed to choose between these.

- Problem 3: Optimization is sensitive to data uncertainties and to the data period used.

FITTING THE MODEL : (2) ITERATIVE METHOD

$T(t) = V(t) + a\,E(t - a_1) + b\,A(t) + c\,S(t) + \varepsilon(t) = T_{est}(t) + \varepsilon(t)$

- Chose a first-order V(t) based on model results and inspection of the raw data.

- Regress T(t) – V(t) against $E(t - a_1)$ to optimize coefficient 'a' and lag 'a_1'.

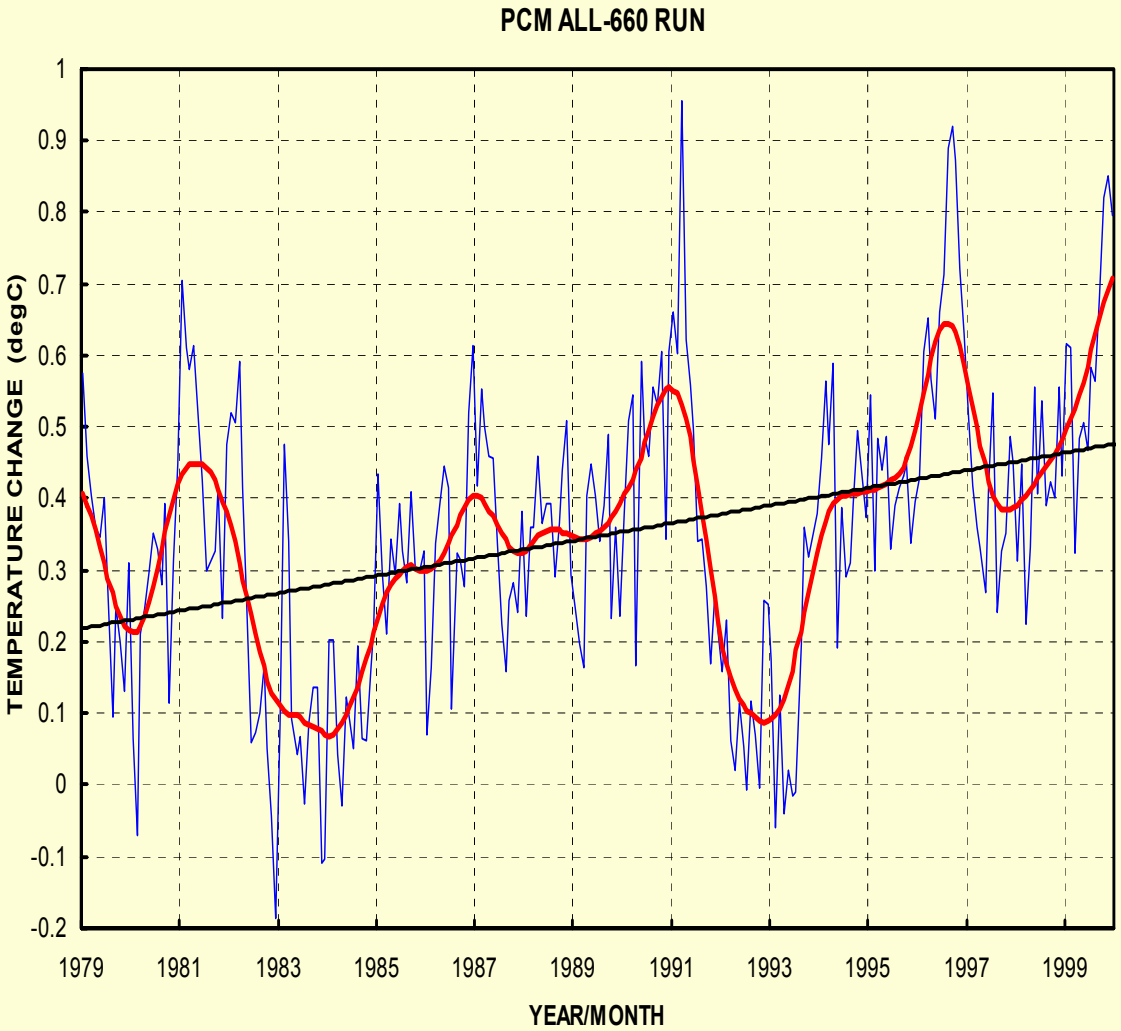
- Examine $T(t) - a\,E(t - a_1)$ to select a second-order V(t).

