

••••

# Hot temperatures and storm surges: Modelling the change of climate extremes

Andreas Sterl

**KNMI, De Bilt, Netherlands**

- Climate system
- Climate change
- Climate modelling
- Climate extremes
  - Hot temperatures
  - North Sea storm surges

••••

Henk van den Brink, Gerrit Burgers, Henk Dijkstra, Reindert Haarsma,  
Andreas Sterl, SEAMOCs, Mail  
Wilco Hazeleger, Erik van Meijgaard, Camiel Severijns, Hans de Vries

••••

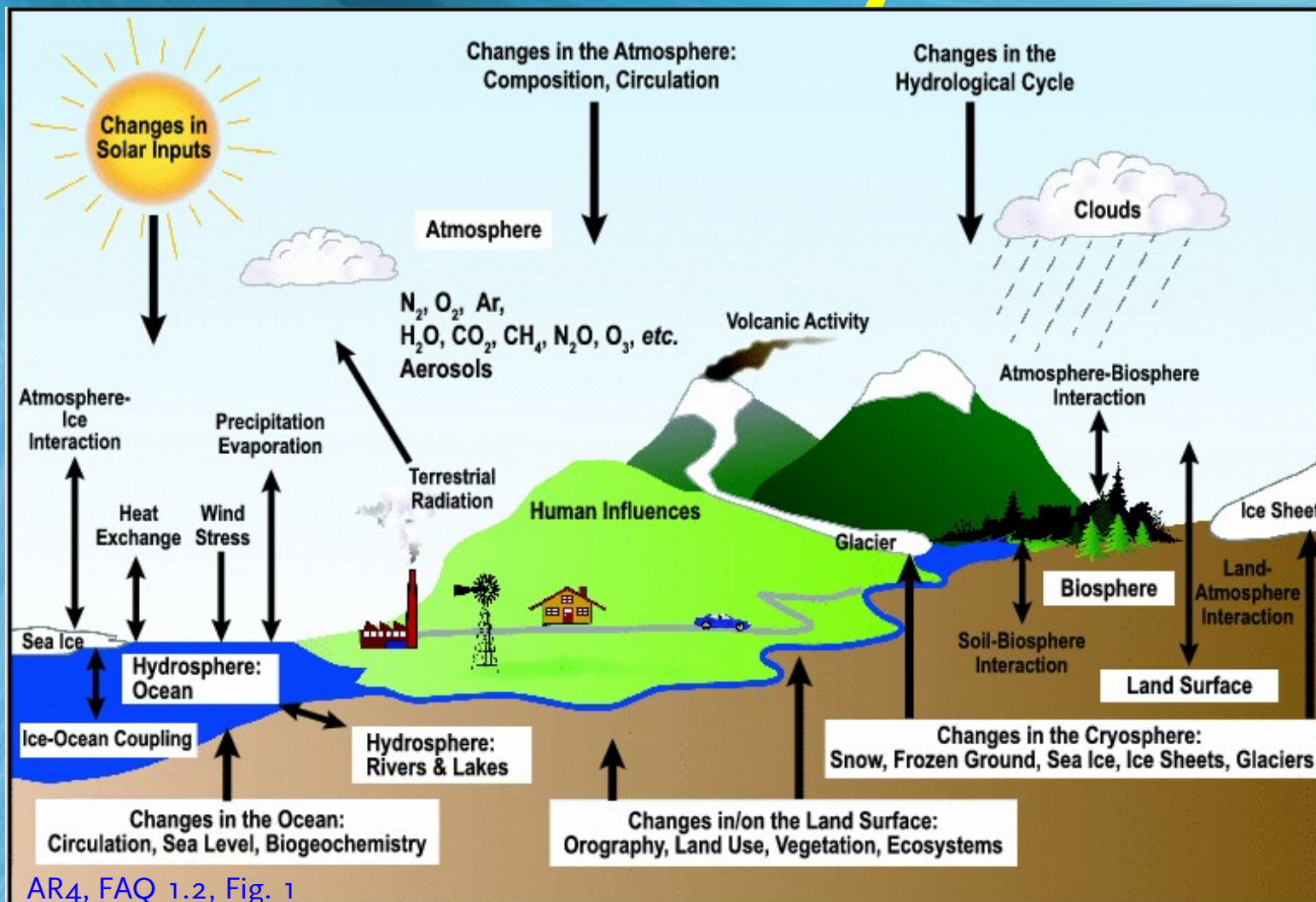
# Climate – what's that?

Climate = statistics of weather

Weather = state of atmosphere at a particular time

“Climate is what you expect,  
weather is what you get”

# The climate system



AR4, FAQ 1.2, Fig. 1

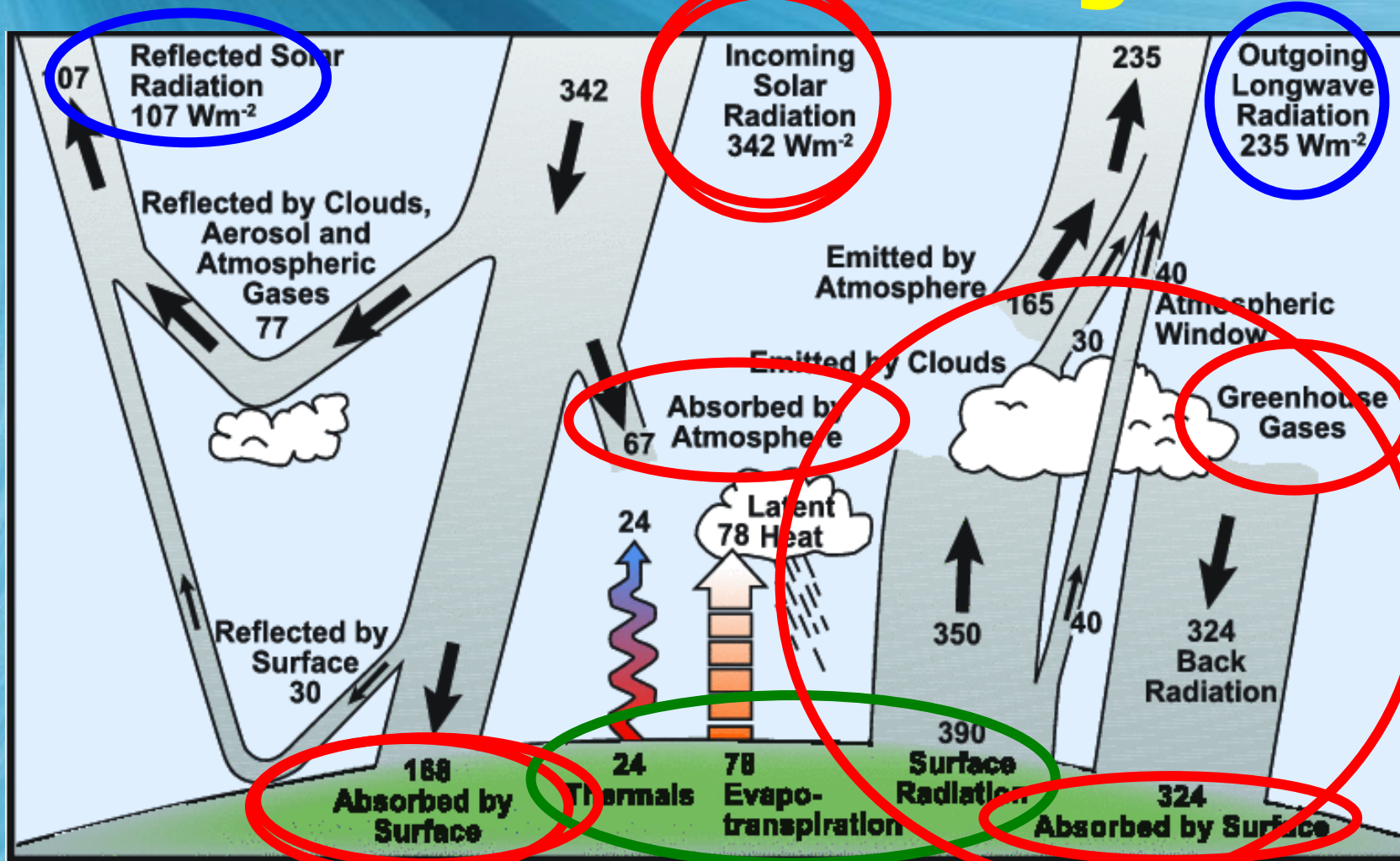


# How does the climate system work?

- short-wave radiation (sun) heats (tropics)
- atmosphere and ocean transport heat poleward (modulated by continents)
- long-wave radiation into space cools



