Global and Greenland Climate: Past, Present and Future

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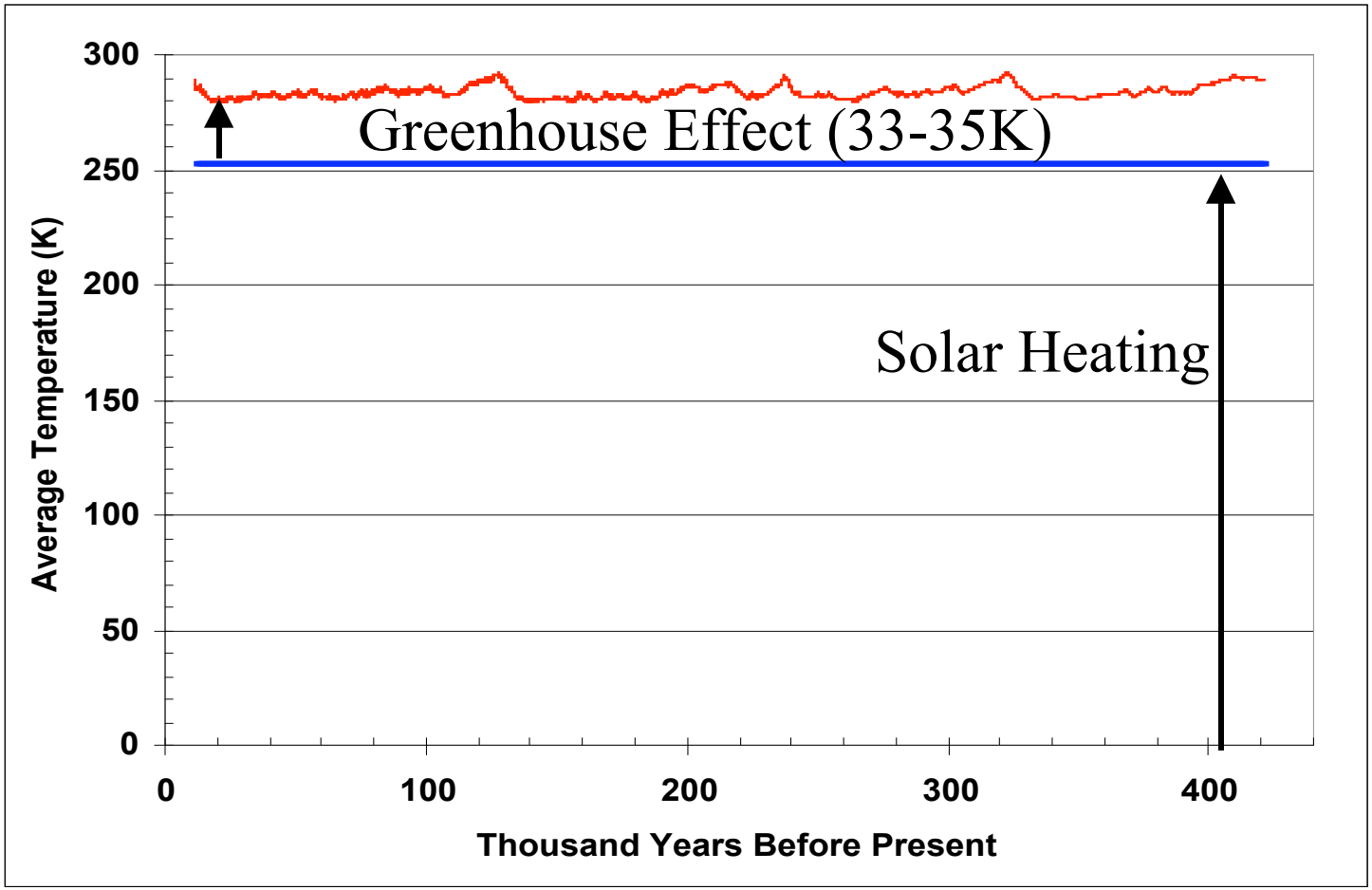
Climate Change: The Scientific Debate is Over

420,000 years record from Vostok ice core



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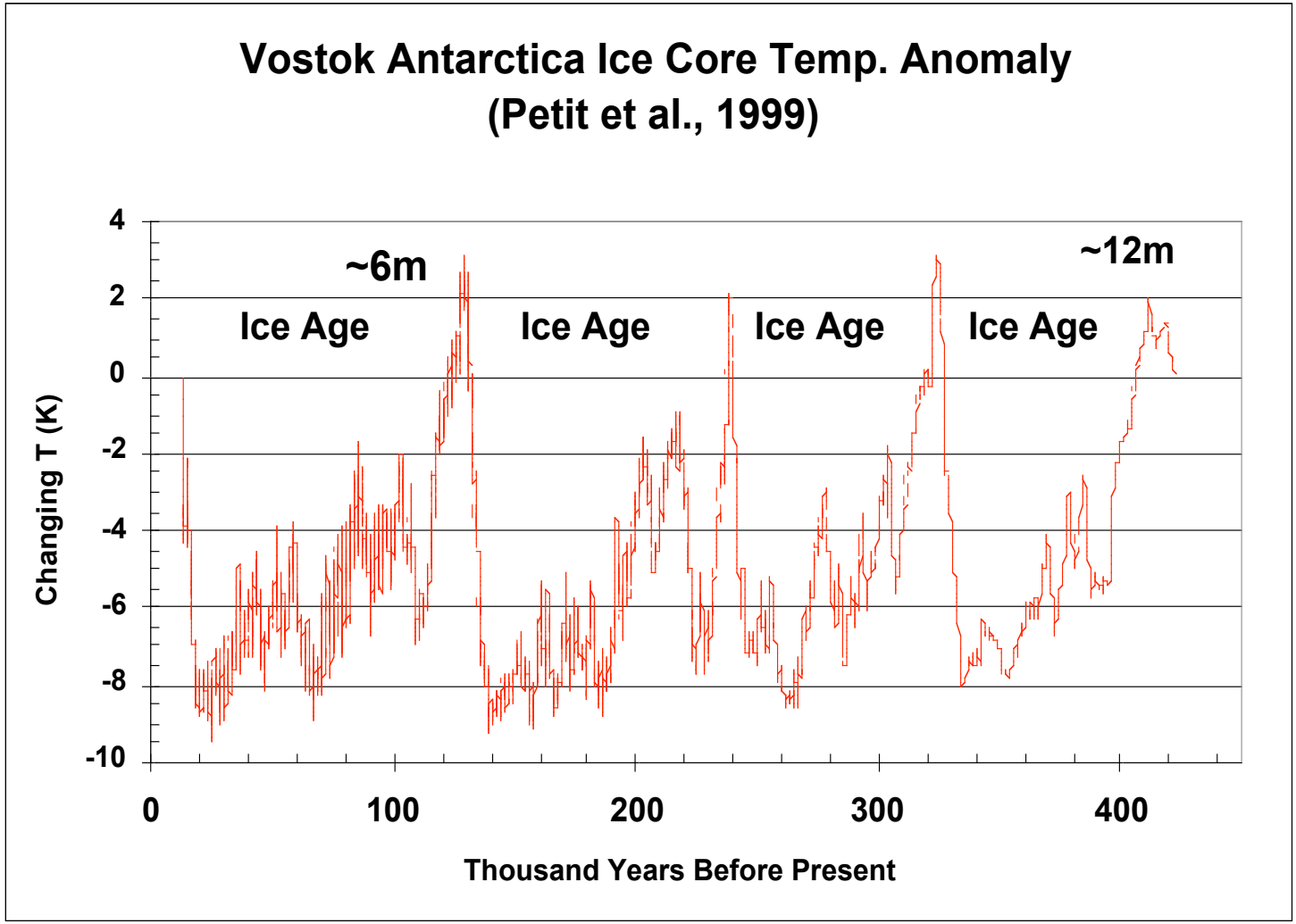
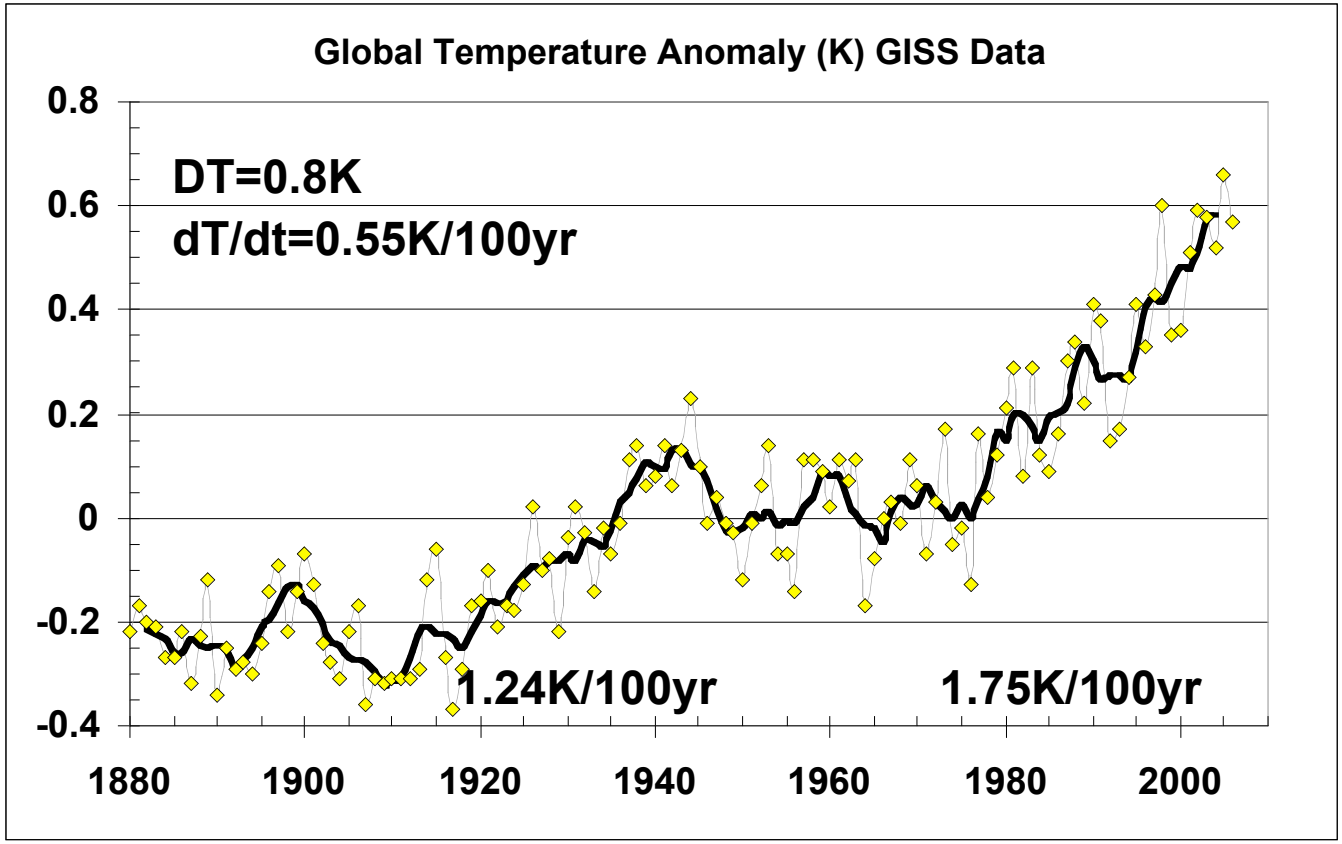