- Iterate above steps to optimize fit for V(t) and $E(t - a_1)$.

- Calculate linear trend in $T(t) - V(t) - a\,E(t - a_1)$ to define the anthropogenic component ($b\,A(t)$).

- Inspect $R(t) = T(t) - V(t) - a\,E(t - a_1) - b\,A(t)$ for evidence of a residual solar signal (i.e., does R(t) correlate with the model estimated S(t)?)

TEST CASE : Results from PCM simulation with all forcings included



TEST CASE : Results from PCM simulation with all forcings included

- In this case, we know the volcanic, anthropogenic and solar signals with high accuracy

- Hence, in the first step (fitting volcanoes and ENSO) we know V(t) so there are no choices in determining the ENSO parameters ‘a’ and ‘a1’

- X(t) = T(t) – V(t) – a E(t – a1), from which the residual trend is calculated, is therefore well-defined

- The trend in X(t) = 0.131 +/- 0.028^{o}C/decade

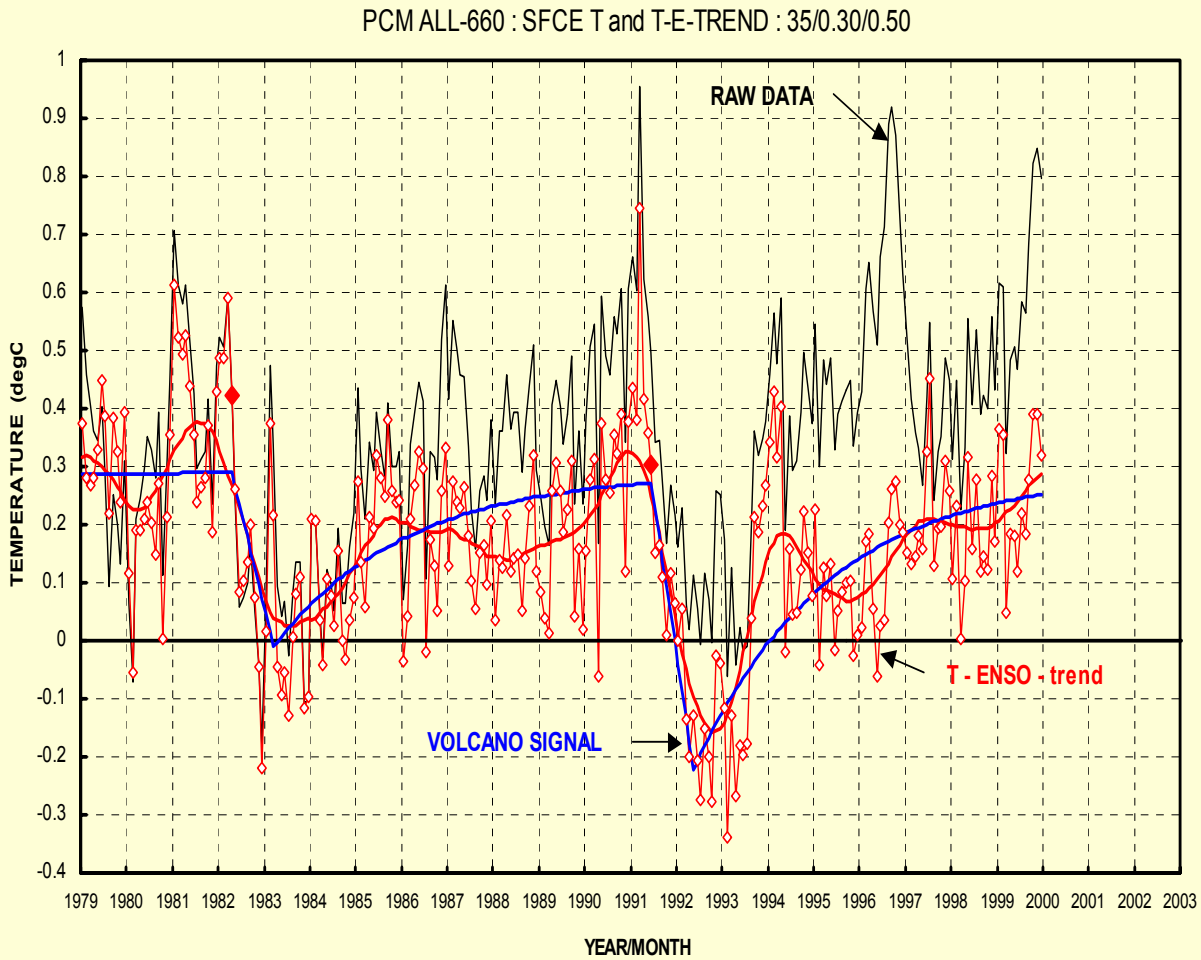
- The *a priori* anthropogenic trend is 0.121^{o}C/decade

