Sea Water Emissivity – A neglected climate forcing

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Overview

- definition of thermal emissivity
- physics of emissivity of water surfaces
- emissivity and paleoclimatological data
- emissivity and neoclimatological data
- emissivity and climate sensitivity
- conclusions

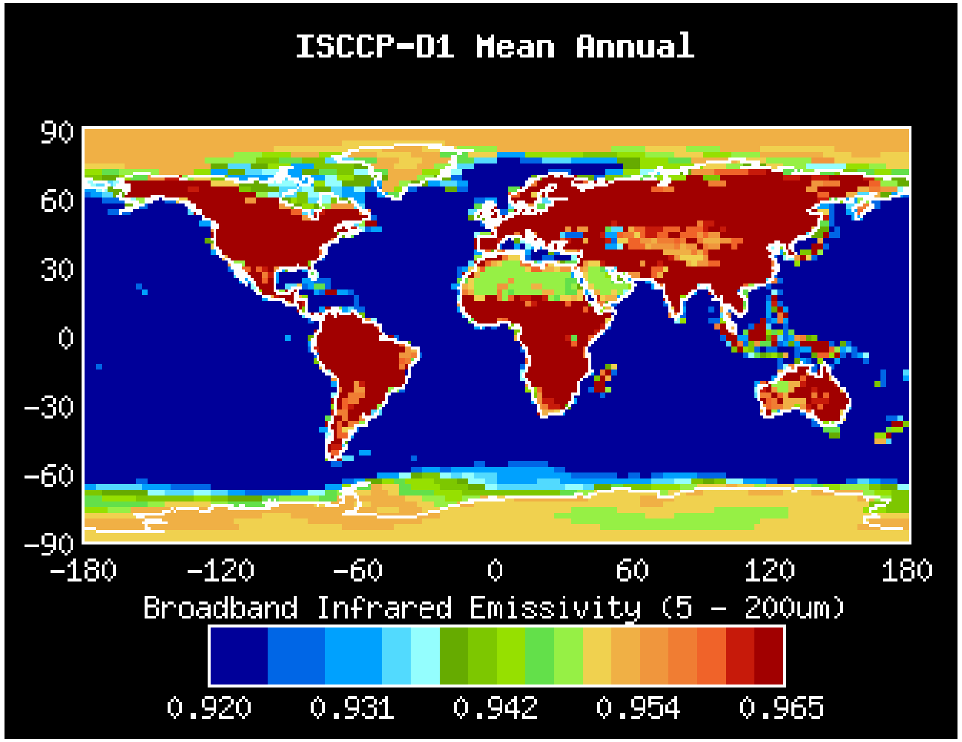
Definition of emissivity

Thermal energy E emitted by a body

$E = \varepsilon * E_{bb} = \varepsilon * \sigma * T^4$ (modified Stefan-Boltzmann-Law)

with $\varepsilon = 1 \rightarrow$ black body (Planck) radiator, thermal energy E_{bb}

Earth system: $0.92 < \varepsilon < 0.965$



"emissivity" not mentioned a single time in the IPCC TAR

$\Longrightarrow$ the following is not "consensus science"

Simplified EnergyBalanceModel (EBM) for calculation of average Earth temperature

energy of insolation must equal outgoing infrared radiation of Earth

$S * (1-\alpha) = 4 * \sigma * T^4$

S = solar „constant“ = 1,368 W/m²

α = albedo of Earth = 0.3 (partial reflexion of insolation, no constant, e.g. dependant on temperature (snow and ice cover))

σ = constant of Stefan-Boltzmann-Law = $5.67*10^{-8}$ $W*m^{-2}*K^{-4}$

result: average Earth temperature T = -18 °C.

modified calculation with 2 additional parameters

$S * (1-\alpha) = 4 * \varepsilon * \sigma * T^4 * \tau$

ε = ***emissivity*** = 0.95

τ = atmospheric IR-transmissibility parameter = 0.65

result: average Earth temperature +14.5 °C

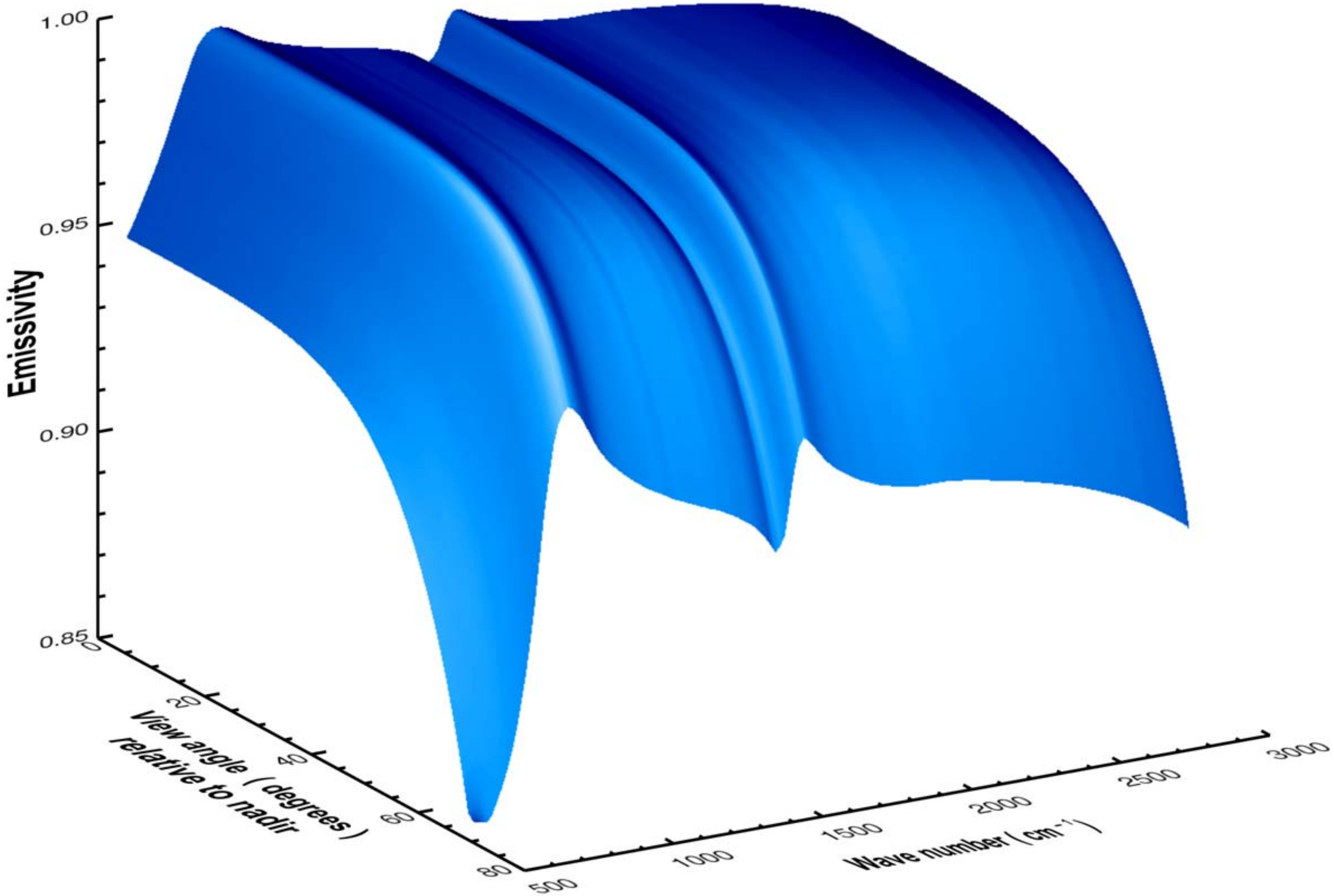
τ = f (type and concentration of greenhouse gases, aerosols, cloud coverage and altitude, Earth temperature, temperature profile of atmosphere etc.)