# Radiative forcing



AR4, FAQ 1.1, Fig. 1

Andreas Sterl, SEAMOCS, Mali

# Greenhouse effect

Outgoing longwave radiation is absorbed in the atmosphere and radiated back to the surface.

without:  $T_{\text{glob}} = -15^{\circ}\text{C}$

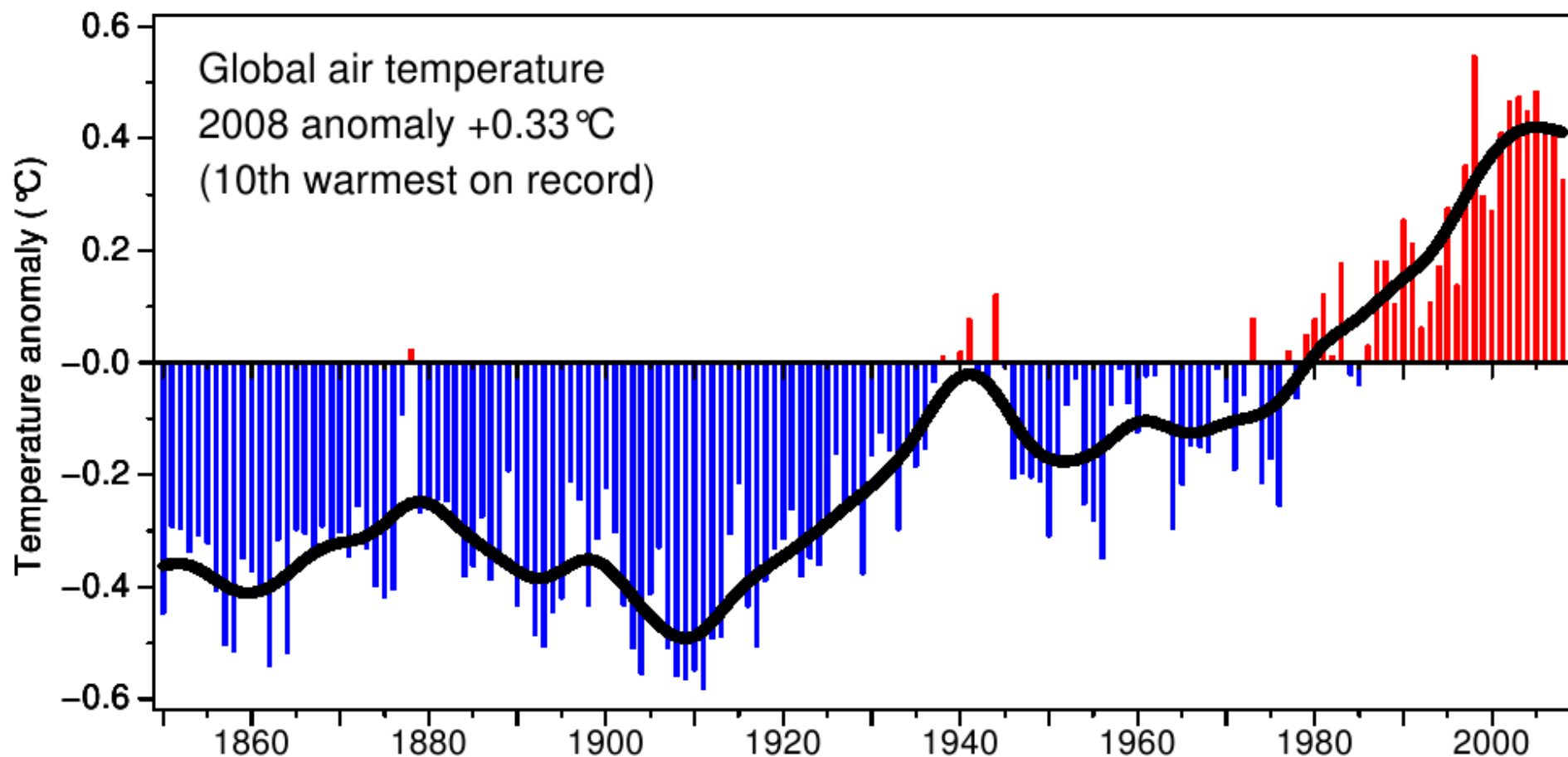
observed:  $T_{\text{glob}} = +15^{\circ}\text{C}$

# Greenhouse gases

only 1 % of atmosphere

- $H_2O$  70 %  $\leq$  feedback ( $\sim 2x$ )
- $CO_2$  15 %
- $CH_4$  )
- $N_2O$  ) 5 %
- Ozone, ...)
- (clouds 10 %)  $\leq$  feedback (?)