PCM TEST CASE : Searching for the solar signal (1)

KEY : Black = raw temperatures [T(t)]

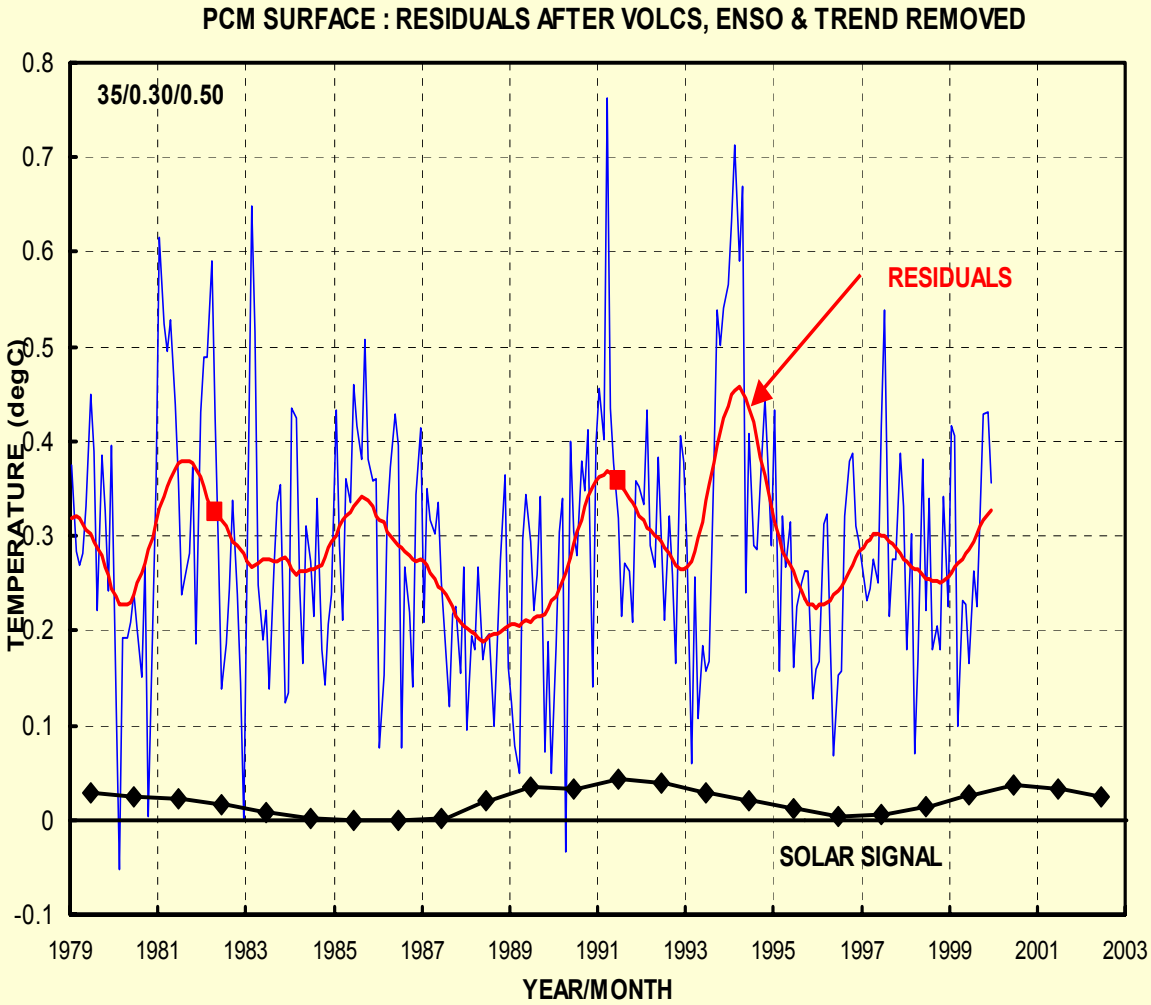
Blue = volcanic response [V(t)]