→ **ε** = “constant“ of substance; with water/oceans f (wave height, ***wind speed***)

71 % of Earth surface covered by water

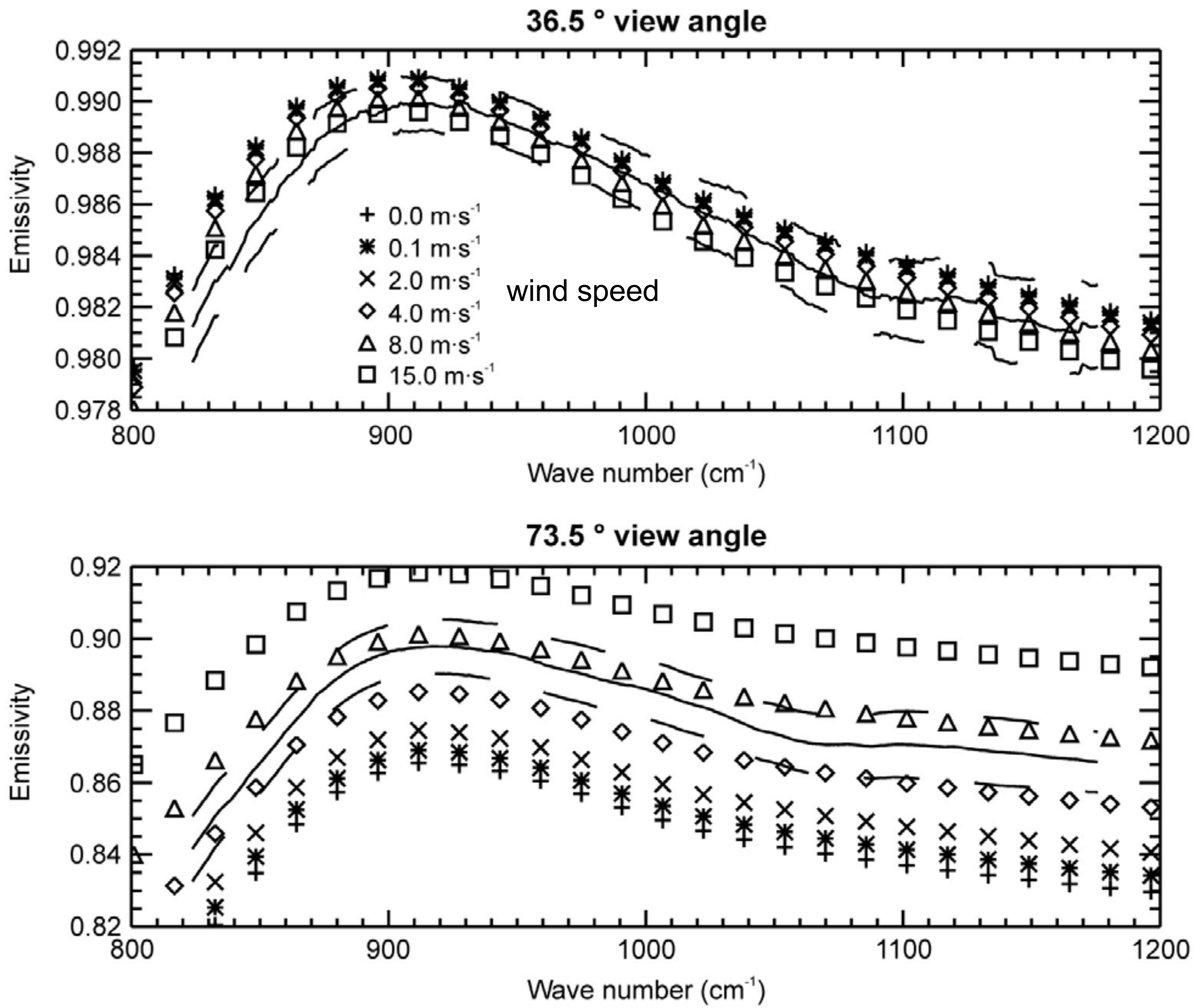
Emissivity of rough sea surface for 8-13 µm: modeling and verification

Emissivity variation with view angle for 0 m*s^{-1} wind speed



Wu, X. and W.L. Smith, Appl. Opt. **36**, 2609-2619 (1997)
van Delst, P. and X. Wu, http://airs3.ssec.wisc.edu/~paulv/

A high resolution infrared sea surface emissivity database for satellite applications



van Delst, P. and X. Wu, http://airs3.ssec.wisc.edu/~paulv/

Quantitative estimation of variation of oceanic emissivity with wind speed, using the data of Wu, Smith, and van Delst

1. In climatology the IR-radiation is quantified over the entire **hemisphere** (integral over a room angle of 90 ° around the nadir)
2. large angles around the nadir dominate the integral, e.g. angles above 70 ° determine 34 % of the total area of the hemisphere (cos-function)
3. with angles above 75 ° data and emissivity calculation are not precise.

Water radiator of 15 °C, varying wind speeds:

- with hypothetical emissivity 1→ 390 W/m² (Planck radiator)
- with emissivity for 0 $m*s^{-1}$ → ~363.0 W/m² ($\varepsilon \leq 0.93$)
- with emissivity for 15 $m*s^{-1}$ → ~374.1 W/m² ($\varepsilon \leq 0.96$)
- **difference in emittance of sea surface for 0 and 15 $m*s^{-1}$ → 11.1 W/m², presumably higher**.
- **difference multiplied with atmospheric transmissibility (0.65) → 7.2 W/m²**

intermediate conclusion: **variations of oceanic wind speed have a *dominating* influence on climate system, also in comparison with doubling of atmospheric CO_2-concentration (3.7 W/m²)**

Variation of oceanic emissivity with wind speed, derivation of Stefan-Boltzmann-Law

$E = \varepsilon * E_{bb} = \varepsilon * \sigma * T^4$

$$dT / dE = \frac{1}{4 * \sigma * T^3}$$

with T = 288

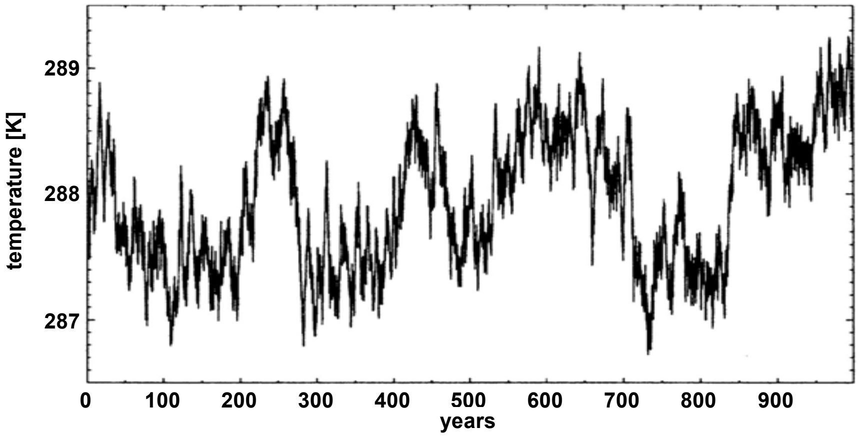
$\Delta E = \Delta\varepsilon * E_{bb} \geq 11.1\ W/m^2$ (difference in emittance of waveless to stormy surface)