Global Average of Temperature Anomaly



Causes of Climate Change

- Human or anthropogenic forcing (W/m^2)- greenhouse gases, aerosols, agriculture, land surface uses, …..
- Natural external forcing – solar radiation, cosmic radiation, earth orbital parameters,..
- Natural climate variability- changes in atmospheric and ocean circulation without external forcing,…..

IPCC 2007 Summary for Policymakers

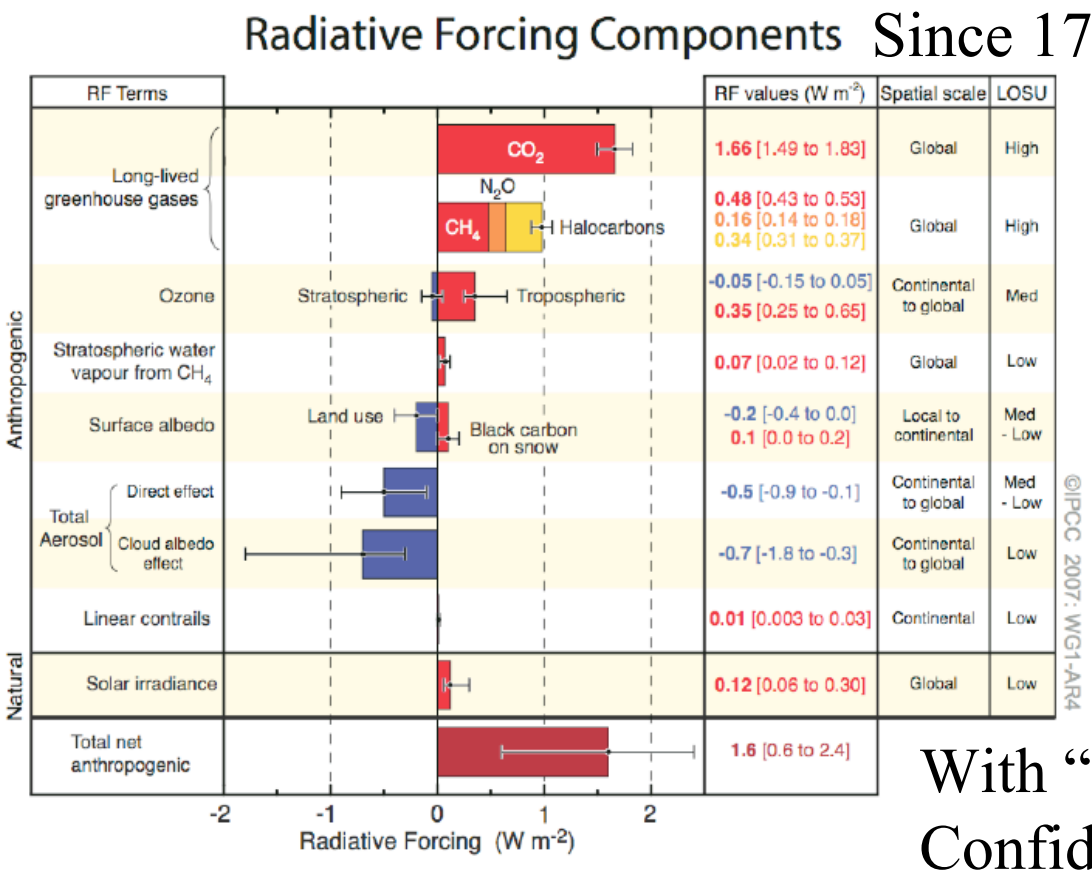
Anthropogenic with high and medium confidence (GHG):
$\mathbf{F_{High} = 3W/m^2}$