Red = T(t) – a E(t – a_1) – linear trend = V(t) + c S(t) {R – B = a S(t)}



PCM TEST CASE : Searching for the solar signal (2)

[T(t) – a E(t – a1) – trend – V(t) should correlate with S(t)]

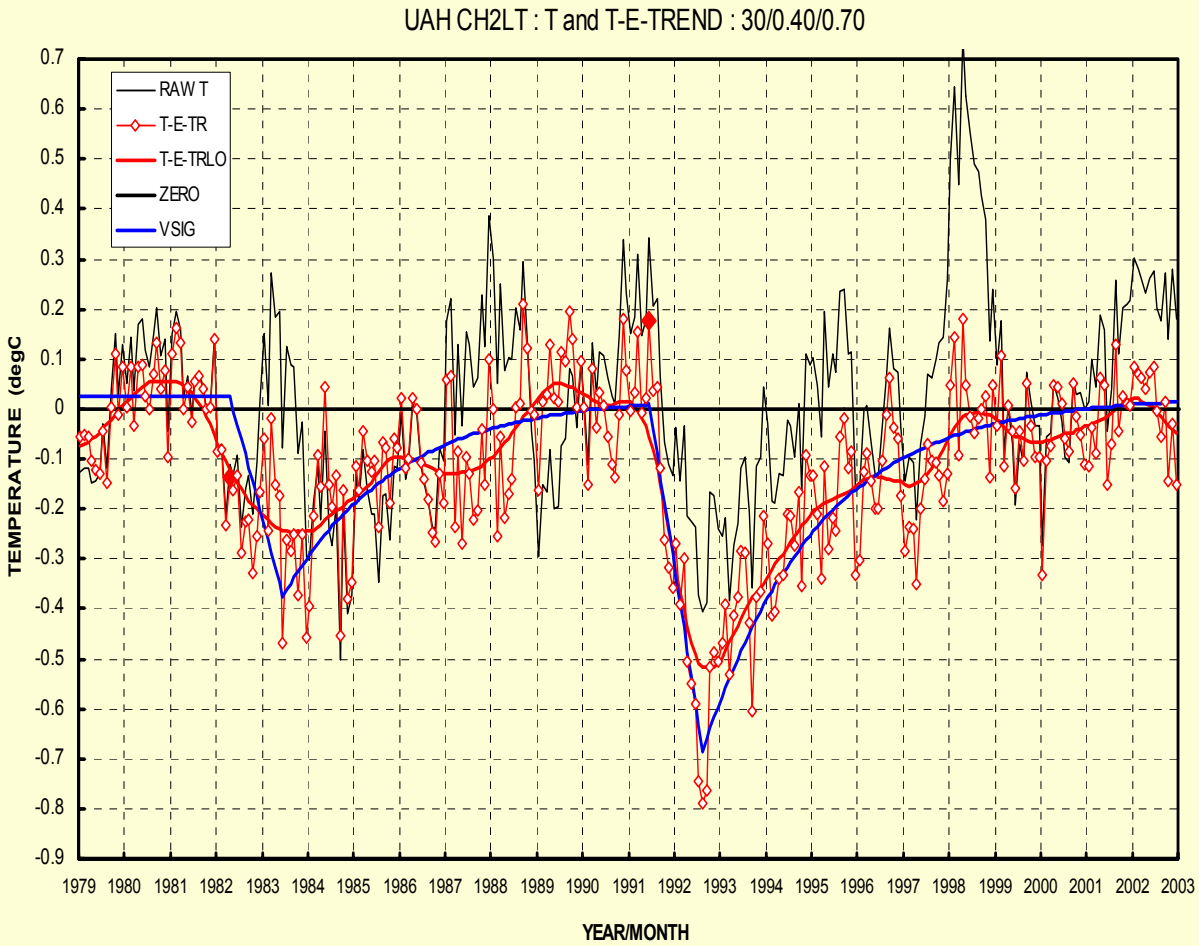


ANALYSIS OF OBSERVED DATA (UAH 2LT)

KEY : black = raw temperatures [T(t)]

blue = V(t)

red = T(t) – a E(t – a1) – trend = V(t) – c S(t)