$\Delta T \geq 2.0\ K$

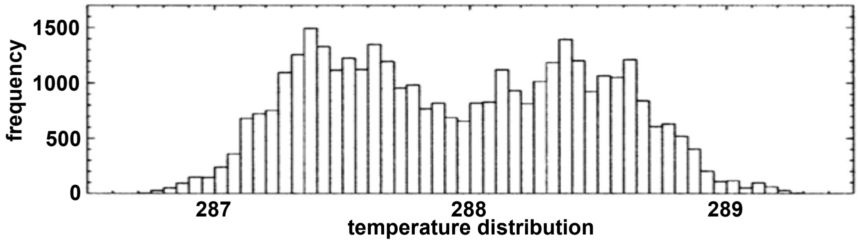
$\Rightarrow$ a waveless sea surface of 17°C and stormy surface of 15°C emit the same amount of IR-radiation

Characterisation of oscillating systems in EnergyBalanceModel (EBM)

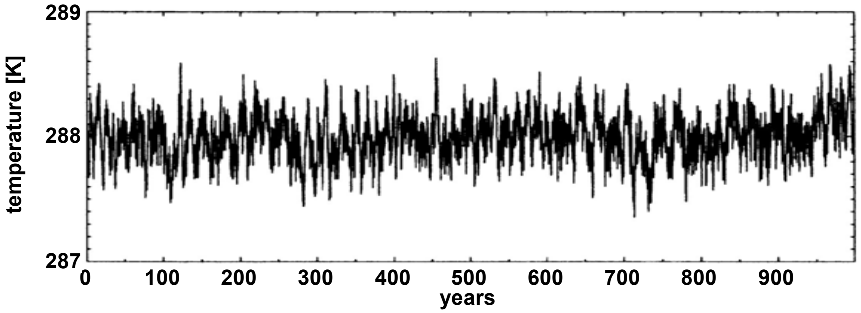
acc. to H. von Storch et al. (1999)



long-time behaviour of EBM with temperature dependant albedo α (positive feedback)



nomogram of result
bimodal temperature distribution

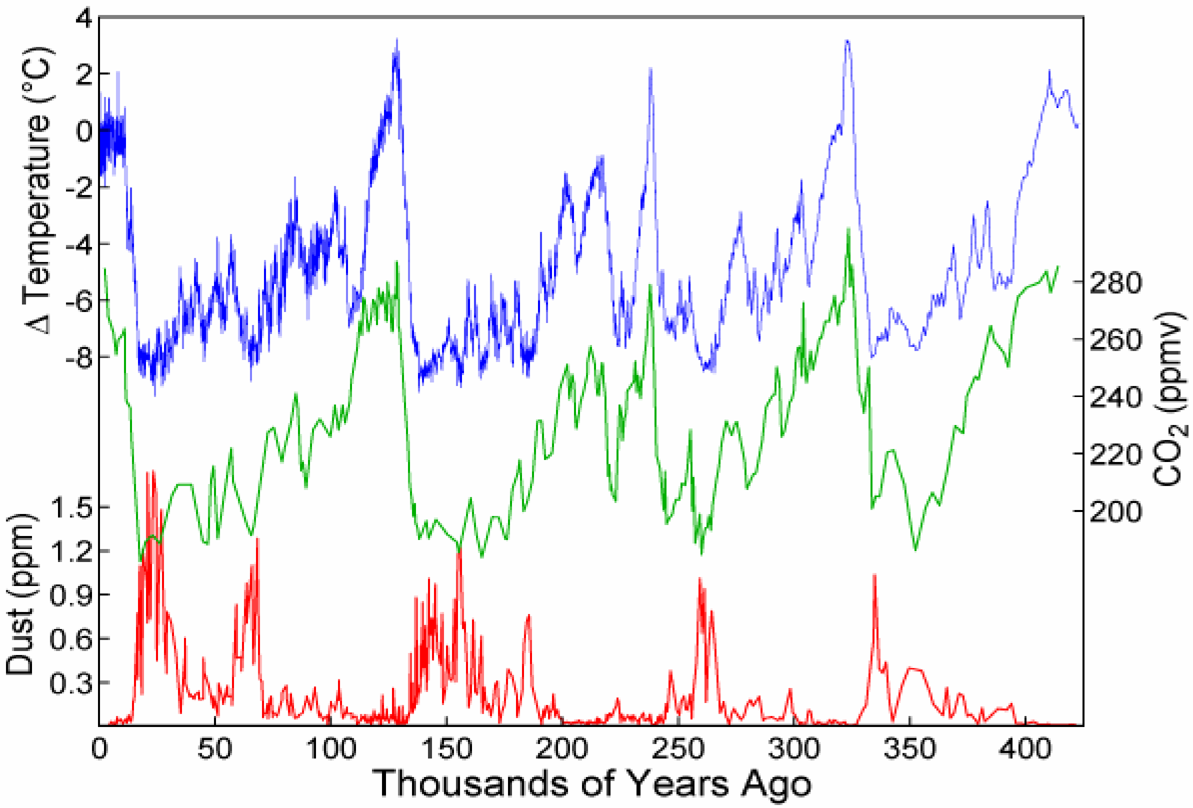


for comparison long-time behaviour of EBM with constant albedo α
no feedback

$$\alpha\,(T_i) = 0.3 \cdot (1 - 0.025 \cdot \tanh(1.548 \cdot (T_i - 288\ \mathrm{K})))$$

Paleoclimatology: Antarctica temperature, CO_2, dust

"Climate and Atmospheric History of the Past 420,000 years from the Vostok Ice Core, Antarctica" Petit J.R. et al., *Nature* **399**: 429-436



inverse correlation of wind proxy dust with temperature and atmospheric greenhouse gas concentration

Paleoclimatology: Wind proxy Antarctica

„Aerosol concentrations over the last climatic cycle (160 kyr) from an Antarctic ice core", De Angelis, M. et al., Nature, **325**, 318-321 (1987)

Summary:

- Time series ... for **dust and marine salt loadings** in the Antarctic atmosphere have been constructed... These results extend our understanding of aerial transport processes during the last glacial cycle.