Medium low and low confidence aerosols and land use

$\mathbf{F_{Low} = -1.4W/m^2}$

Net Anthropogenic forcing

$\mathbf{F_{Net} = 1.6W/m^2}$

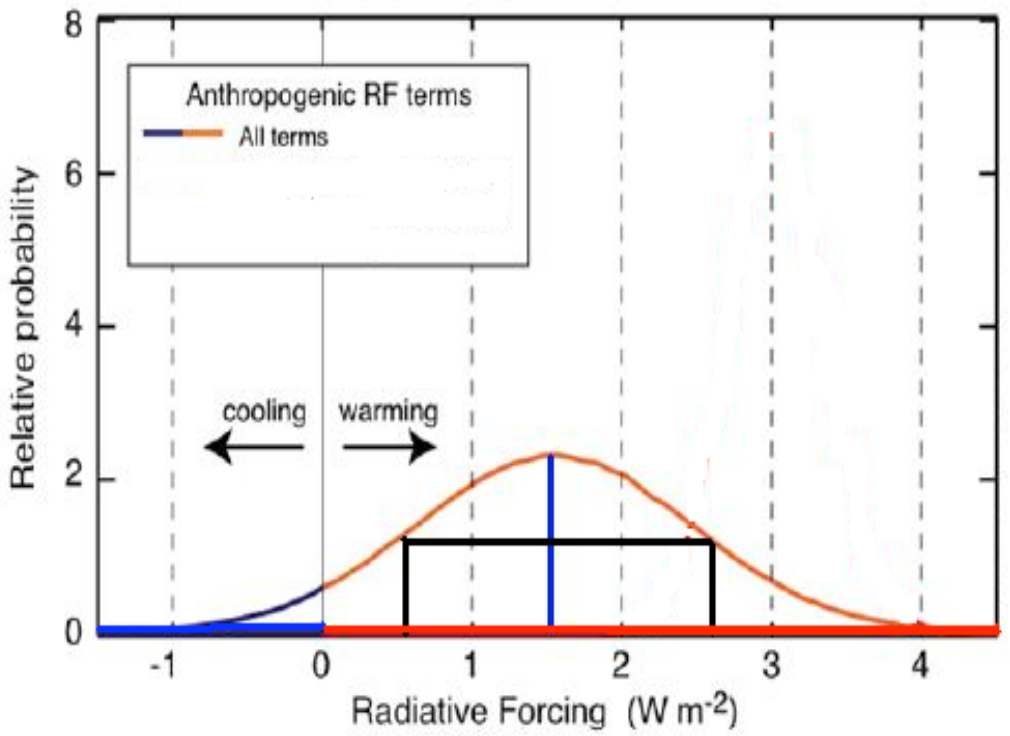


With "High Confidence"

Most of the observed increase in globally averaged temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic greenhouse gas concentrations[12]. This is an

It is *likely* that increases in greenhouse gas concentrations alone would have caused more warming than observed because volcanic and anthropogenic aerosols have offset some warming that would otherwise have taken place. {2.9, 7.5, 9.4}

Anthropogenic Radiative Forcing (ARF): Range of Uncertainty



Since 1750 till 2005

ARF=1.6W/m^2

[0.6 to 2.4]W/m^2

Gaussian Distribution

1 St Dev

Note: Small but nonzero probability for total anthropogenic forcing to be zero

GRL 32, 2005

Nature's style: Naturally trendy

Timothy A. Cohn and Harry F. Lins
U.S. Geological Survey, Reston, Virginia, USA

Table 1. Estimates of Trend Magnitudes and *p*-Values Corresponding to Various Models Fitted to the Annual Northern Hemisphere Temperature Departure Data, 1856–2002

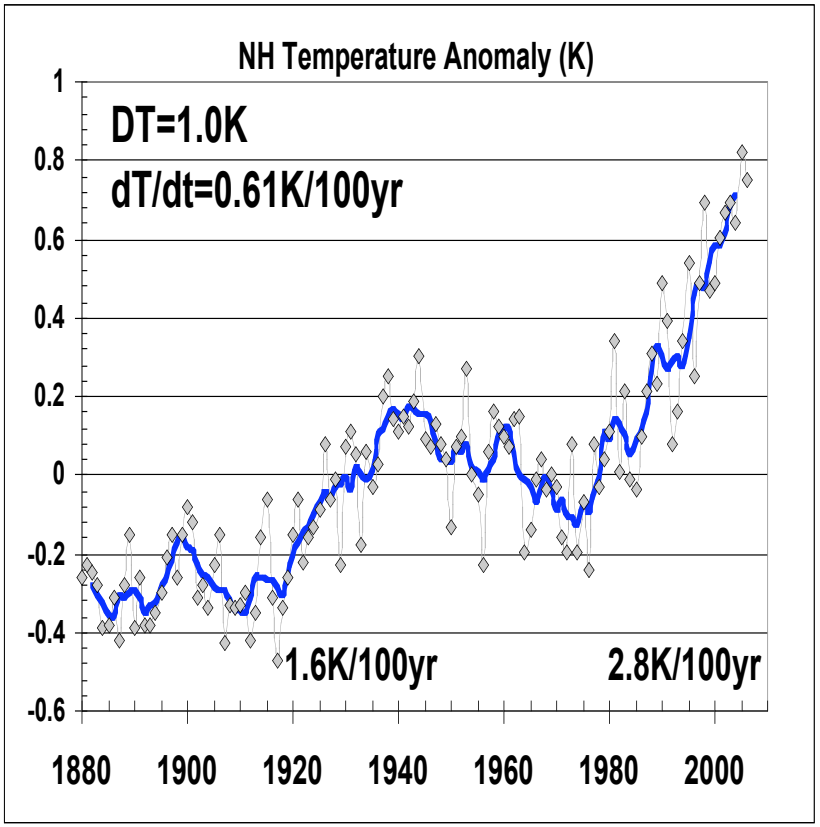
H_0 Process	Test	$\hat{\beta}$[a]	*p*-Value
White noise	$T_{\beta,\{0,0,0\}}$	0.0045	1.8e-27
MA(1)	$T_{\beta,\{0,0,\theta\}}$	0.0046	1.9e-21
AR(1)	$T_{\beta,\{\phi,0,0\}}$	0.0047	5.2e-11
LTP	$T_{\beta,\{0,d,0\}}$	0.0050	4.8e-3
LTP	$T^{A}_{\beta,\{0,d,0\}}$	0.0050	9.4e-3
ARMA(1,1)	$T_{\beta,\{\phi,0,\theta\}}$	0.0053	1.7e-4
LTP + MA(1)	$T_{\beta,\{0,d,\theta\}}$	0.0045	7.2e-2
LTP + AR(1)	$T_{\beta,\{\phi,d,0\}}$	0.0045	7.1e-2

[a]Trend magnitude, $\hat{\beta}$, is expressed in units of °C/year.

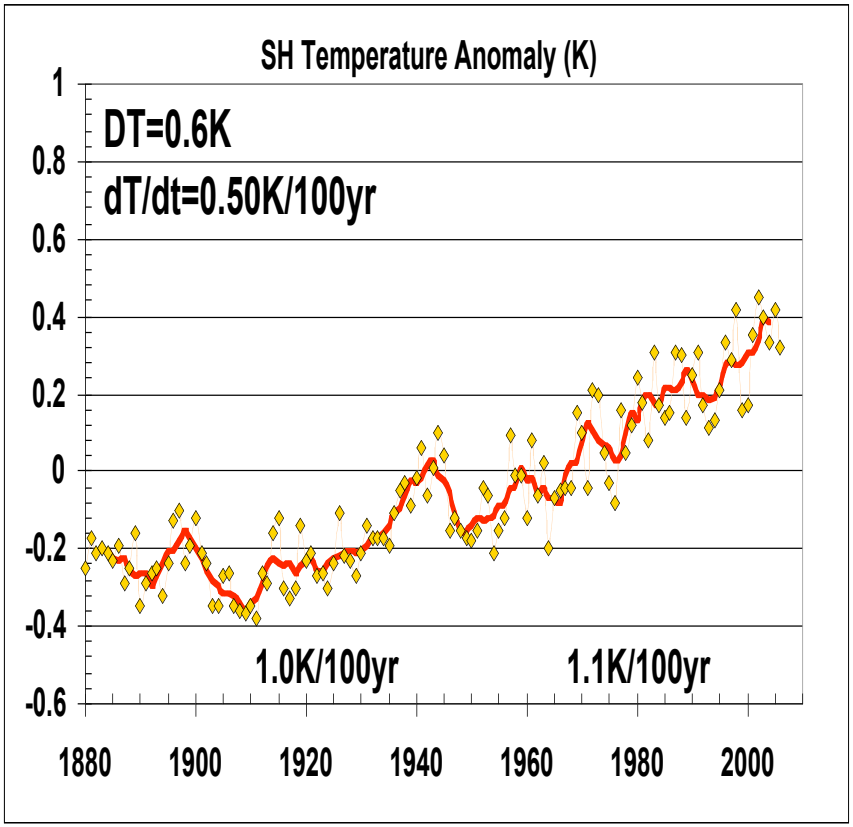
Finally, that reported trends are real yet insignificant indicates a worrisome possibility: natural climate excursions may be much larger than we imagine. So large, perhaps, that they render insignificant the changes, human-induced or otherwise, observed during the past century.