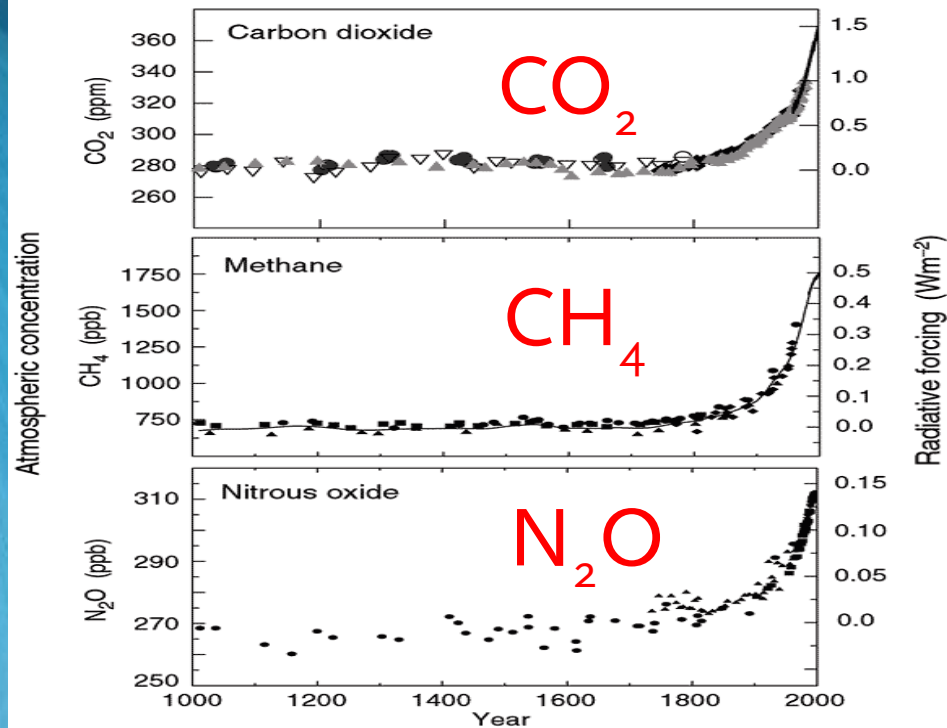
# The past 159 years



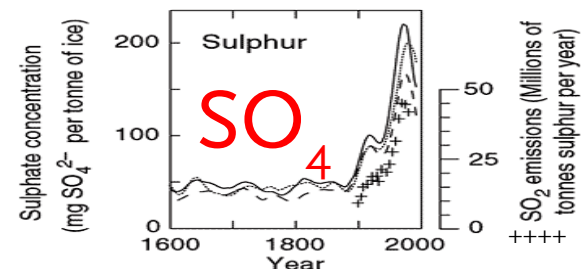
# Increasing GHG concentrations

## Indicators of the human influence on the atmosphere during the Industrial Era

(a) Global atmospheric concentrations of three well mixed greenhouse gases



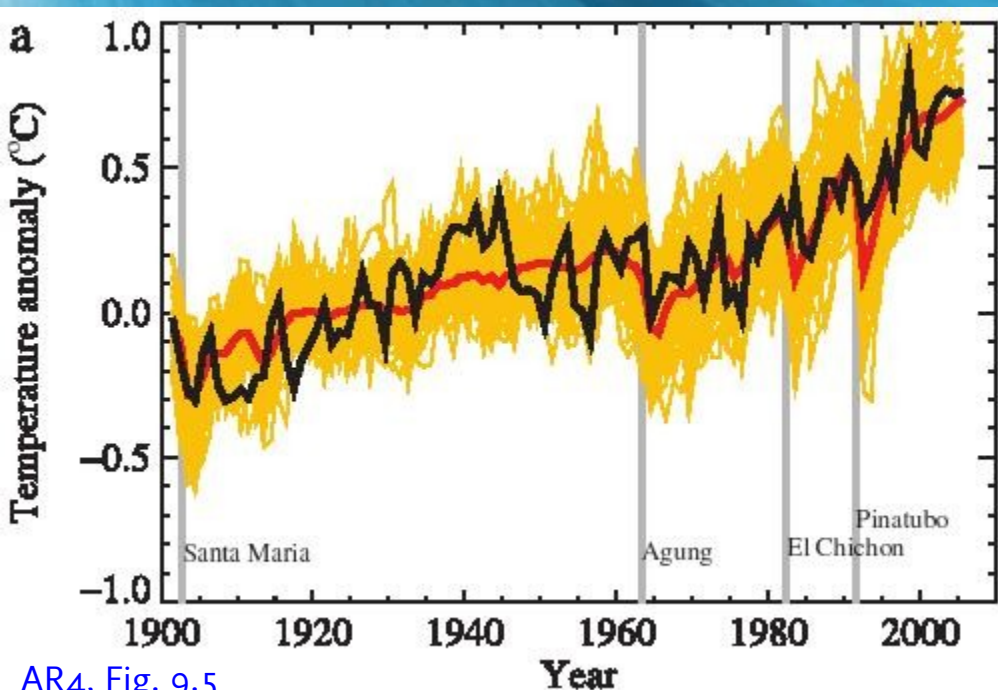
(b) Sulphate aerosols deposited in Greenland ice



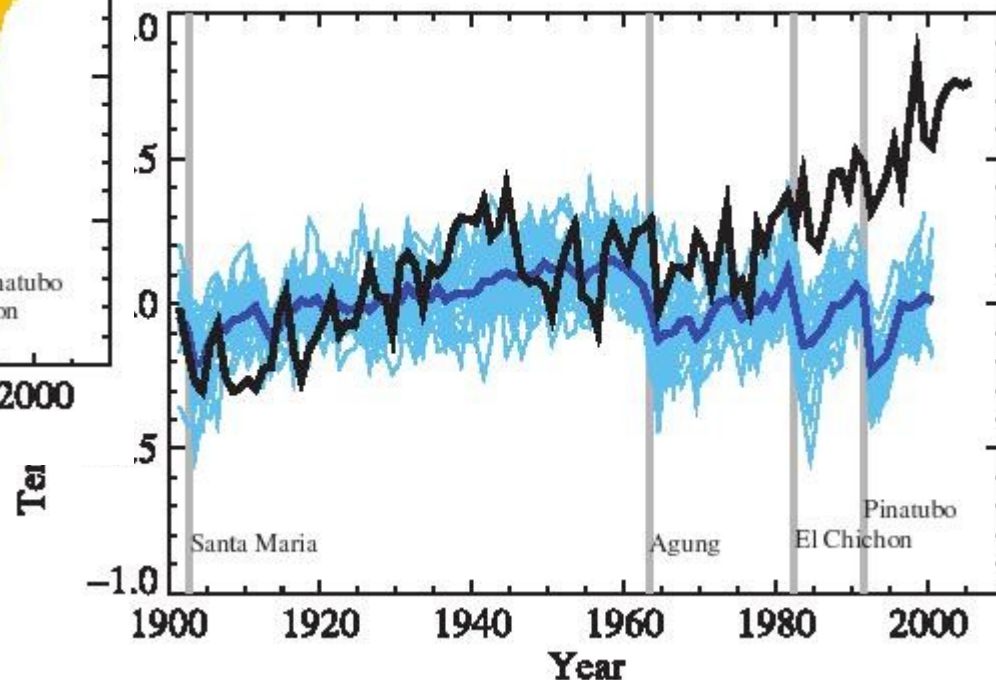
(IPCC, 2001, Fig. SPM-2)

Andreas Sterl, SEAMOCS, Mali

# Simulations



$\leftarrow$  multi model, all forcings



AR4, Fig. 9.5

Multi model, natural forcings =>



# Projections

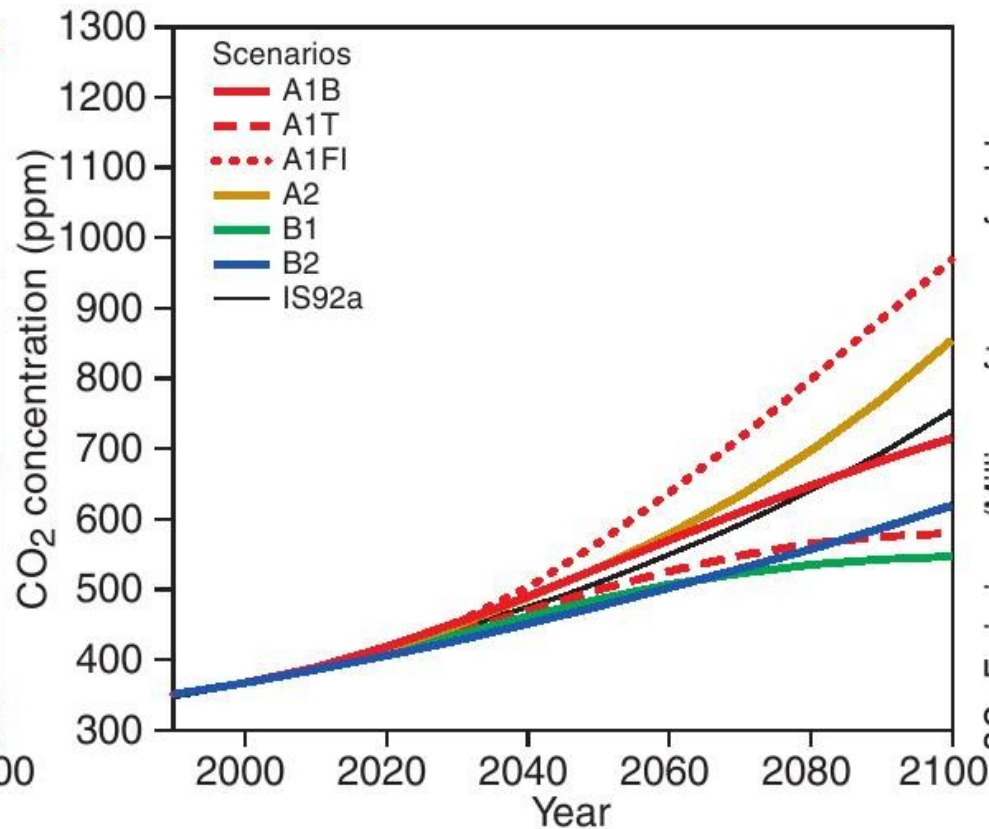
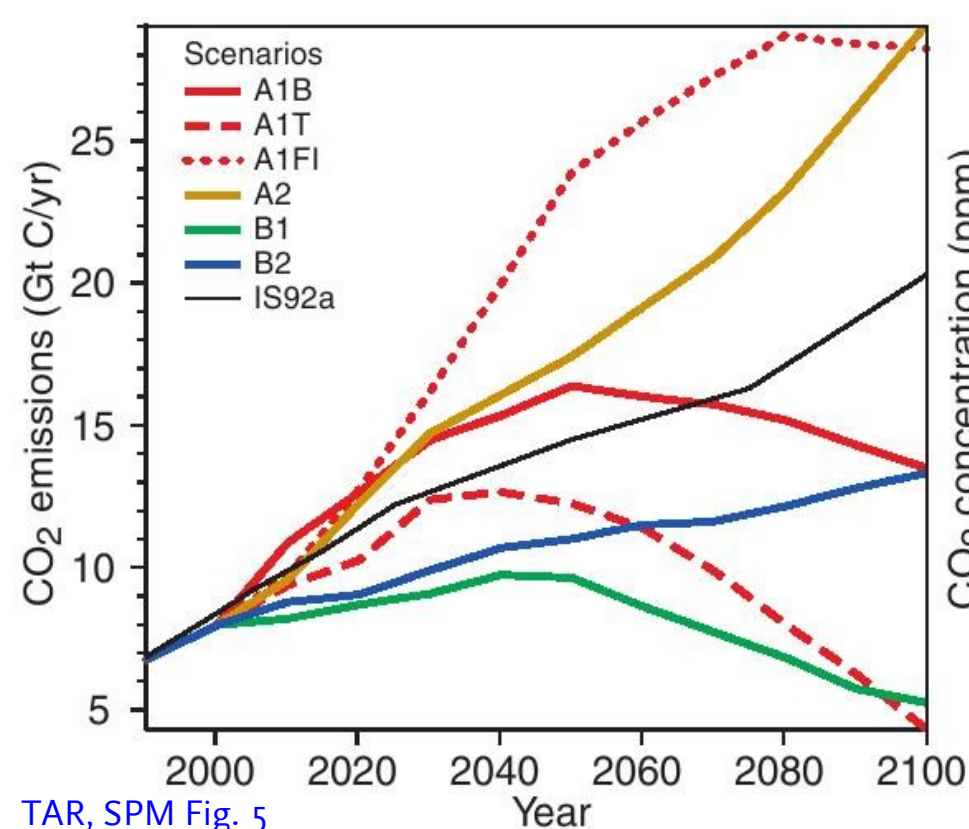
- Scenarios  
“How will the world change?”
- Scenarios => CO<sub>2</sub> emissions and concentrations
- CO<sub>2</sub> concentrations => climate