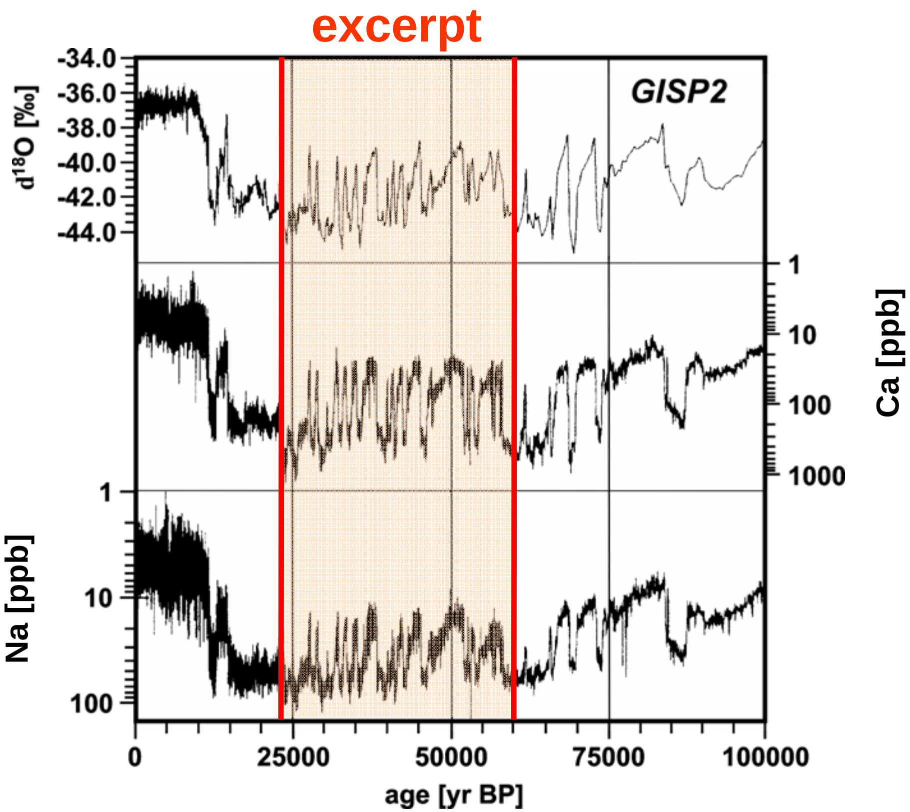
Excerpt:

- It has been proved that the **LGM (Last Glacial Maximum dust) concentration peak** was … of **aeolian** origin.
- We estimate the upper limit of **wind speed**: ...A progressive **increase of 7-10 m*s^{-1}** could account for the background variation, and a **further increase of 1.5-3 m*s^{-1}** could account for the mean **peak values**.

Intermediate conclusion:

- Not only variation in greenhouse gases and albedo, but also the increase in **wind speed** are the cause of **positive feedbacks** during glacials/interglacials via sea surface emissivity **(increased IR radiation during stormy periods)**

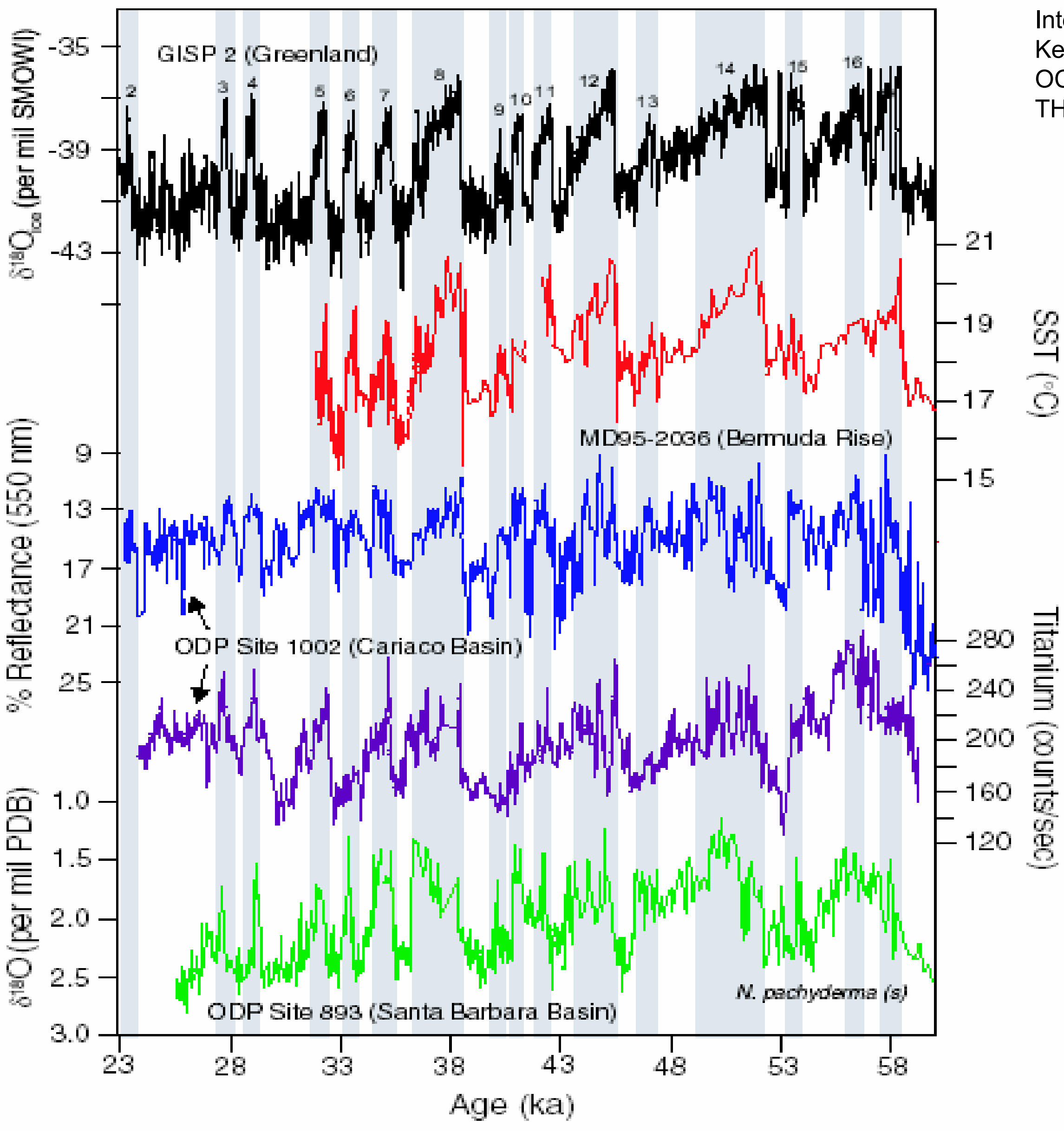
Paleoclimatology: Greenland GISP 2 ice core (1)



Data acc. to
B. Mieding, AWI or
http://www.ngdc.noaa.gov/paleo/paleo.html

- **GISP 2 exhibits a typically oscillating system, with temperature variations of 6 to 10 °C within a decade or less**
- **highly significant inverse correlation with oceanic wind proxy (Na)**
- **comparatively poor correlation with greenhouse gases**
- **“mainstream“ interpretation: temperature variation/oscillation is caused by Dansgaard-Oeschger und Heinrich events. But: why do wind proxies correlate so highly significantly with temperature variation?**

Paleoclimatology: Greenland ice core and IODP sediments



International Ocean Drilling Program
Kennett, J.P. and L.C.Peterson, „RAPID CLIMATE CHANGE: OCEAN RESPONSES TO EARTH SYSTEM INSTABILITY IN THE LATE QUATERNARY“, JOIDES **28**, 5-9, (2002)