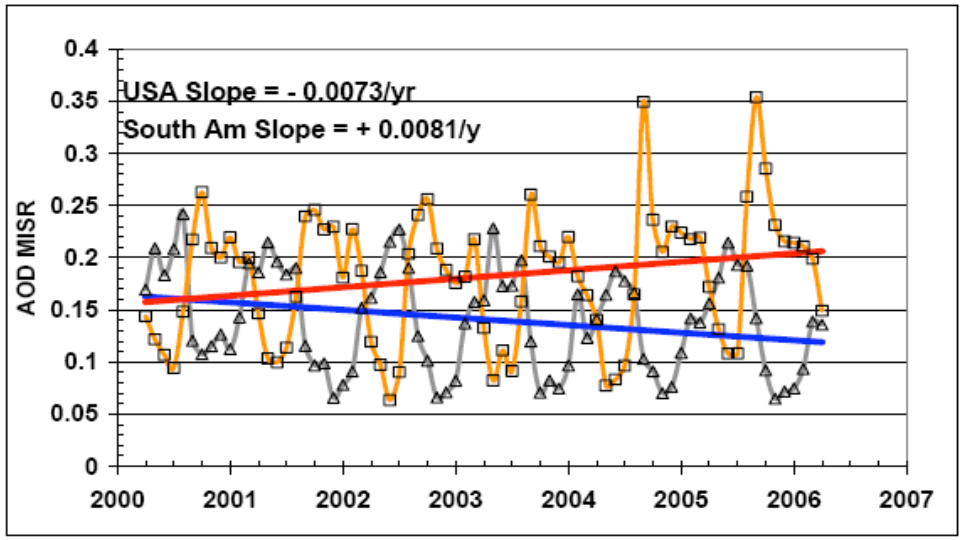
N and S Hemisphere Average

North



South





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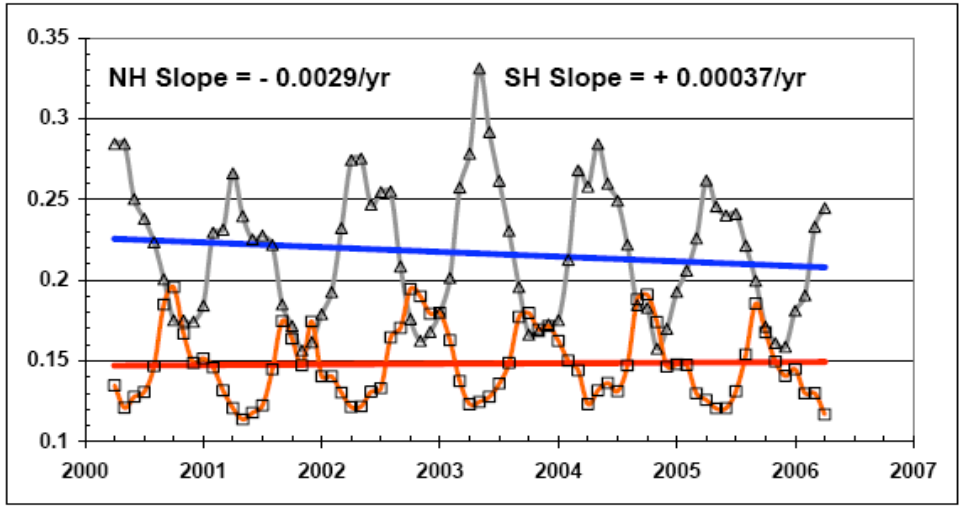


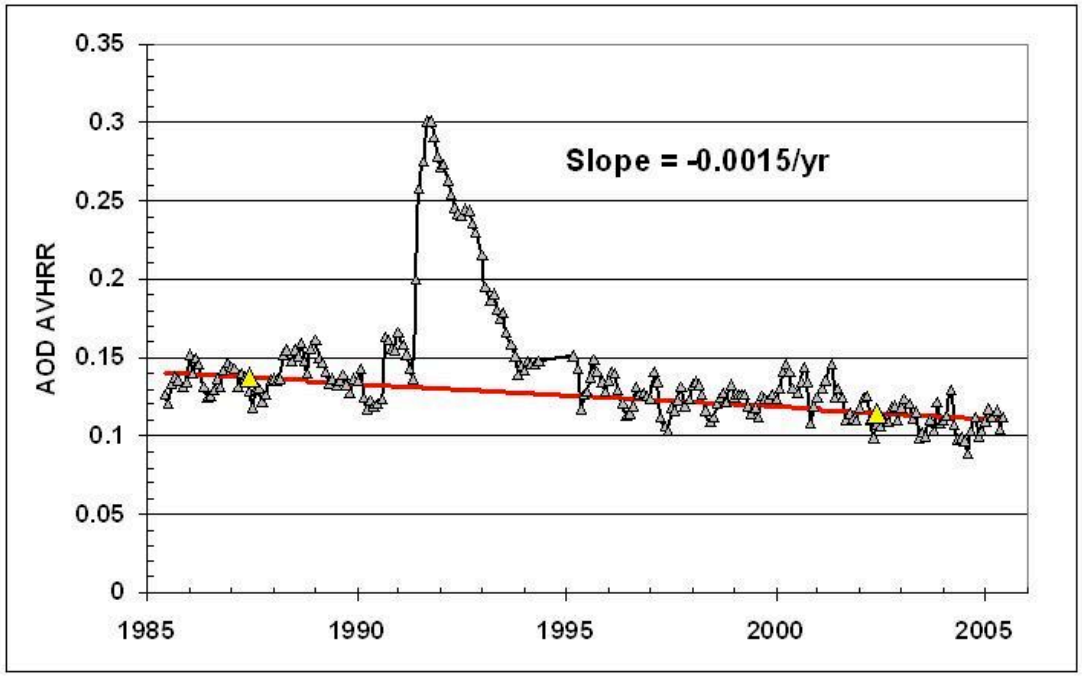
2

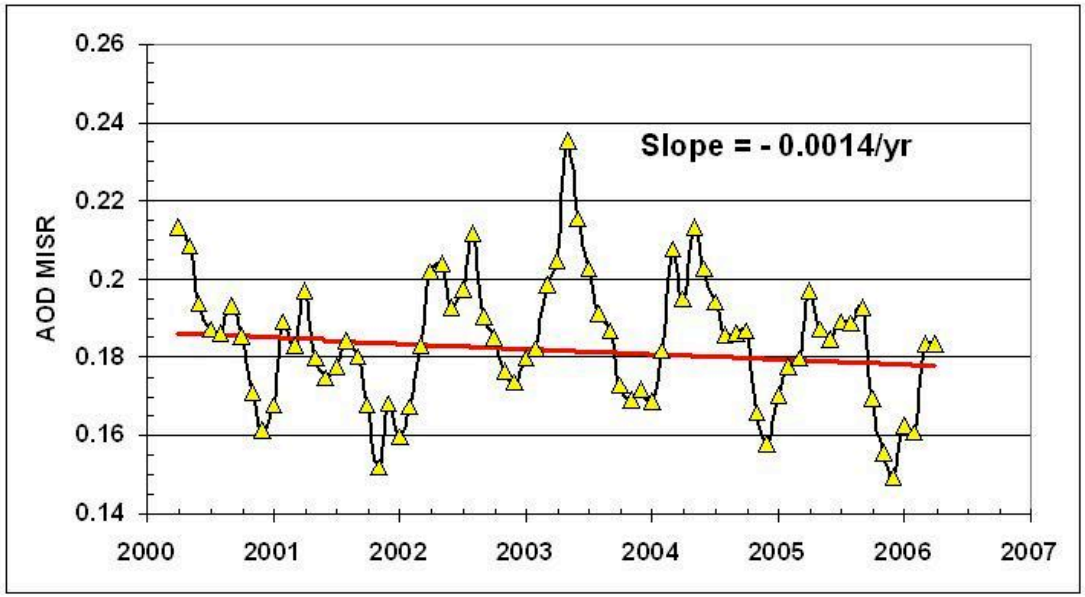
USA: Decreasing AOD

South Am: Increasing AOD

Northern H: Decreasing AOD

Southern H: No Change





Aerosol Optical Depth (τ)
Increasing 1950-1975
Decreasing 1980-2006
[Mishchenko et al., *Science*, 2007]