# Emission scenarios

(a) CO<sub>2</sub> emissions

(b) CO<sub>2</sub> concentrations

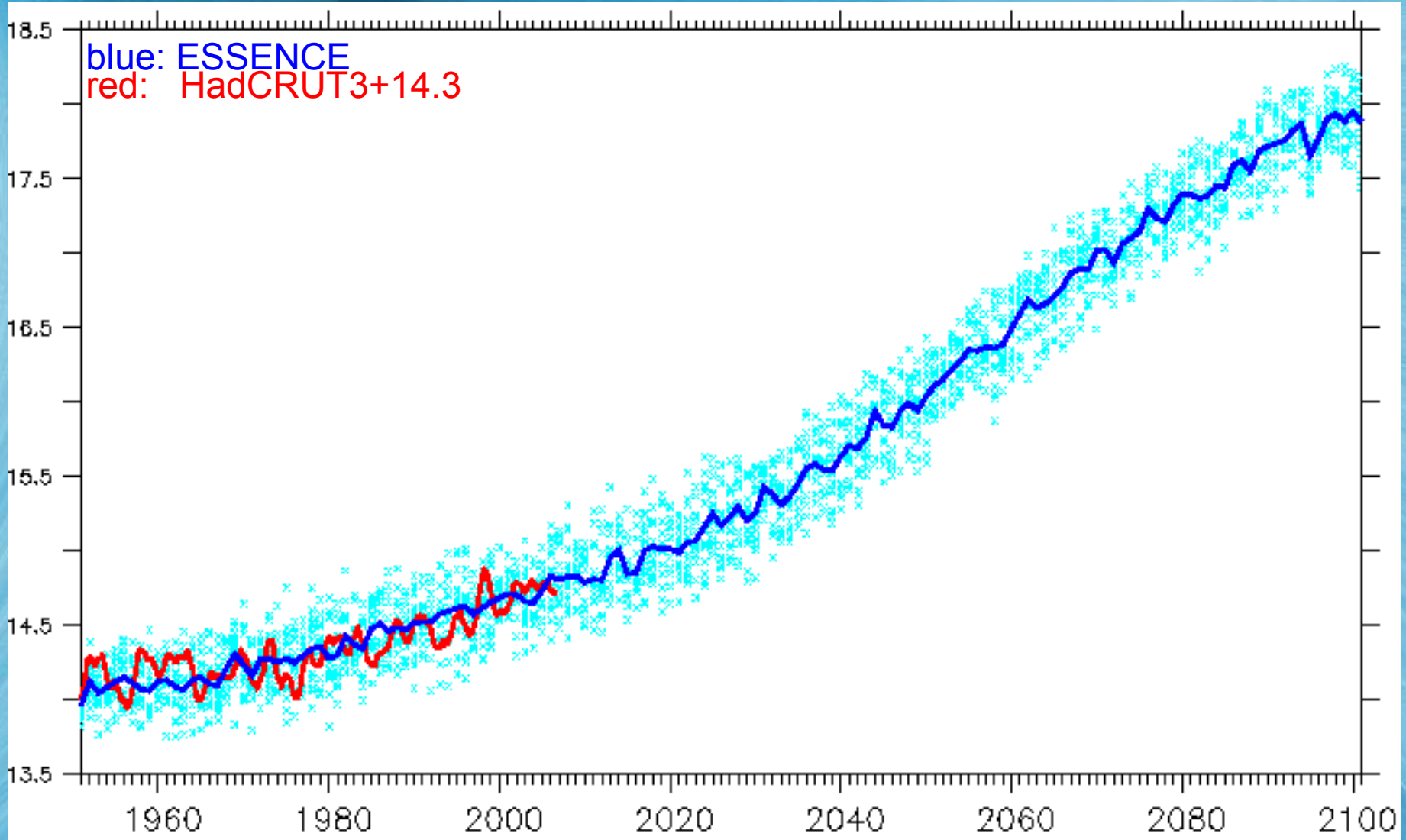


TAR, SPM Fig. 5

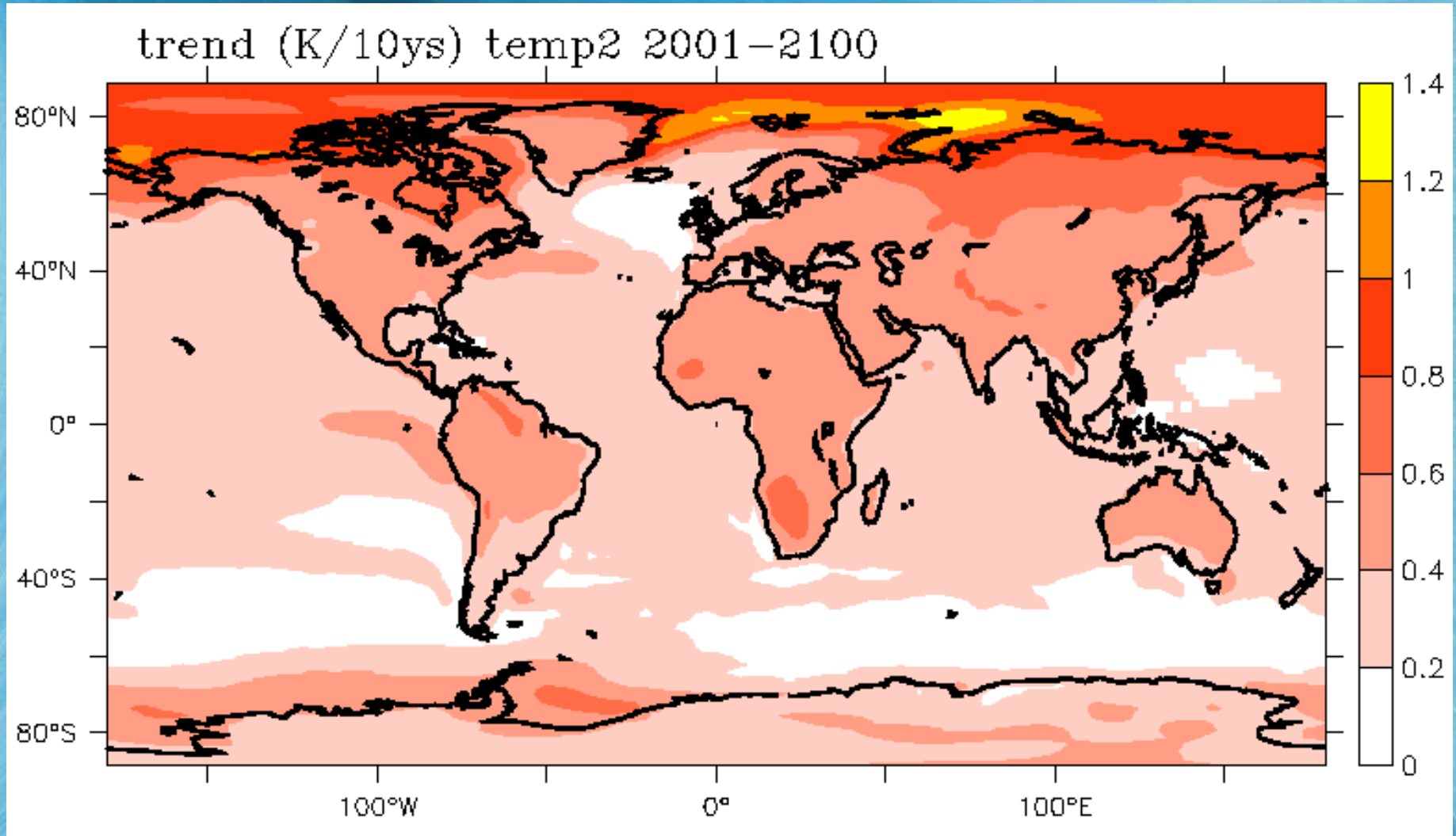
# ESSENCE

- ECHAM<sub>5</sub>/MPI-OM
- observed GHG's – SRES A1b
- 1950 – 2100
- 17 runs => good statistics