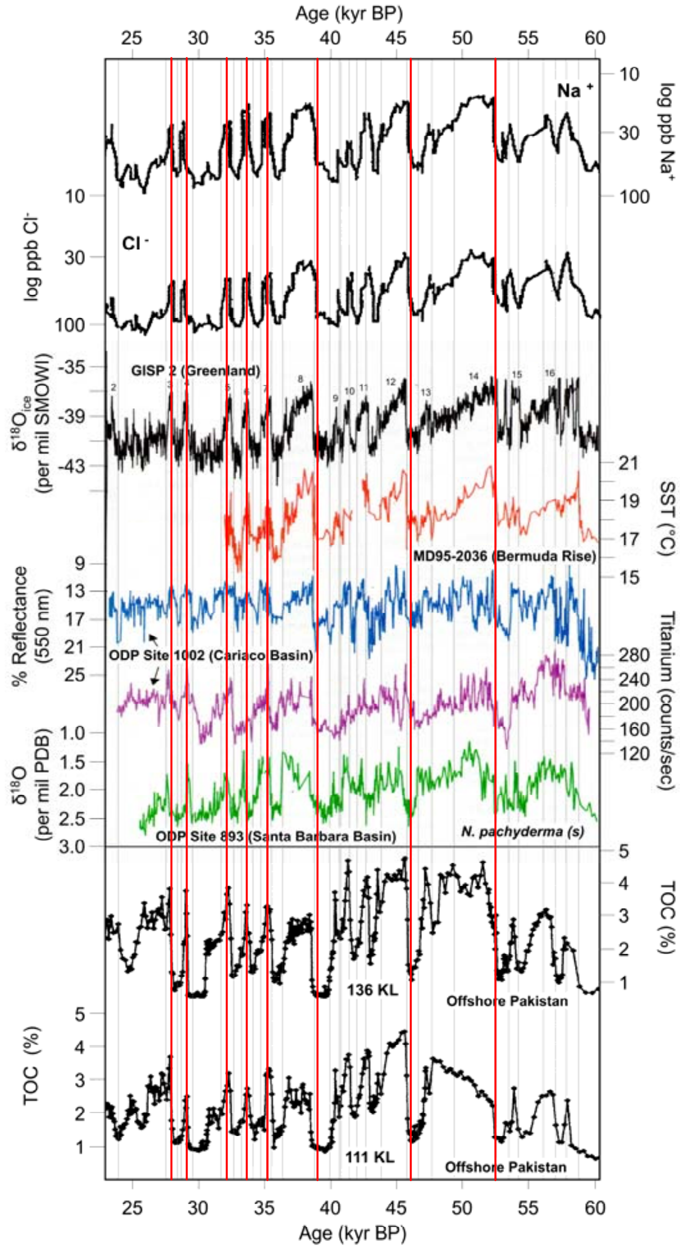
correlation of T-proxies with

- **Greenland (Arctica, Atlantic)**
- **Bermuda Rise (Northern Subtropics, Atlantic)**
- **Cariaco Basin, Offshore Venezuela (Tropics, Atlantic)**
- **Santa Barbara Basin, Offshore California (Northern Subtropics, Pacific)**

Conclusion of authors:

These studies have revealed the ocean's remarkable capacity to switch between glacial and interglacial states within decades or less.

Paleoclimatology: Wind proxies, ice core climate proxies, sediment climate proxies (IODP)

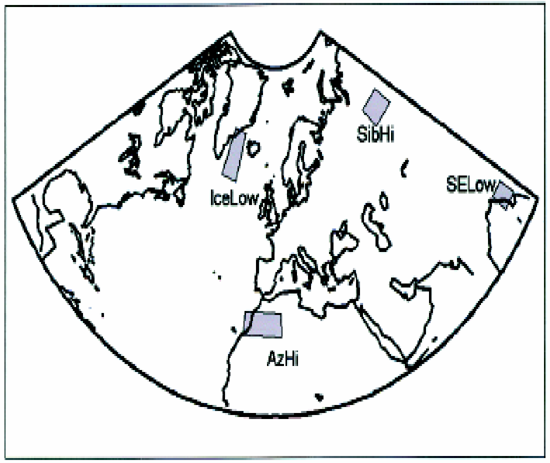


„RAPID CLIMATE CHANGE: OCEAN RESPONSES TO EARTH SYSTEM INSTABILITY IN THE LATE QUATERNARY“, further excerpts by Kennett, J.P. and L.C.Peterson

- „…a **completely unexpected discovery** that implicates **the ocean as a source of major feedbacks** that serve to reinforce or amplify the climatic shifts.
- Furthermore, the remarkable similarities in short-term climate behavior between such geographically distant regions argue strongly for **synchronous** **teleconnections via the atmosphere** as a mechanism for promulgating such rapid climate change.
- Of course, these discoveries beg **the question of ultimate cause** - **understanding the feedbacks** and linkages within the global system that create such abrupt climate change represents one of the major current challenges in earth science.“

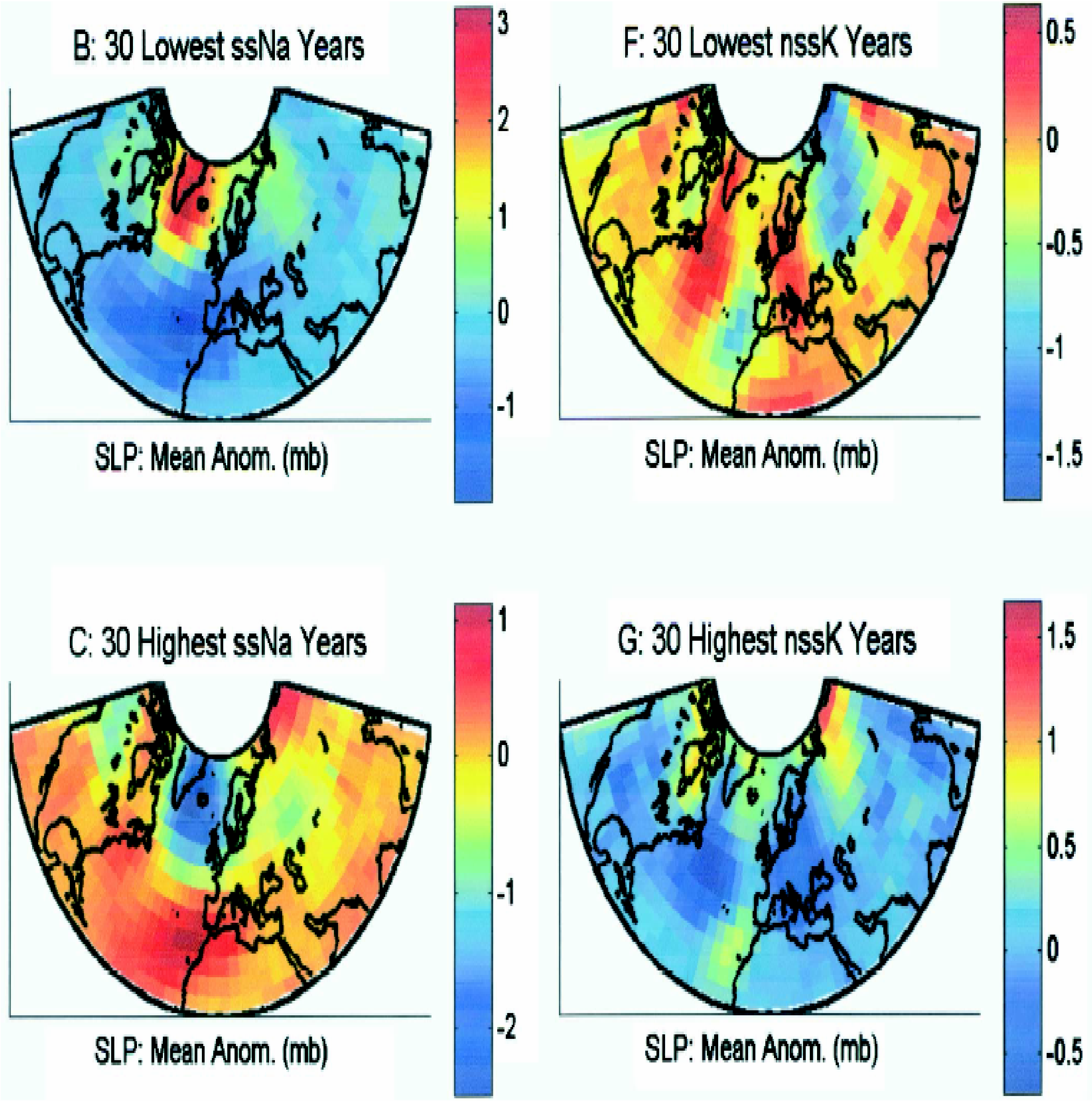
My annotation:
This presentation identifies a major **positive feedback (emissivity of oceans), not yet implemented in climate models.**