(1) US Clean Air Act of 1970
Reduction of sulfate aerosols in USA, Europe, N Atlantic
(2) Collapse of the USSR

$\Delta\tau/\Delta t$ = -0.0014/yr

Unique Current Situation:
(1) Increasing CO_2 (+)
(2) Decreasing AOD (+)
(3) No volcanic eruption
(4) Stable methane
(5) Stable solar

Climate Sensitivity

$\Delta T = \lambda \Delta F$

λ – *Climate Sensitivity* K/Wm^{-2}

ΔF – *Change in TOA Radiative Forcing*

ΔT – *Change in Global Average of Surface T*

Climate Models: $\lambda = 0.39 - 1.20\, K/Wm^{-2}$

$2CxCO_2$ $\Delta F = 3.7 W/m^2$

$\Delta T = 1.5\text{-}4.5K$

$\lambda = \Delta T/\Delta F = (\Delta T/\Delta t)/(\Delta F/\Delta t)$

TOA Radiative Forcing

- Carbon Dioxide

$$\Delta F = 5.35 \ln(C / C_0) \ \ W / m^2$$ [Myhre et al., *GRL,* 1998]

$C_o = 375$ ppmv $\quad \Delta C = 2$ ppmv/yr

$C = C_o + 2 = 377$ ppmv

$$(\frac{\Delta F}{\Delta t})_{CO_2} = 0.028 W m^{-2} / yr$$

TOA Radiative Forcing

- Aerosols Direct Effect

$$\frac{\Delta F}{\Delta t} = -\frac{S_0}{4} T^2 (1-N) \frac{\Delta \tau}{\Delta t} [(1-a)^2 (1-g)\omega - 4a(1-\omega)]$$

[Chylek and Coakley, *Science,* 1974; Chylek and Wong, *GRL,* 1995]

S_o – Solar Constant, T – Atmospheric transmission

N - Cloudiness; a – surface albedo, g – asymmetry parameter, w – single scattering albedo

$\Delta\tau/\Delta t = -0.0014/yr$

$$(\frac{\Delta F}{\Delta t})_{DIRECT} = 0.018 Wm^{-2} / yr$$

TOA Radiative Forcing – Climate Sensitivity

$$\left(\frac{\Delta F}{\Delta t}\right)_{DIRECT} = 0.018 Wm^{-2} / yr$$

$$\left(\frac{\Delta F}{\Delta t}\right)_{INDIRECT} = (0.018 \pm 0.009) Wm^{-2} / yr$$

$$\left(\frac{\Delta F}{\Delta t}\right)_{DIRECT+INDIRECT+CO_2} = (0.064 \pm 0.009) Wm^{-2} / yr$$

Observed rate of global T increase in 2000s: $\Delta T/\Delta t = 0.025 K/yr$

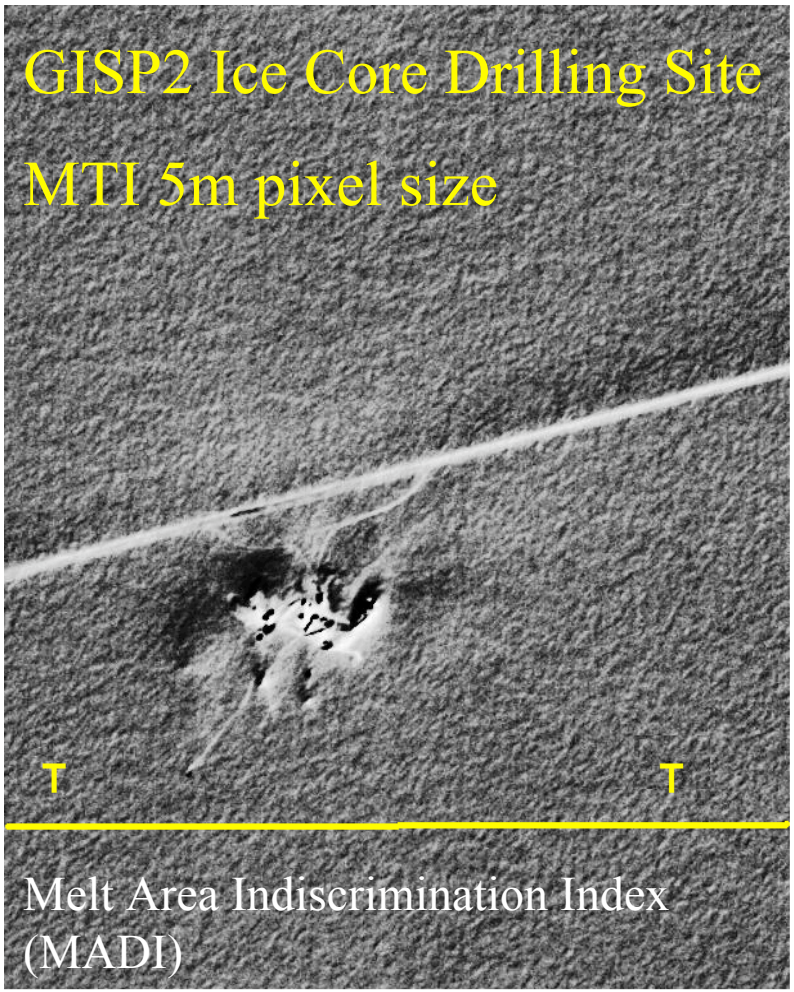
$\lambda = \Delta T/\Delta F = 0.4$ (+- 0.1) K/Wm^{-2}