# Global mean temperature



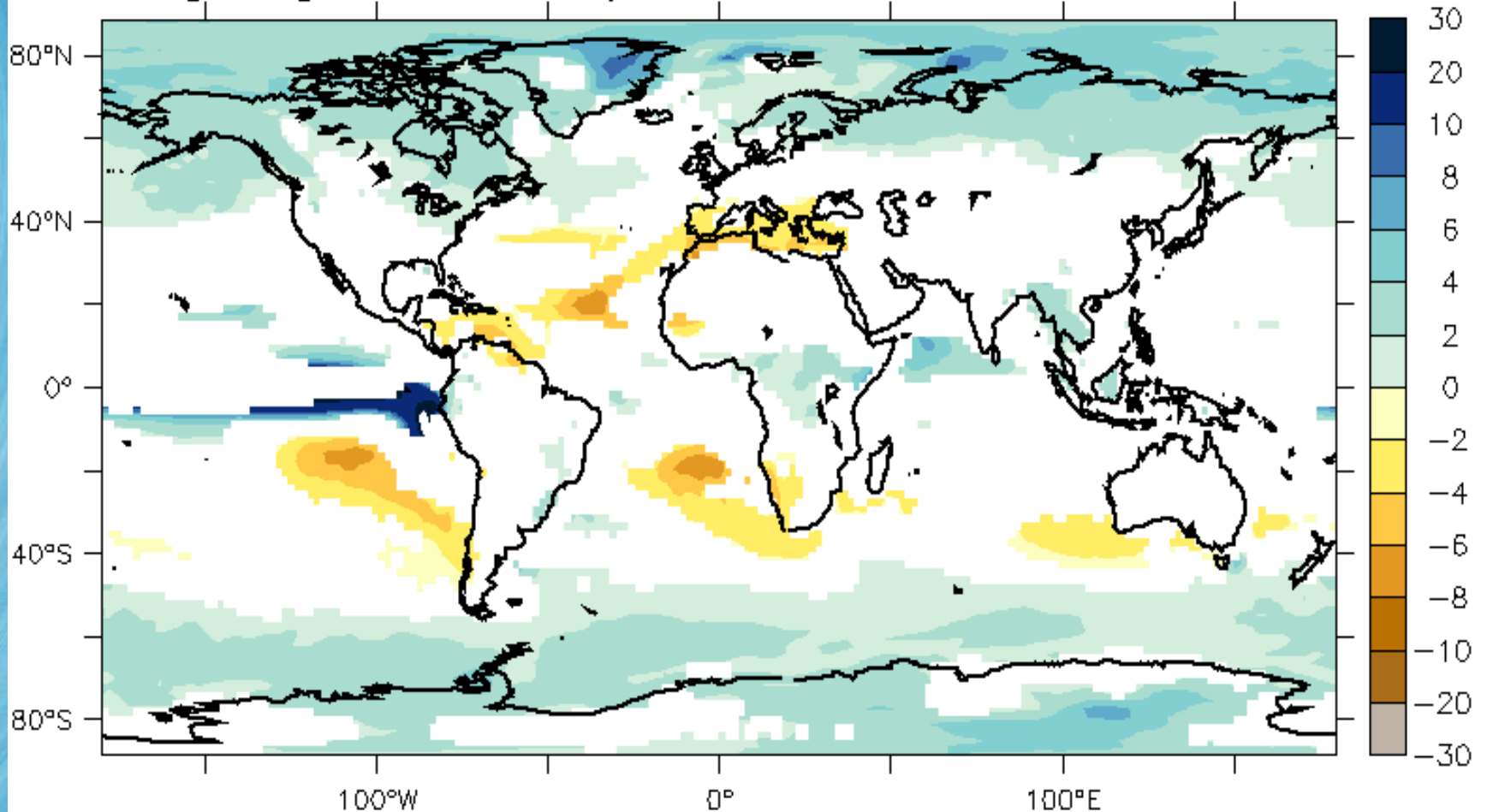
# Temperature trend



# Precipitation

.....

trend precip 2001-2100 year



••••

# The N-year return value - 1

- value that on average occurs once per N years
- obtained by fitting a GEV to annual maxima ( $x$ ):

$$G(x) = \exp \left\{ - \left[ 1 + \xi \left( \frac{x - \mu}{\sigma} \right) \right]^{-1/\xi} \right\}$$

$\mu$ : location

$\sigma$ : scale

$\xi$ : shape

••••

# •••• The N-year return value - 2

$$G(x) = \exp \left\{ - \left[ 1 + \xi \left( \frac{x - \mu}{\sigma} \right) \right]^{-1/\xi} \right\}$$

defined for  $1 + \xi \left( \frac{x - \mu}{\sigma} \right) > 0$

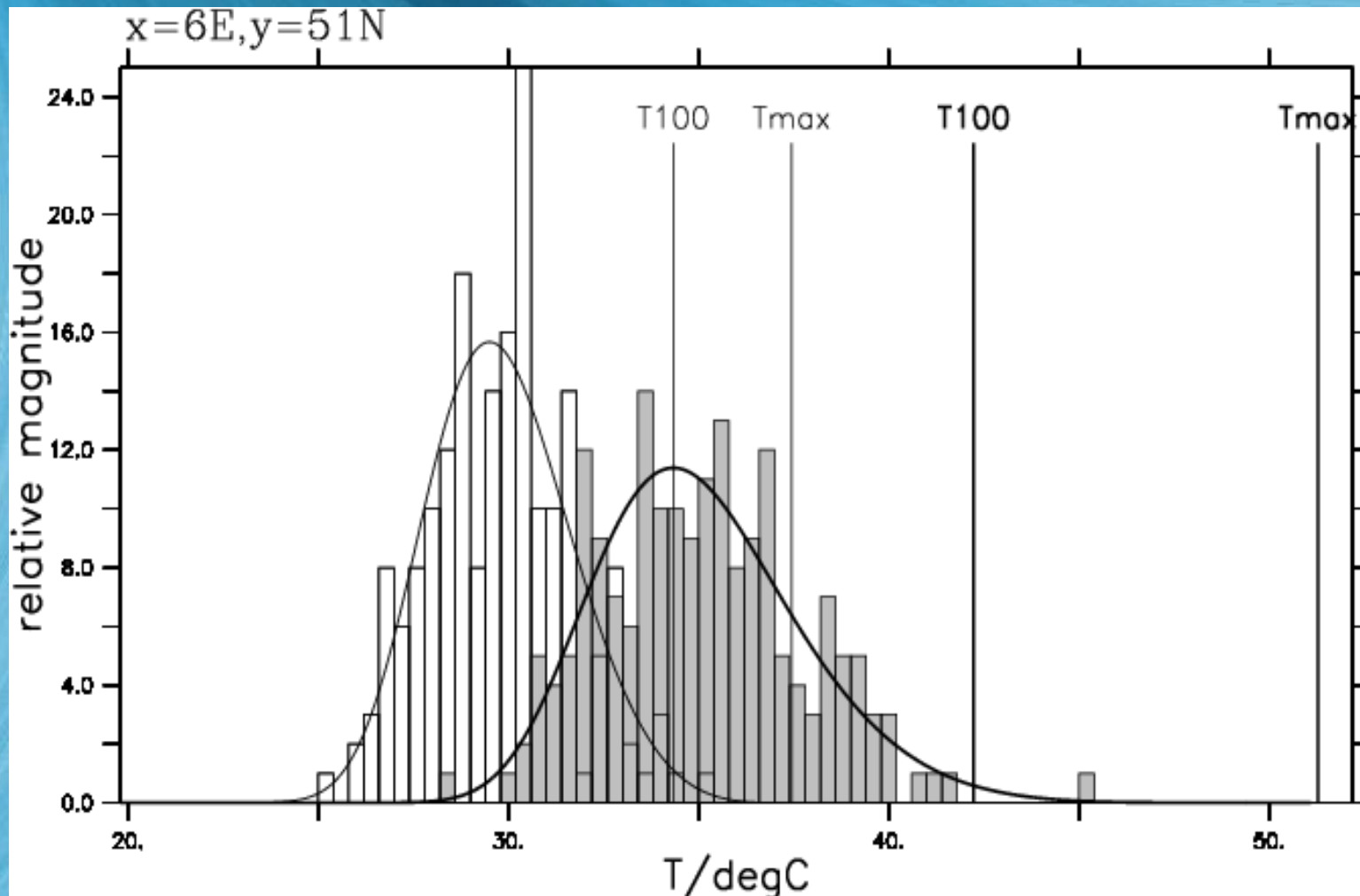
=> bounded by  $x_{\max} = \mu - \sigma/\xi$  for  $\xi < 0$