Neoclimatology: ice core wind proxies North Atlantic und Asia



A 1400-year high-resolution record of atmospheric circulation over the North Atlantic and Asia
Meeker, L.D. and P.A. Mayewski
The Holocene **12**, 257–266 (2002)

Calibration of proxies with instruments of the 20th century: ssNa as oceanic wind proxy and corresponding SLP (sea level pressure).
nssK as terrestric wind proxy and SLP, each in ice cores



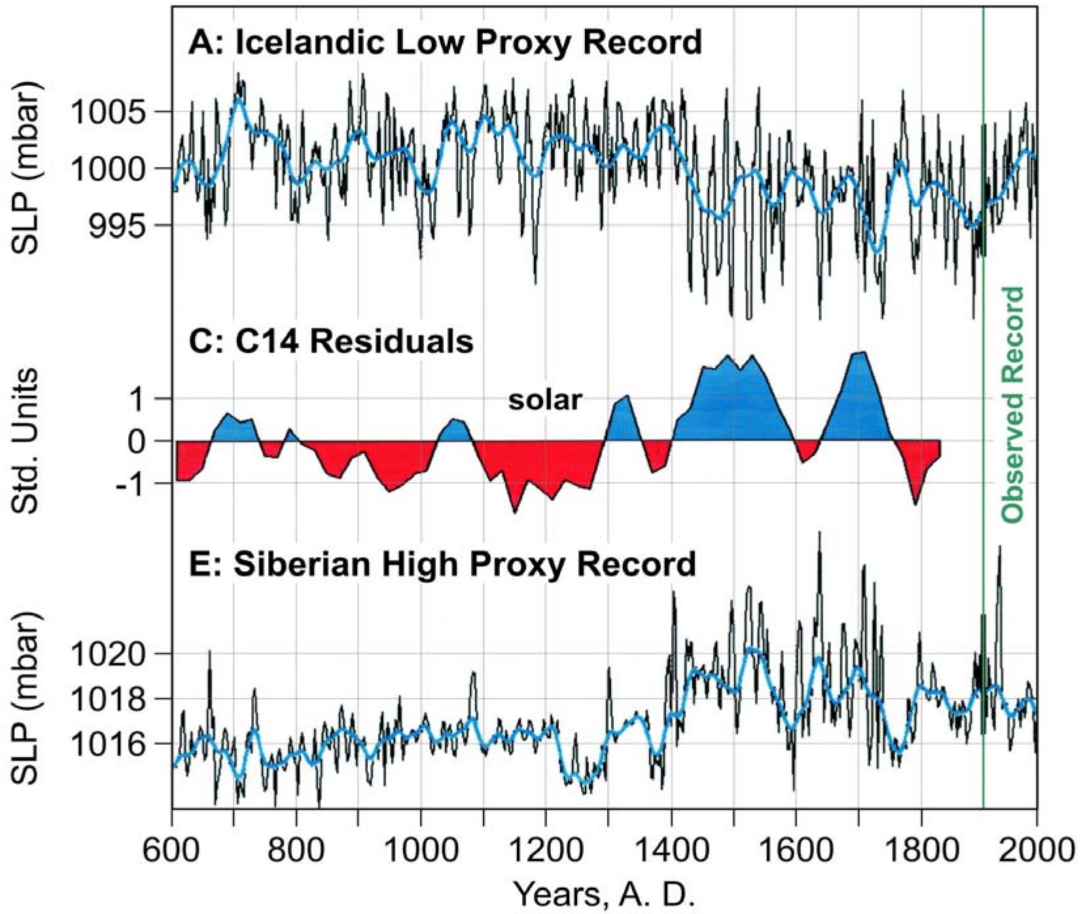
Neoclimatology: wind proxies North Atlantic und Asia (2)

Excerpt: Meeker, L.D. and P.A. Mayewski (2002):
To investigate this **possible ocean sea surface temperature and atmosphere sea level pressure association** we compare sea salt sodium series to annual average SSTs derived for geographic ‘boxes’ over the North Atlantic (Hansen and Lebedeff, 1988).....

...the **high ssNa proxy** (my annotation: **higher wind speed**) for **deep Icelandic Low** is **strongly correlated to 4–6 year lagged cold SST in the North Atlantic** consistent with previously described ocean-atmosphere associations (Deser and Blackmon, 1995).

My annotation: the effect to be expected by physics:
higher pressure differences → higher wind speed → higher waves → higher oceanic emissivity → cooling (and vice versa), with the cooling being measurable after some years only.

Paleoclimatology: North-Atlantic and Asia during Holocene



Meeker, L.D. and P.A. Mayewski (2002):

- weakened Icelandic low and weakened Siberian high during Medieval Warm Period (low wind speed)
- strengthened Icelandic low and strengthened Siberian high during Little Ice Age (high wind speed)
- correlation with solar forcing.