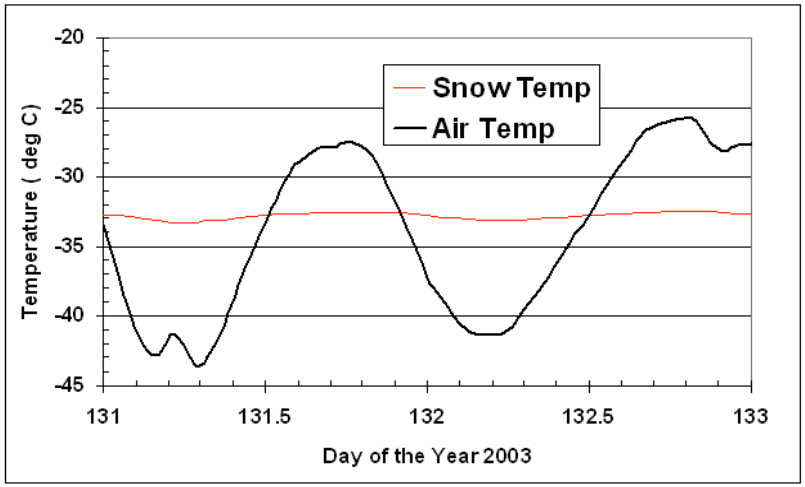
$2xCO_2$ $\Delta T = 1.5$ (+- 0.4) K

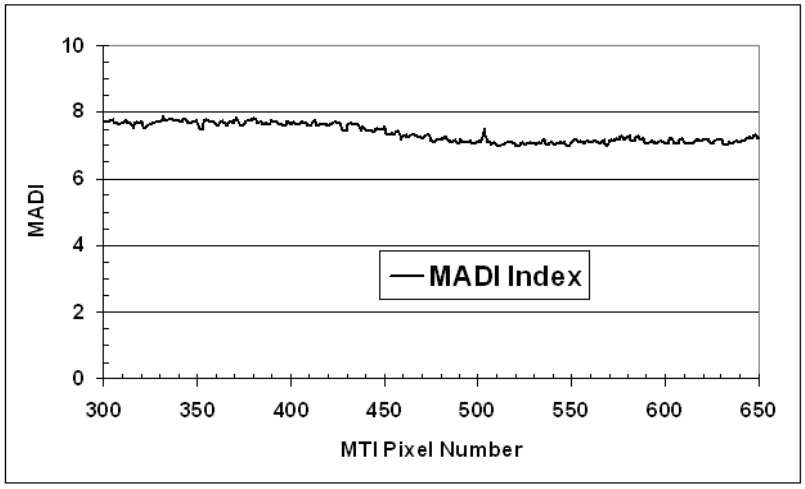
IPCC, 2007: $\Delta T = 2 - 4.5K$

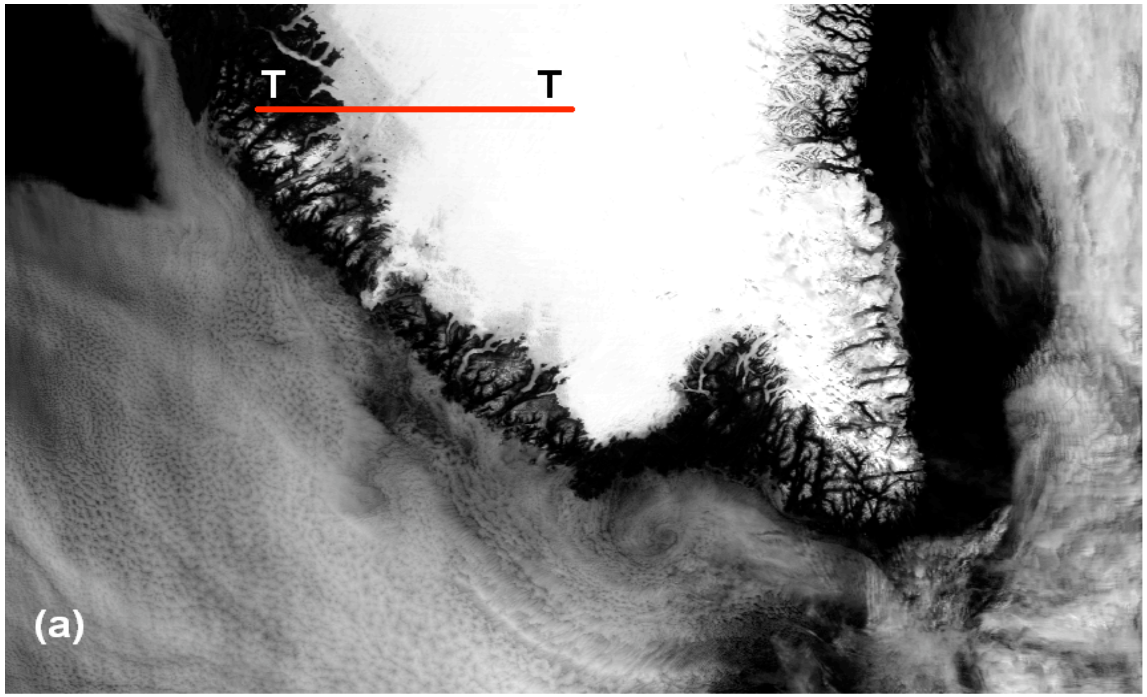
$\Delta T < 1.5K$ "very unlikely"

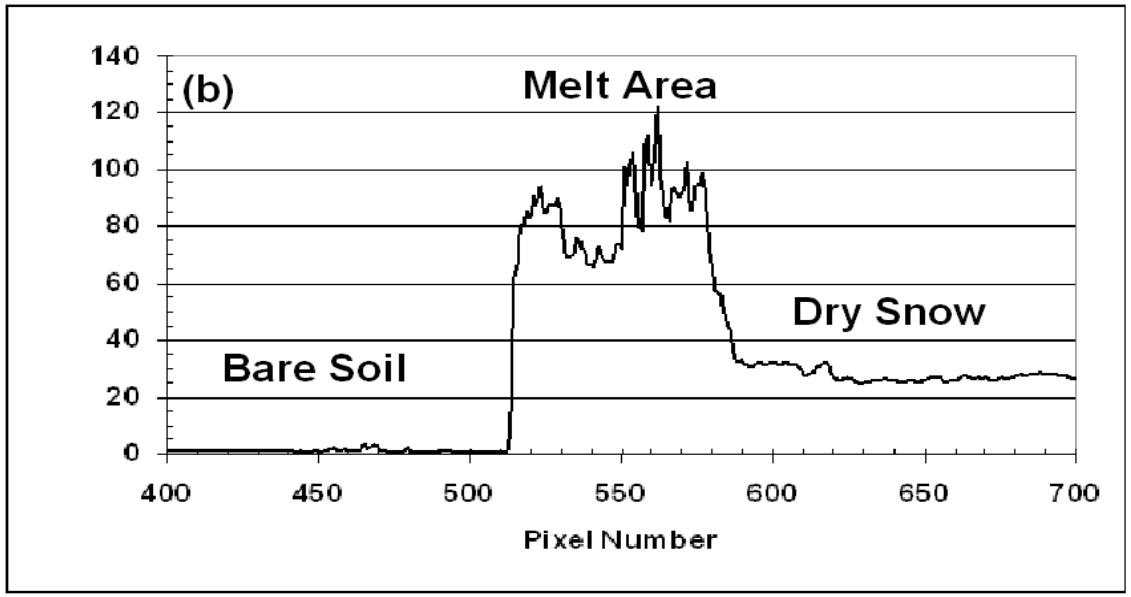
MTI (Multispectral Thermal Imager)
Summit Greenland Ice Sheet