return time  $T(x)$  for level  $x$  is  $1 - 1/T(x)$  percentile:

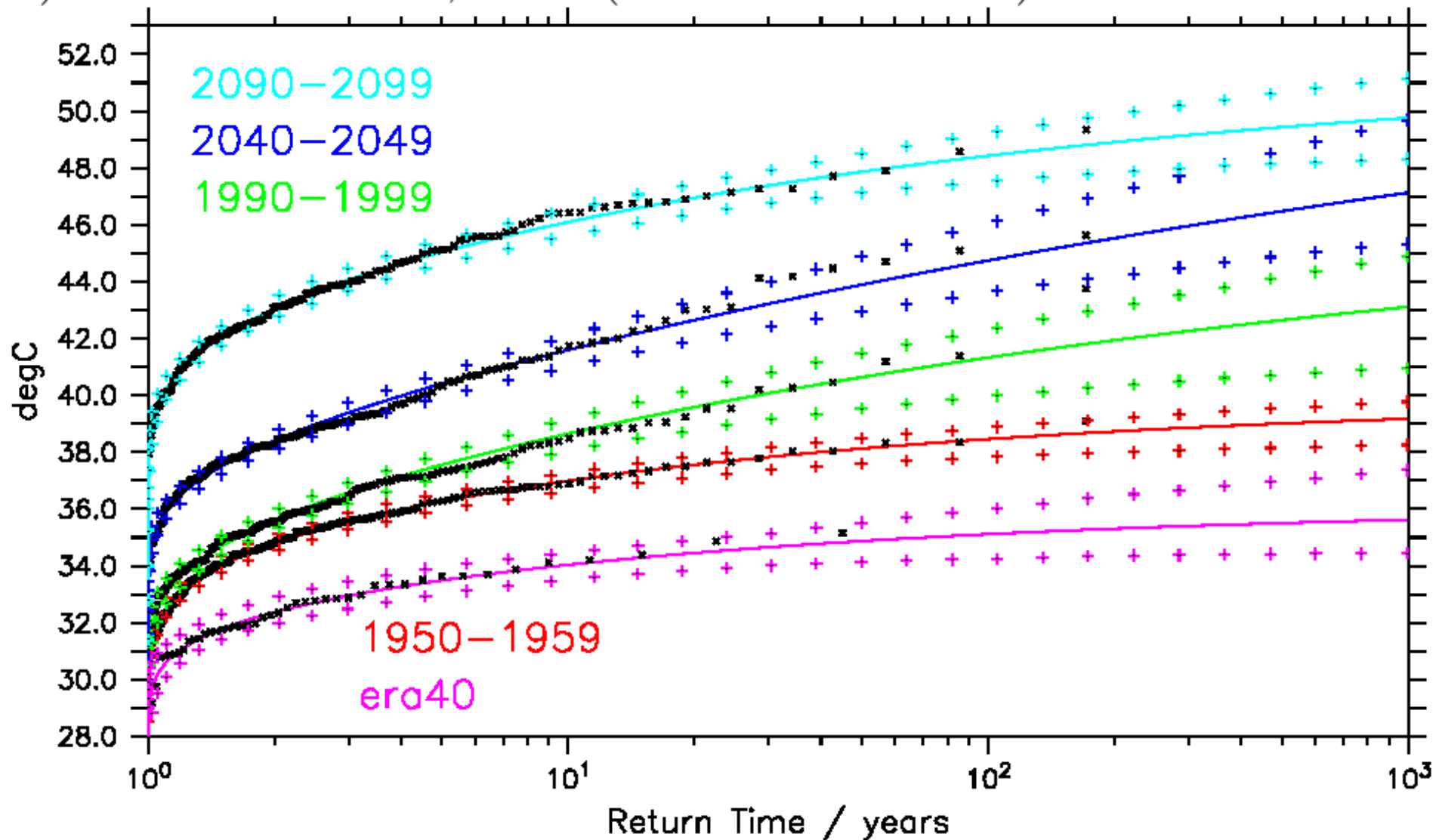
$$T(x) = \frac{1}{1 - G(x)}$$

••••

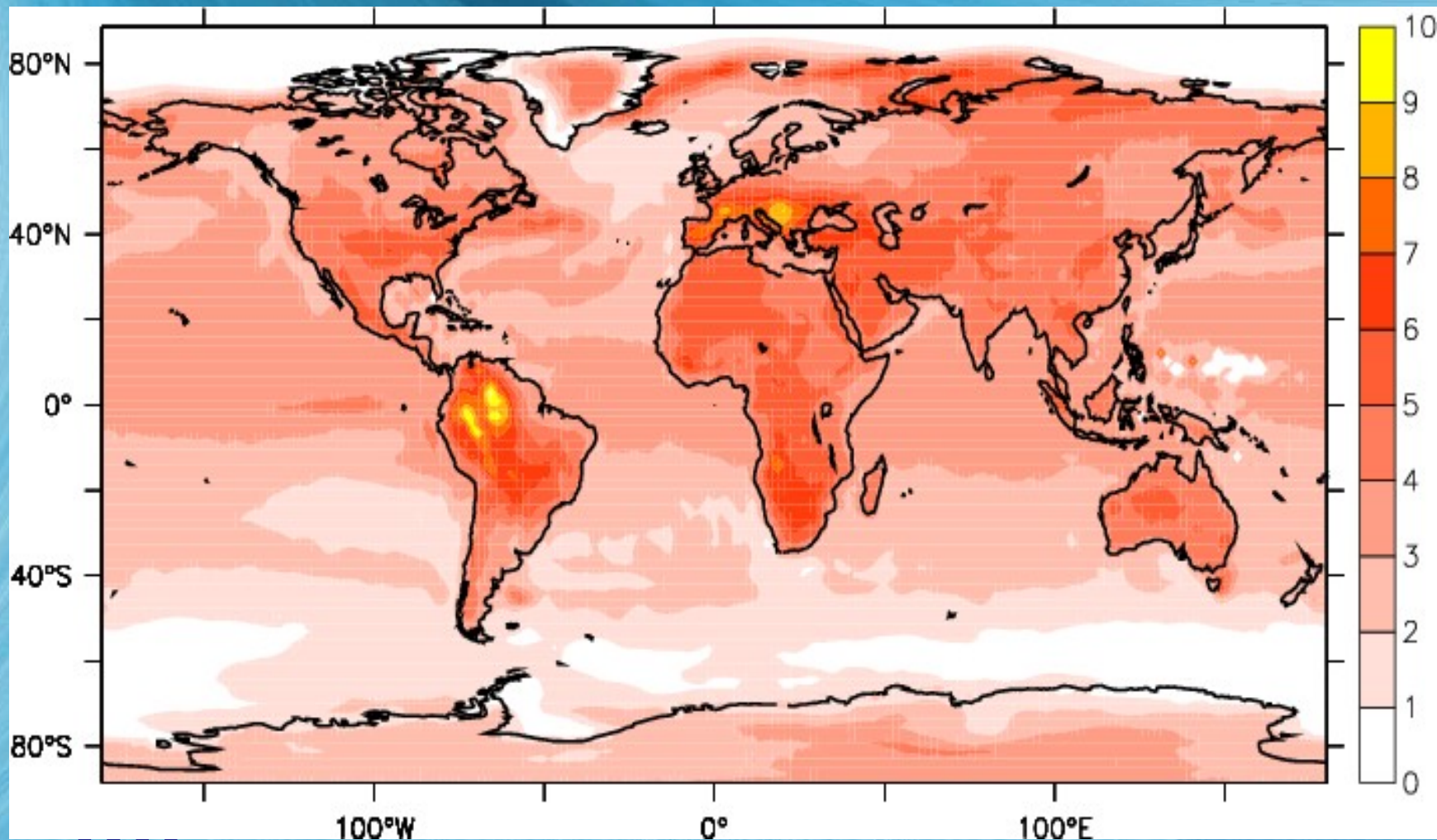