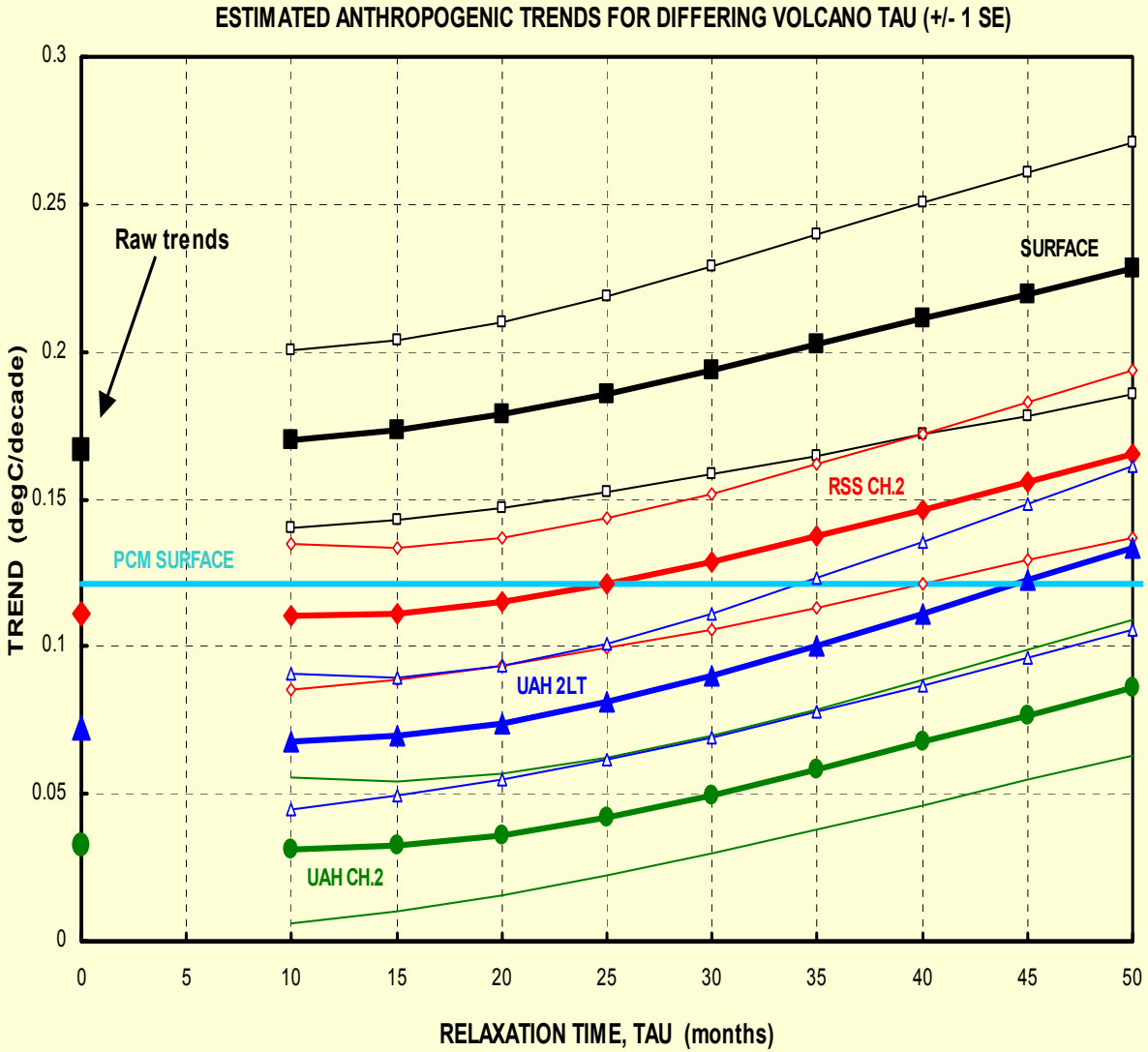


SUMMARY OF BEST-FIT RESULTS

	ΔTchich (⁰C)	ΔTpinat (⁰C)	τ (mon)	ENSO reg. coeff [correl.]	Lag (mon)	Trend [S.E.] (⁰C/decade)
PCM (sfce)	0.30	0.50	35	0.266 [0.532]	1	0.131 [0.028]
Surface	0.20(?)	0.54	17	0.103 [0.467]	6	0.175 [0.028]
UAH 2LT	0.40	0.70	27	0.171 [0.754]	6	0.085 [0.017]
UAH Ch.2	0.35	0.60	45	0.182 [0.773]	6	0.077 [0.018]
RSS Ch.2	0.35	0.60	33	0.187 [0.737]	6	0.134 [0.020]