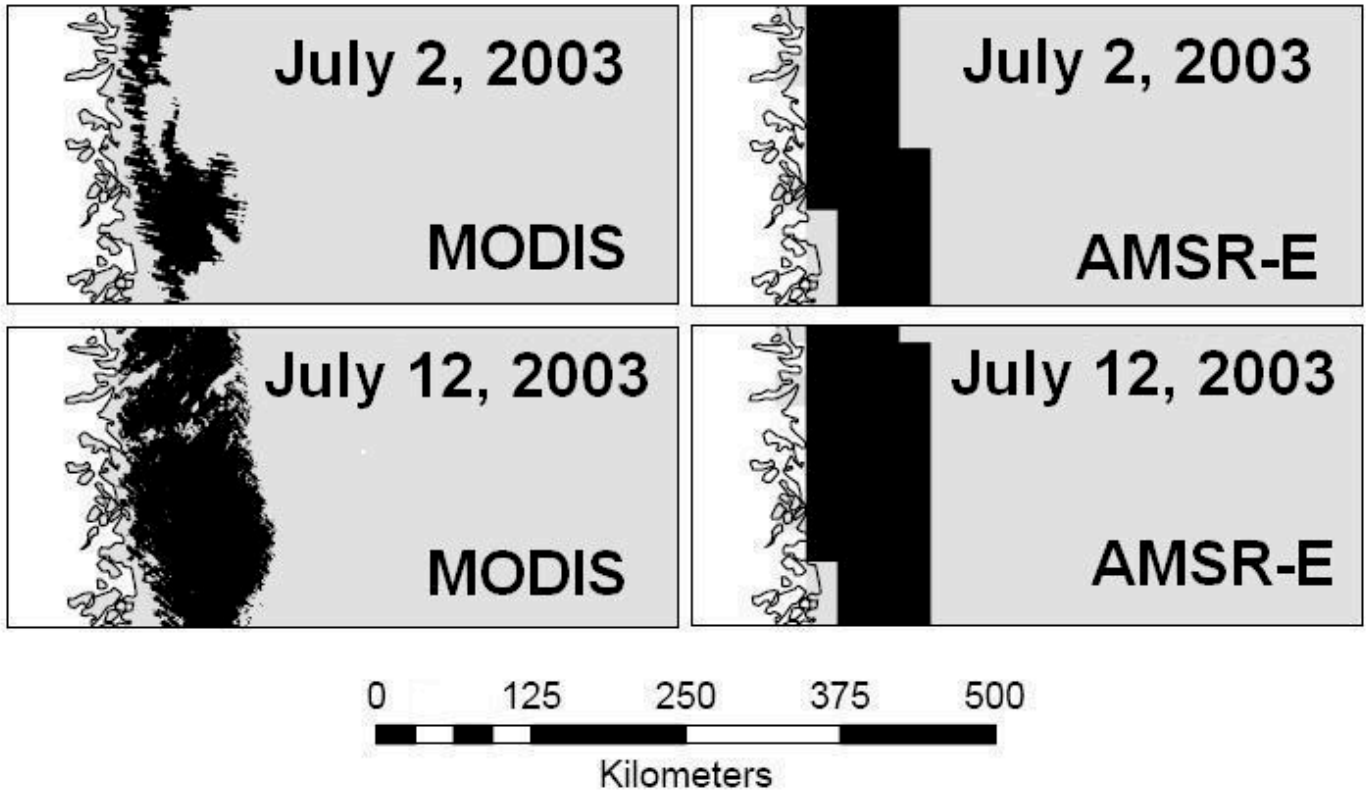




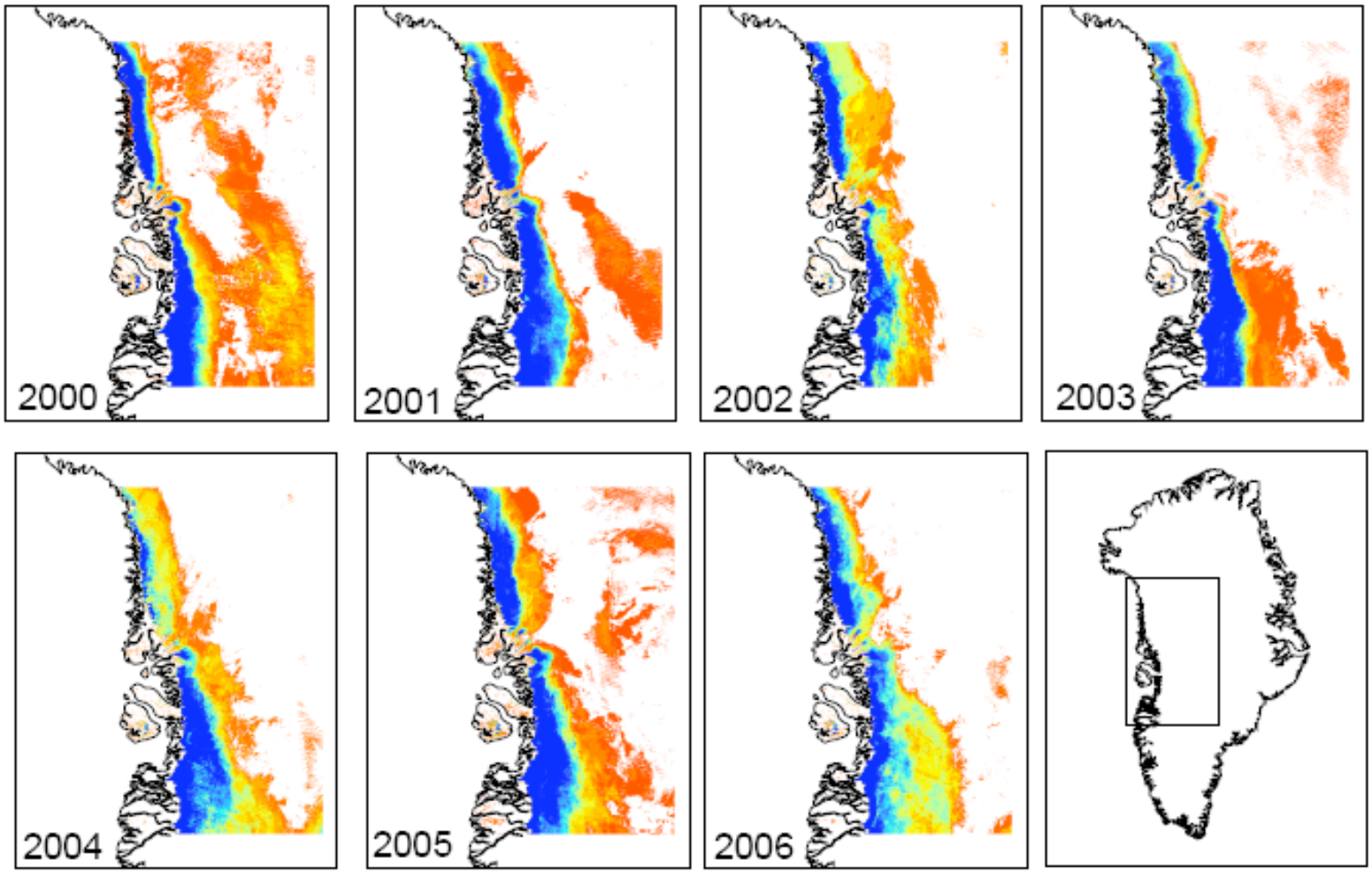
Greenland Ice Sheet Melt Area

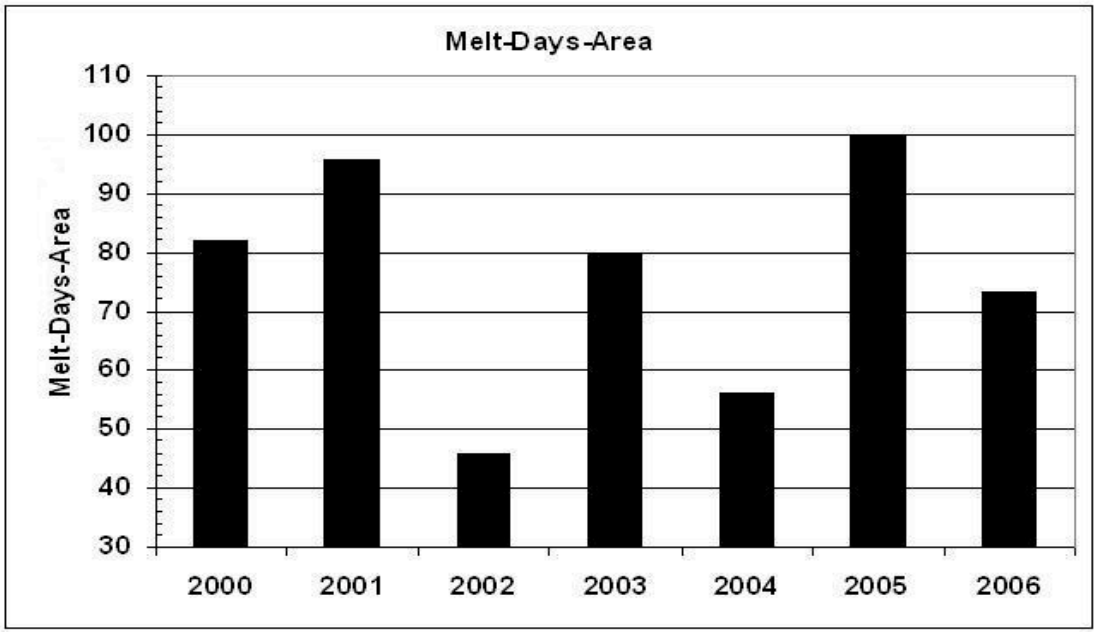
Using MODIS NIR and VIS radiances MADI Spatial resolution 1 km^2