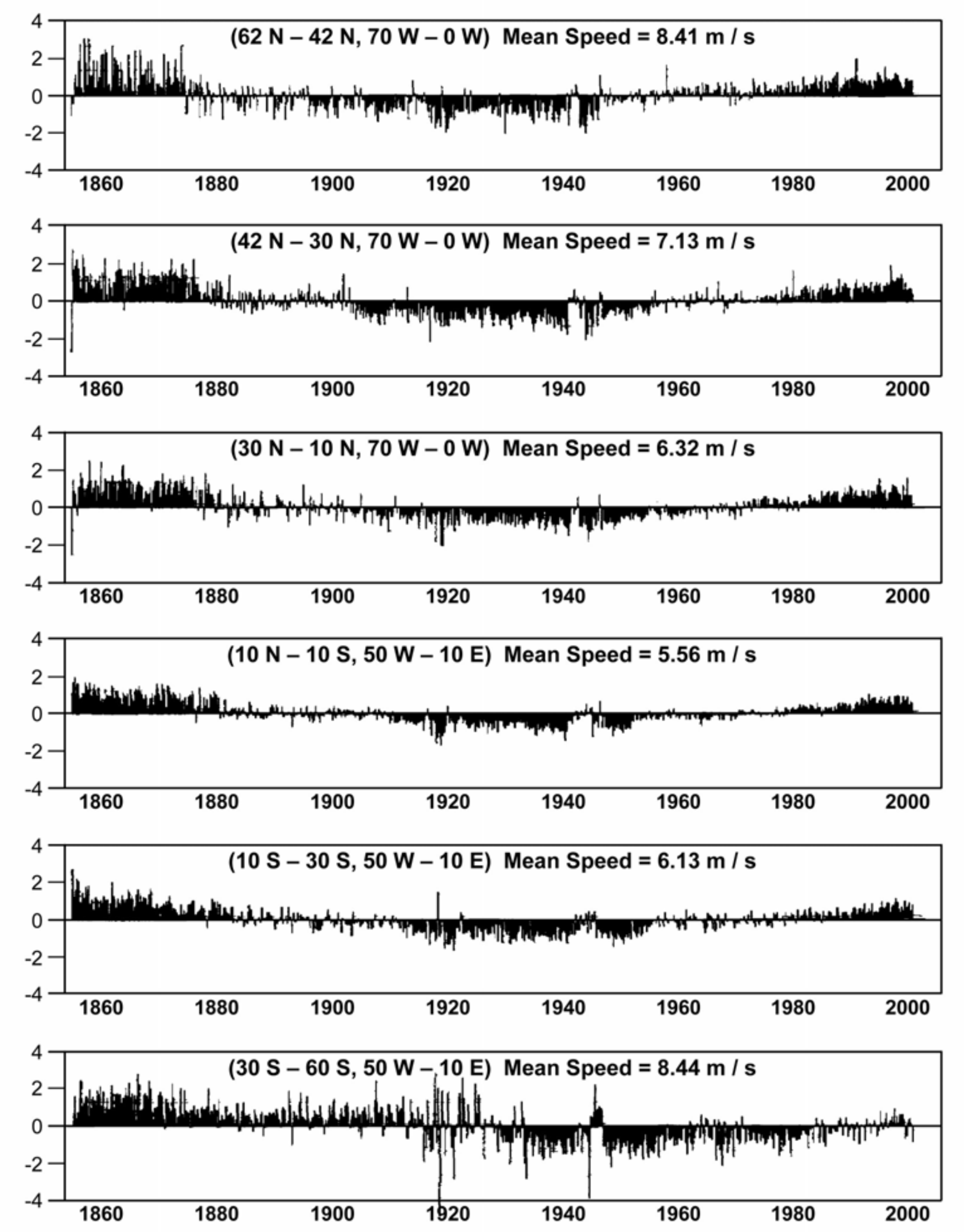
My annotation:

high solar activity correlates with low wind speed and warming, low solar activity with high wind speed and cooling.

→sea surface emissivity amplifies via positive feed-backs solar influence on climate.

→sole consideration of “solar forcing” without amplifier is not justified.

Atlantic Ocean Winter Wind Speed Departures, 1850 - 2000



Data from COADS (Comprehensive Ocean – Atmosphere Data Set)
http://www.cdc.noaa.gov/coads/
according to Sharp, G. D. „Future climate change and regional fisheries: a collaborative analysis",
FAO Technical Paper No. **452,** 75pp (2003)

- **Characteristic sinus-shaped fluctuations of winter wind speed in multi-decadal range around average wind speed.**
  Not chaotic fluctuation.
- **Same with Pacific and Indian Ocean.**
- **Indication of systematic forcing, amplified by sea water emissivity.**

Climate fluctuations in time scales of decades to millenia

Loehle, C., "Climate change: detection and attribution of trends from long-term geologic data", Ecological Modelling, **171**, 433-450 (2004)