# ... Example: Netherlands



# a) GEV-fit at 2°E, 42°N (Southern France)

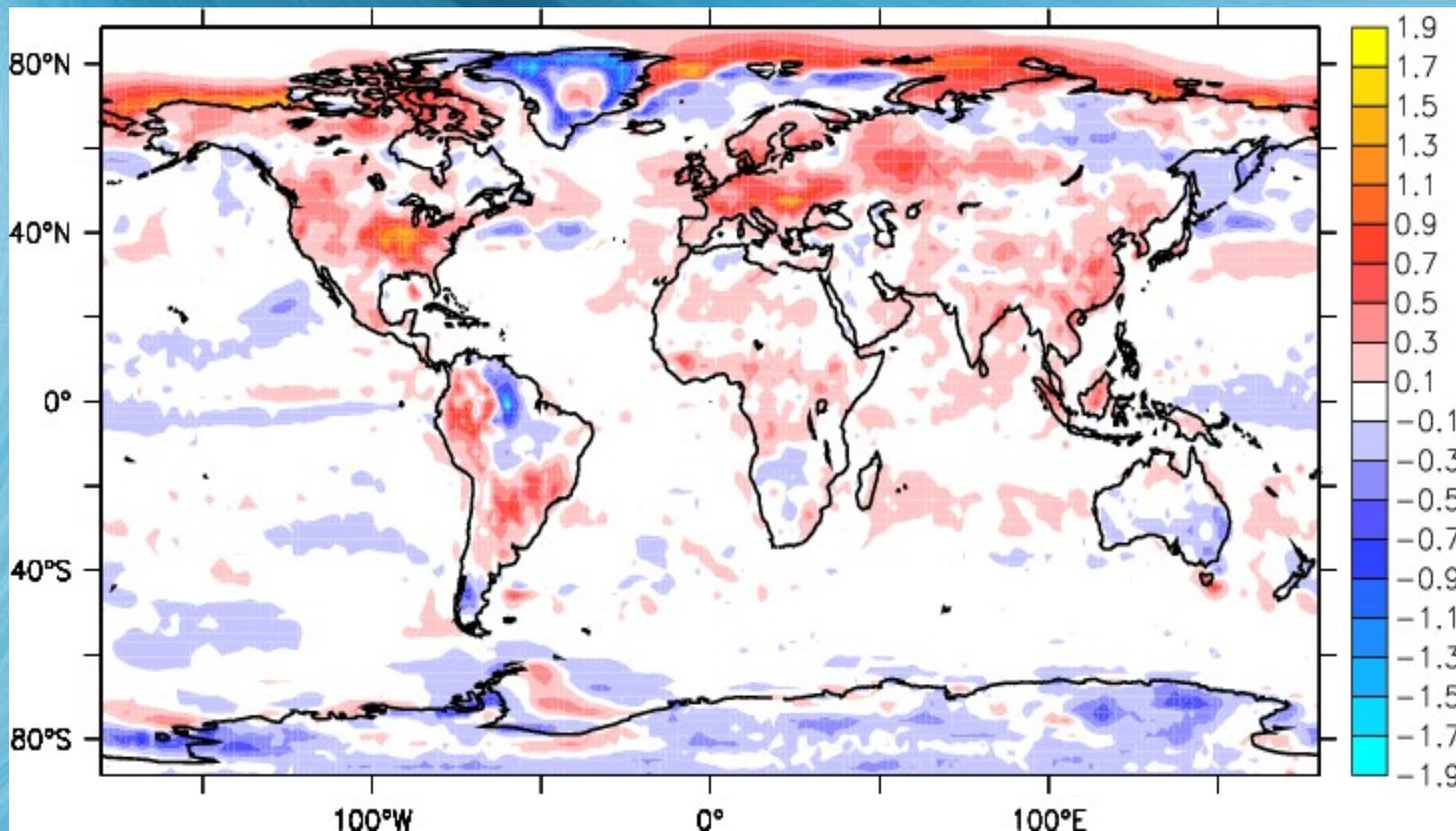


$\Delta\mu$

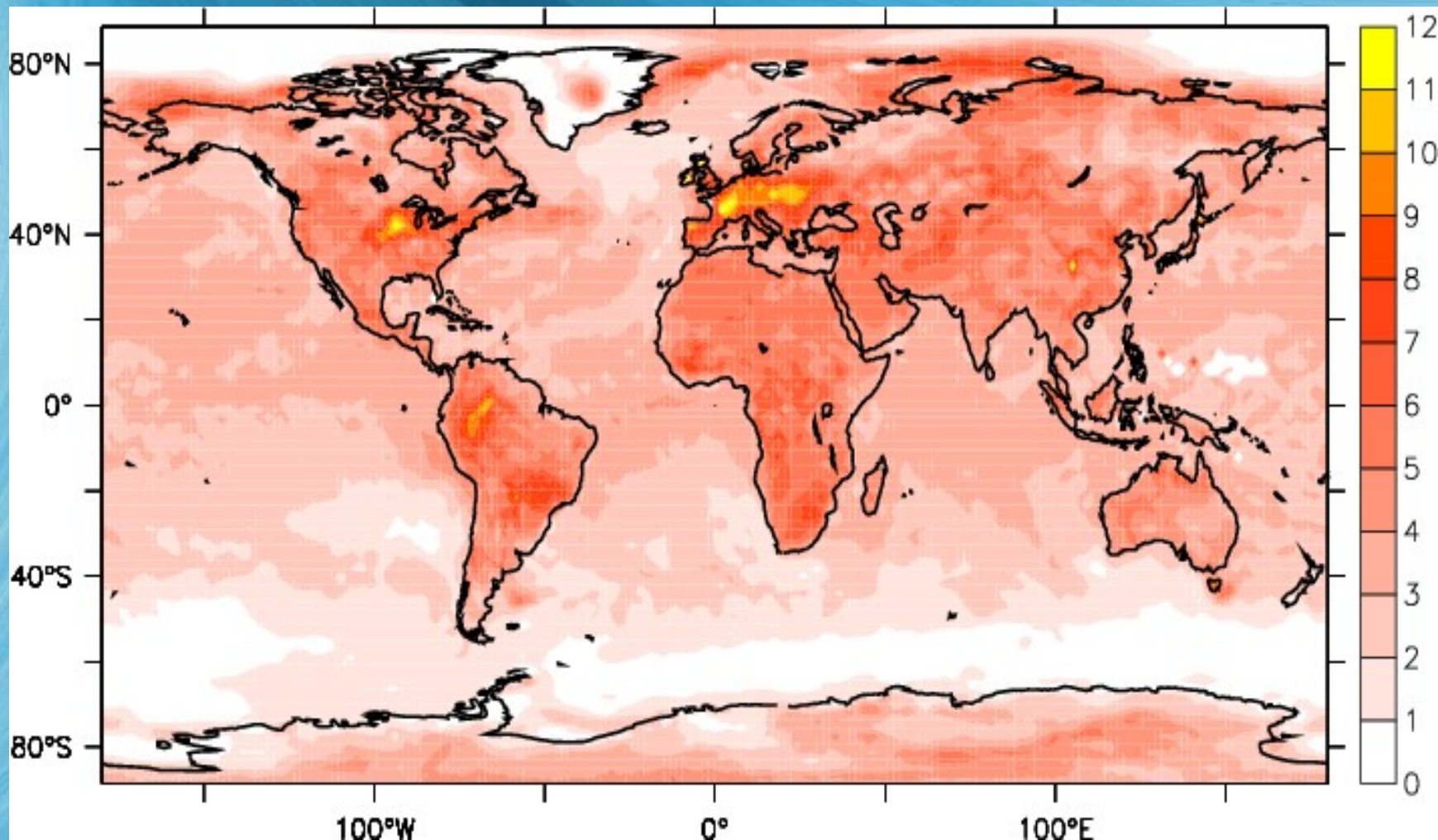


Andreas Sterl, SEAMOCS, Malt