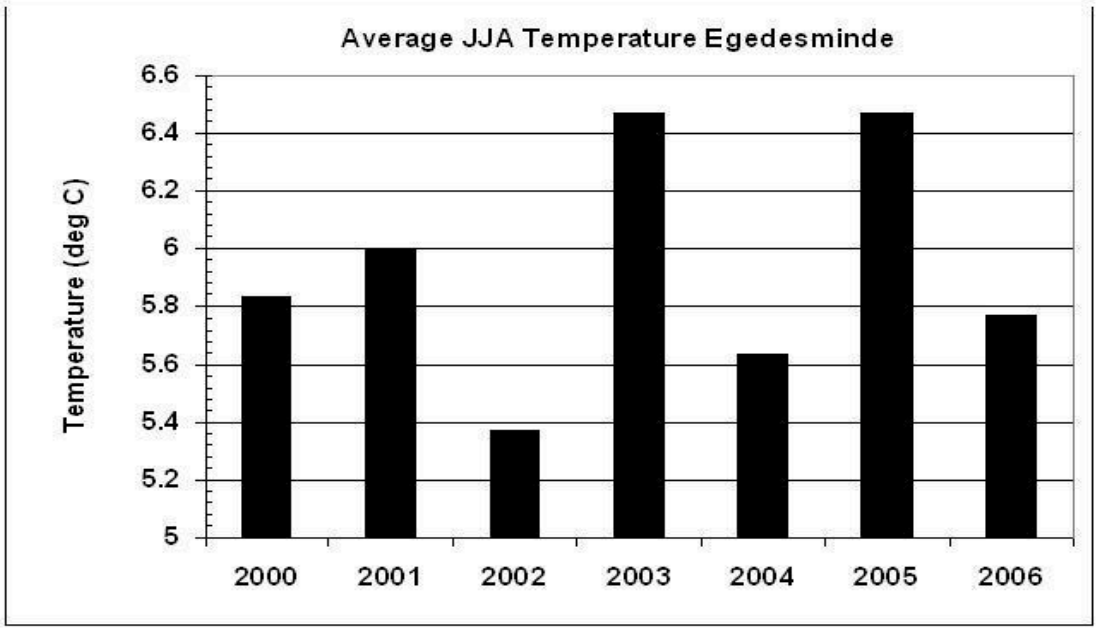
RS: Comparison of MADI and Microwaves



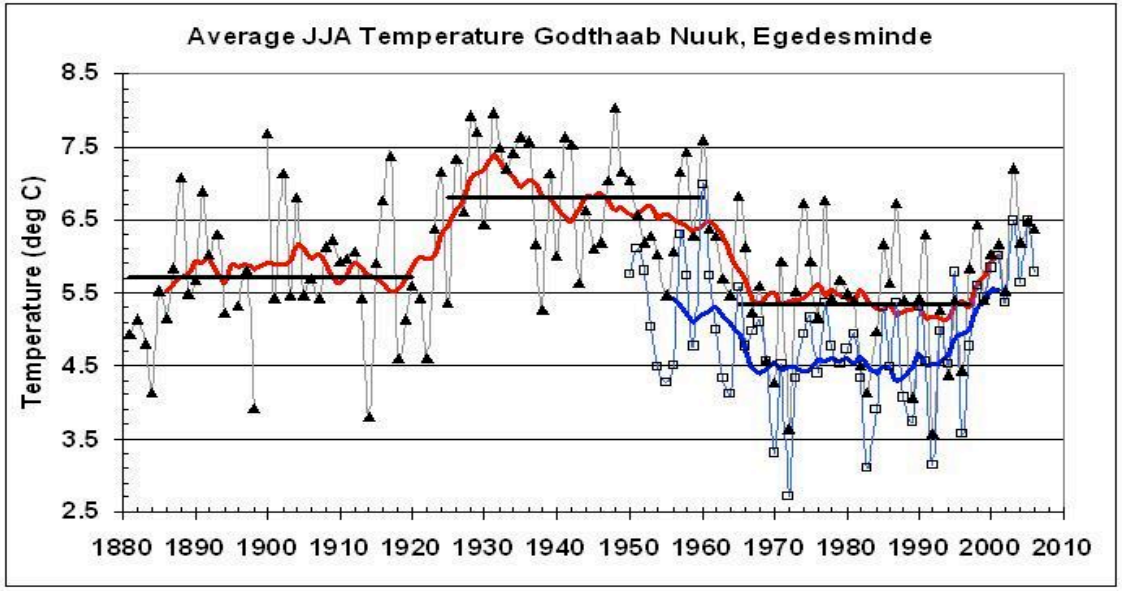
Melt Area 2000-2006

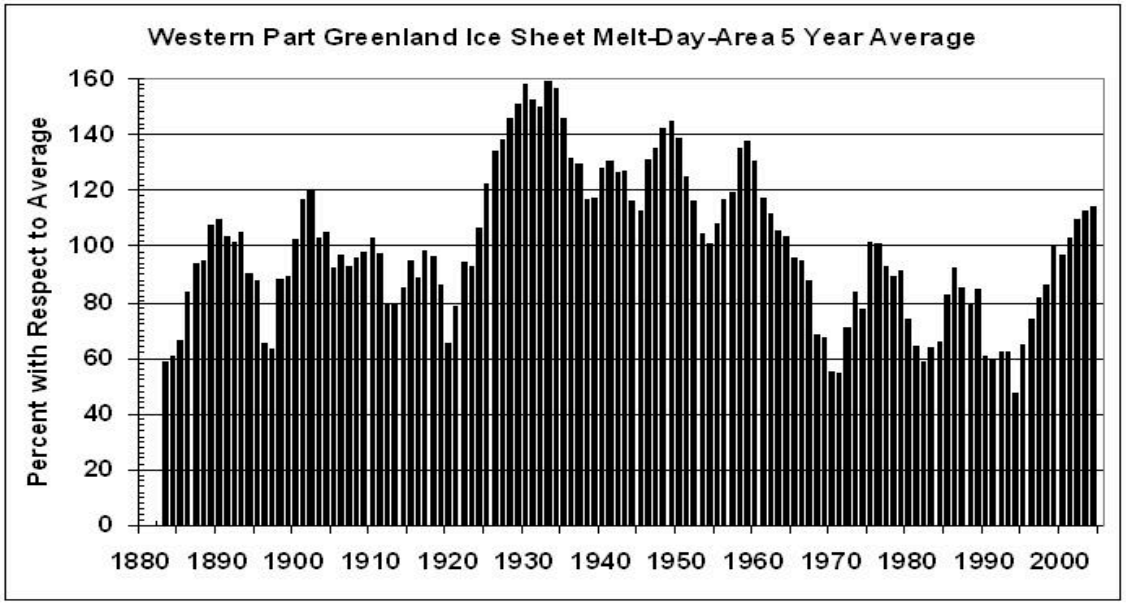






High correlation **r = 0.80** between melt area and Egedesminde average summer (JJA) temperature





An average summer temperature (5yr average) at Godthaab Nuuk used as a proxy for the past ice sheet melting (1882-2004)

Is there a record of extensive melting in Greenland in 1930-1040?

Ahlmann, A.,The Present Climatic Fluctuation, *Geographical Journal* **112**, 165-193 (1948)

"The last decades have reduced the ice in some parts of Greenland to such an extent that the whole landscape has changed in character."

Conclusion

- Do we have a period of global warming? Yes
- Do humans contribute to it? Yes
- Is it a planetary emergency? No
- What are the current emergencies?

  Wars, Fast Growing Populations, Poverty, Hunger, Diseases, ……
- What is the global warming greatest danger ?
  Melting of Greenland ice sheet
- What to do?

  Regional climate engineering to slow down melting of the Greenland ice sheet.