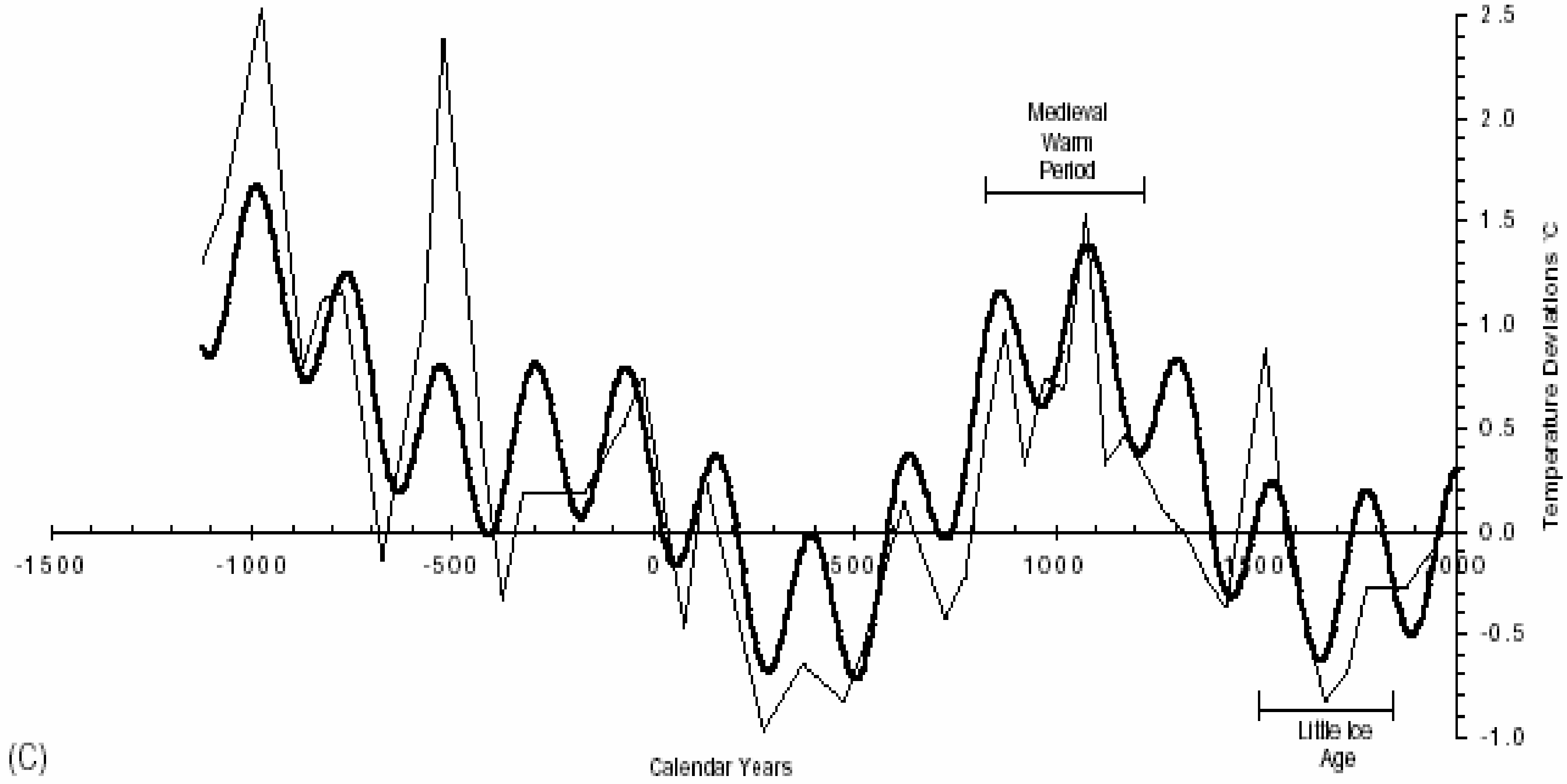
excerpts of summary

- If historical climate data exhibit regularities such as cycles, then these cycles may be considered to be the "normal" behaviour of the system, in which case deviations from the "normal" pattern would be evidence for anthropogenic effects on climate.
- Two 3000-year temperature series (South Africa and Bermuda Rise) with minimal dating error were analyzed.
- Of the seven models, six show a warming trend over the 20th Century similar in timing and magnitude to the Northern Hemisphere instrumental series. One of the models passes right through the 20th Century data. These results suggest that 20th Century warming trends are plausibly a continuation of past climate patterns.
- Anywhere from a major portion to all of the warming of the 20th Century could plausibly result from natural causes according to these results.

My annotation: the cyclic fluctuations described here may possibly be caused by *solar influence, amplified by sea water emissivity*.

Bermuda Rise (Sargasso Sea): data and cyclic fit

Loehle, C., "Climate change: detection and attribution of trends from long-term geologic data", Ecological Modelling, **171**, 433-450 (2004)



"The Medieval Warm Period of 800–1200 a.d. and the Little Ice Age of 1500–1850 a.d. (Broecker, 2001) are clearly seen in both the model and data."

Sea surface emissivity and climate sensitivity

Definition of climate sensitivity C_s :

$C_s = \Delta T / \sum \Delta F$

$\sum \Delta F$ = sum of all changes in forcings

Climate history matching between glacials and interglacials,
e. g. according to James Hansen:

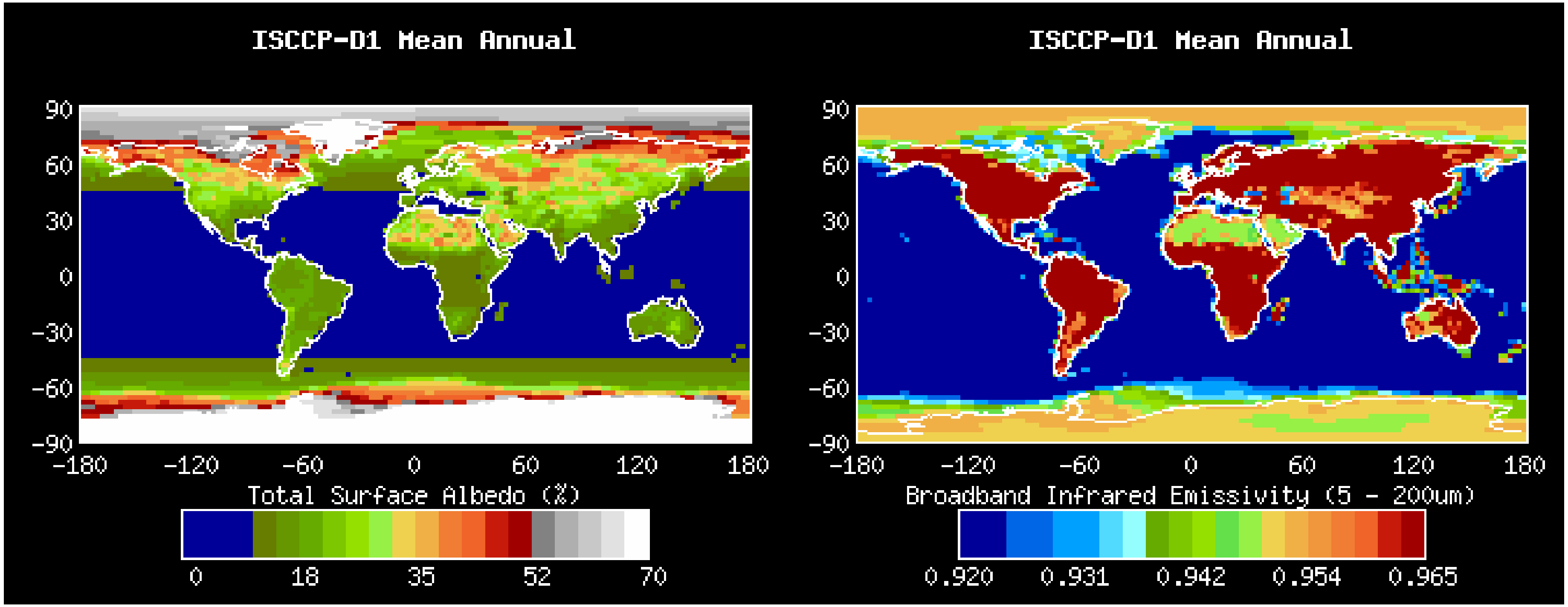
$\Delta T \sim 5$ K

$\sum \Delta F = \Delta F_{albedo} + \Delta F_{ghgs} + \Delta F_{aerosols} \sim 6.6$ W/m²

$\Longrightarrow$ $C_s \sim 0.75$ K per W/m²

BUT : ΔF sea surface emissivity ($\Delta F_{ss\varepsilon}$) between glacials and interglacials should not be neglected. $\sum$ **ΔF** becomes **substantially larger** and $\mathbf{C_s}$ becomes **substantially smaller** when $\Delta F_{ss\varepsilon}$ is included

Hypothesis:
Sea surface emissivity as driver of climate oscillations



- because of global land mass distribution Southern hemisphere has an energy surplus as compared to Northern hemisphere (effect of both albedo and surface emissivity)
- during glacials the energy gradient between equator / pole increases (changes in albedo and emissivity, specific insolation pattern, slow-down of THC?)
- for thermodynamic reasons any system tends to offset energy and temperature gradients
  ⟹ aprupt increases of wind strength between equator and poles, especially Northern hemisphere, climate oscillations
  ⟹ increased global loss of energy to space, global cooling

Summary and conclusions

- **From physical data generated in the context of satellite "remote sensing" it can be shown that wind dependant sea water thermal emissivity is a dominating climate parameter, also in comparison with anthropogenic atmospheric greenhouse gas and aerosol concentrations.**
- **The importance of this parameter can be traced and clearly identified in paleoclimatological as well as neoclimatological records.**
- **Disregard of sea surface emissivity leads to unrealistically high climate sensitivities when these are derived from climate history matches.**
- **By positive feedback mechanisms sea water emissivity characteristically contributes as an amplifier to natural climate fluctuations (glacial / interglacial; other cycles, possibly of solar origin).**
- **Sea water emissivity amplified the solar influence on climate during medieval warm period and little ice age.**


Sea Water IR-Emissivity
A Neglected Climate Forcing
THANKS FOR YOUR ATTENTION !