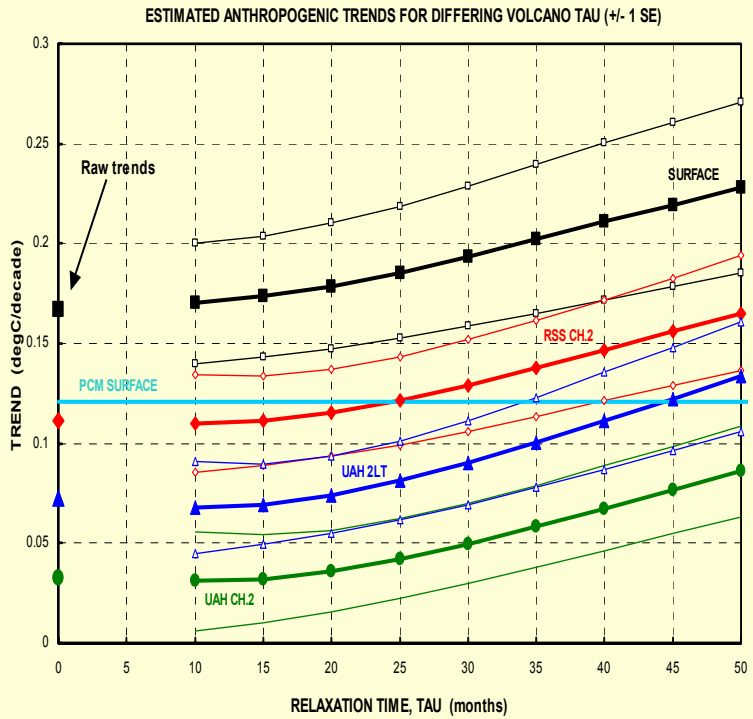
SUMMARY OF RESIDUAL TREND RESULTS

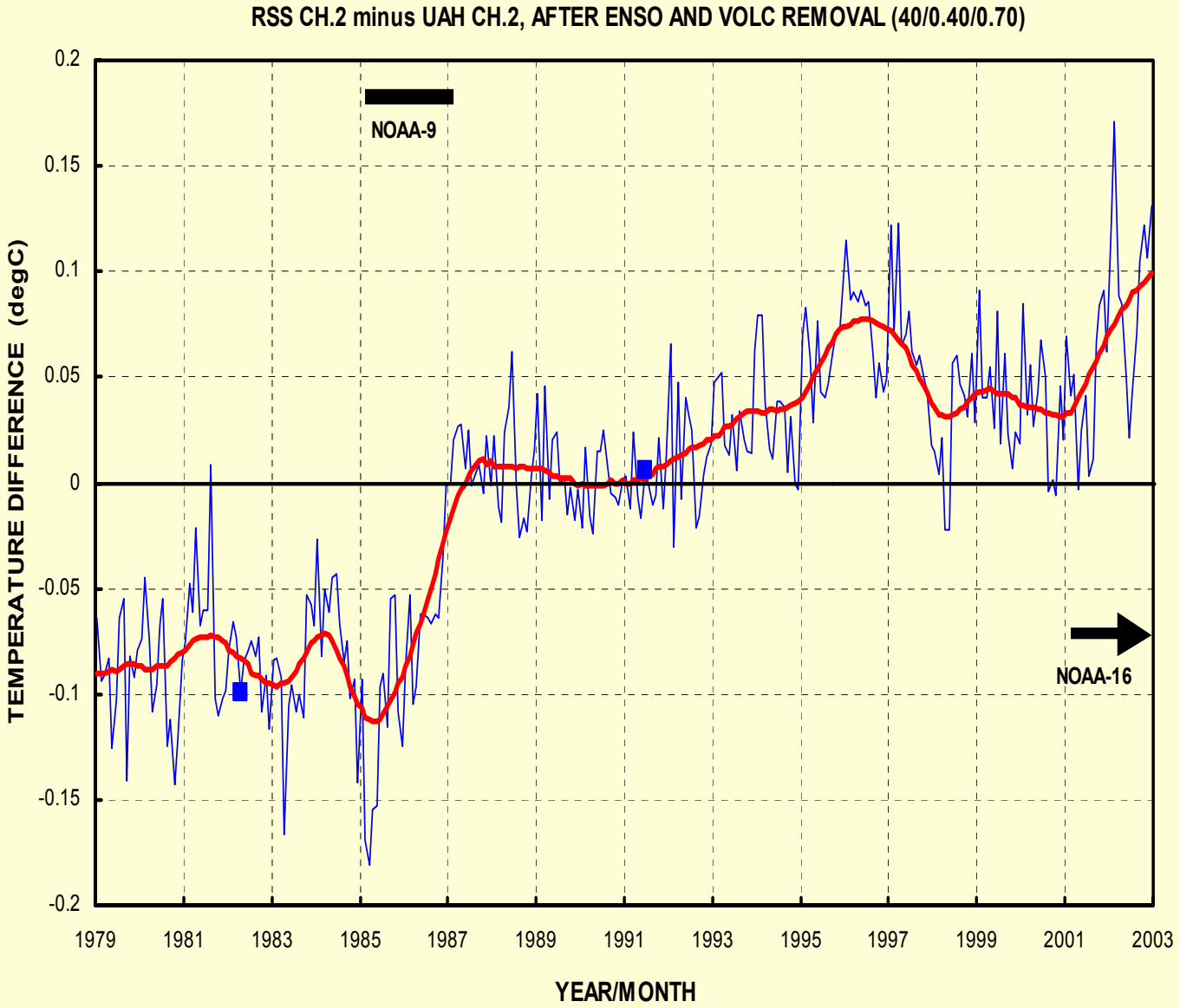
(i.e., estimated anthropogenic signal)



CONCLUSIONS

- • Main source of uncertainty is the relaxation time for volcanic response
- • Even though different data sets have different ENSO and volcano responses, accounting for these does not resolve the raw data trend differences
- • Observed surface warming rate is greater than in PCM (forcing and/or climate sensitivity in PCM too low?)
- • Surface and RSS Ch. 2 results are consistent
- • Surface and UAH Ch. 2 results are not consistent.




RSS CH.2 minus UAH CH.2, AFTER ENSO AND VOLC REMOVAL (40/0.40/0.70)
TEMPERATURE DIFFERENCE (degC)
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
NOAA-9
NOAA-16
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
YEAR/MONTH

Values of target multipliers