$\Delta\sigma$

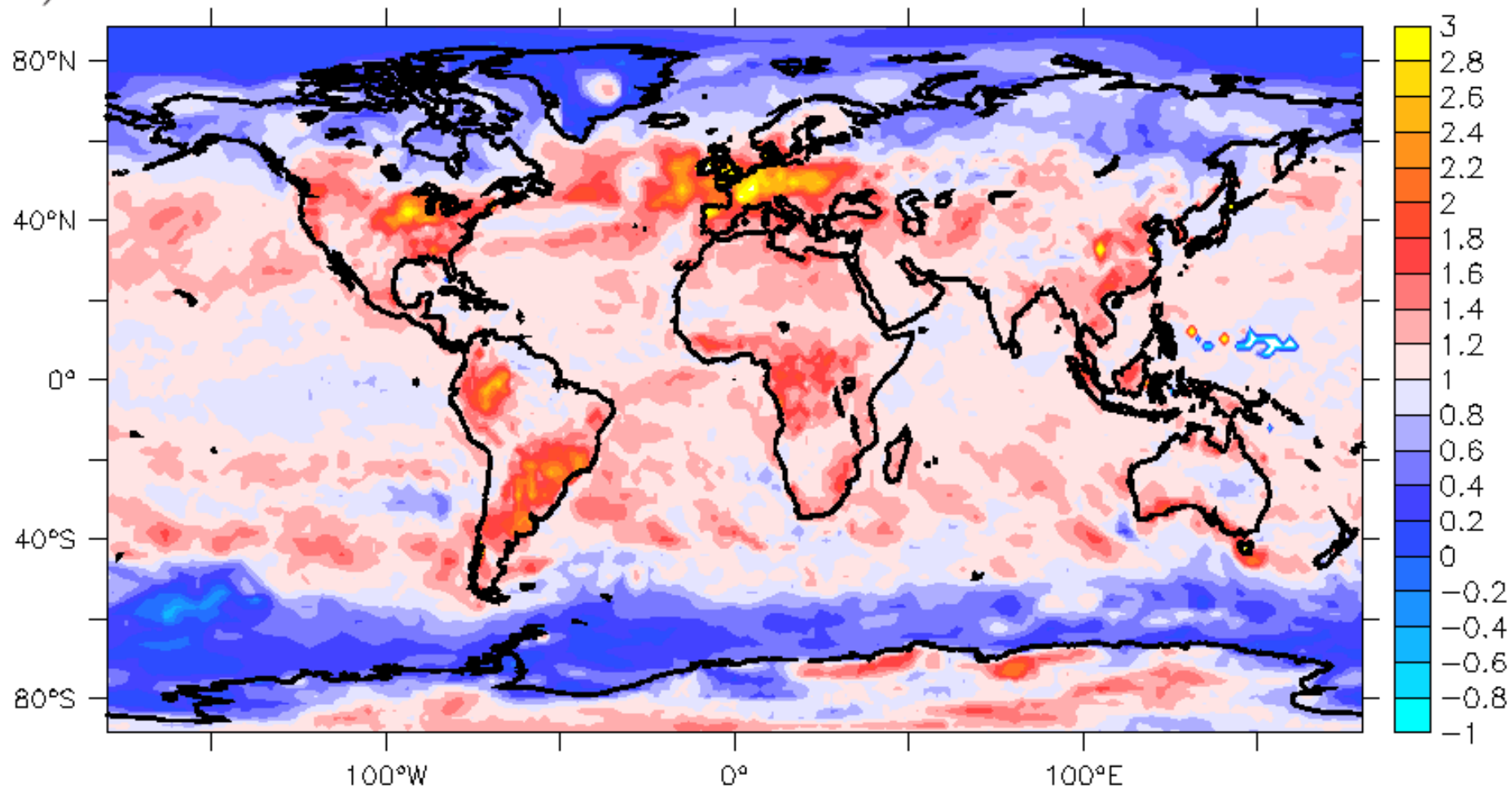


$\Delta T_{100}$



$$\Delta T_{100} / \Delta T_{\text{mean}}$$

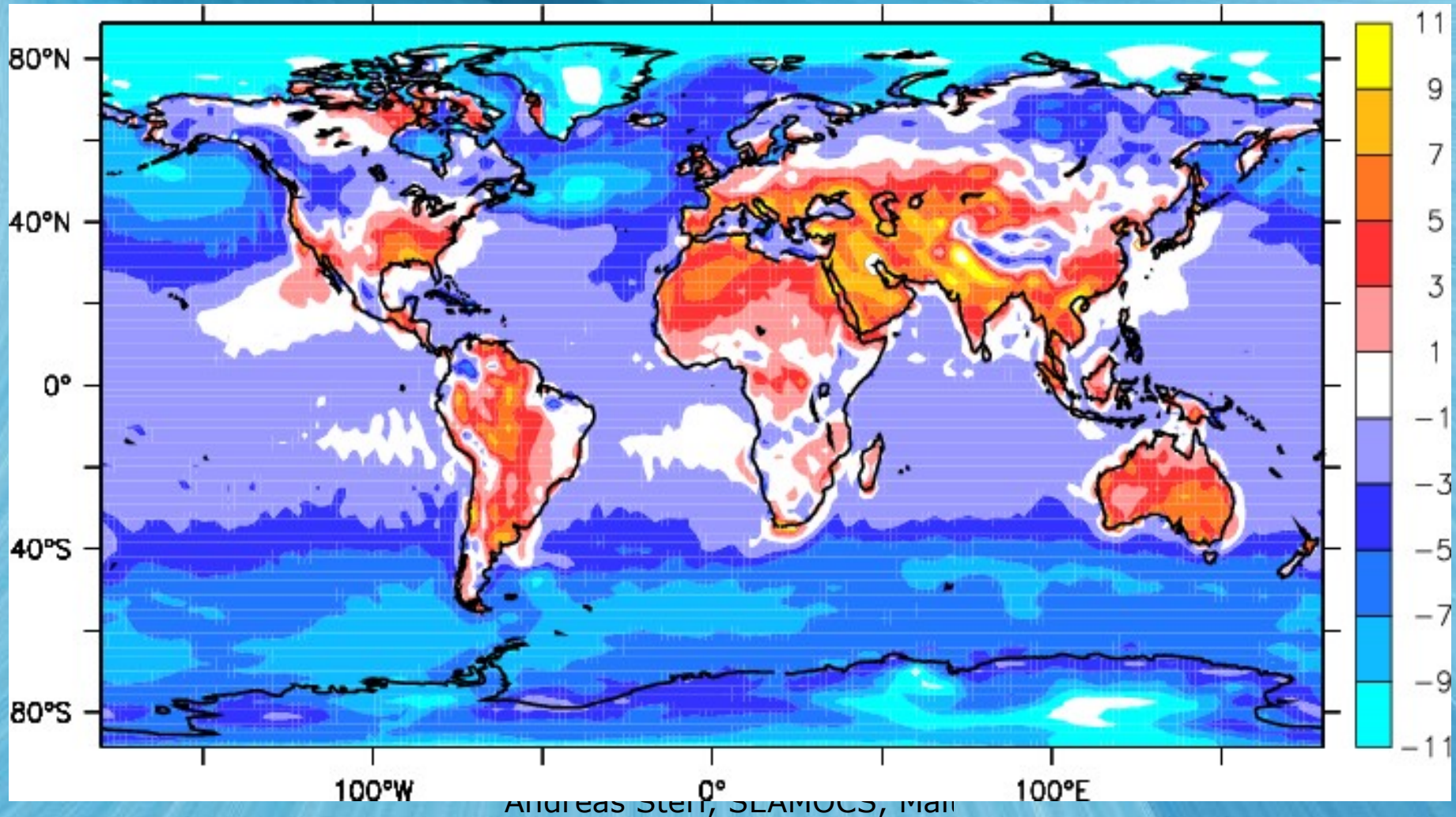
a)  $\Delta T_{100}$



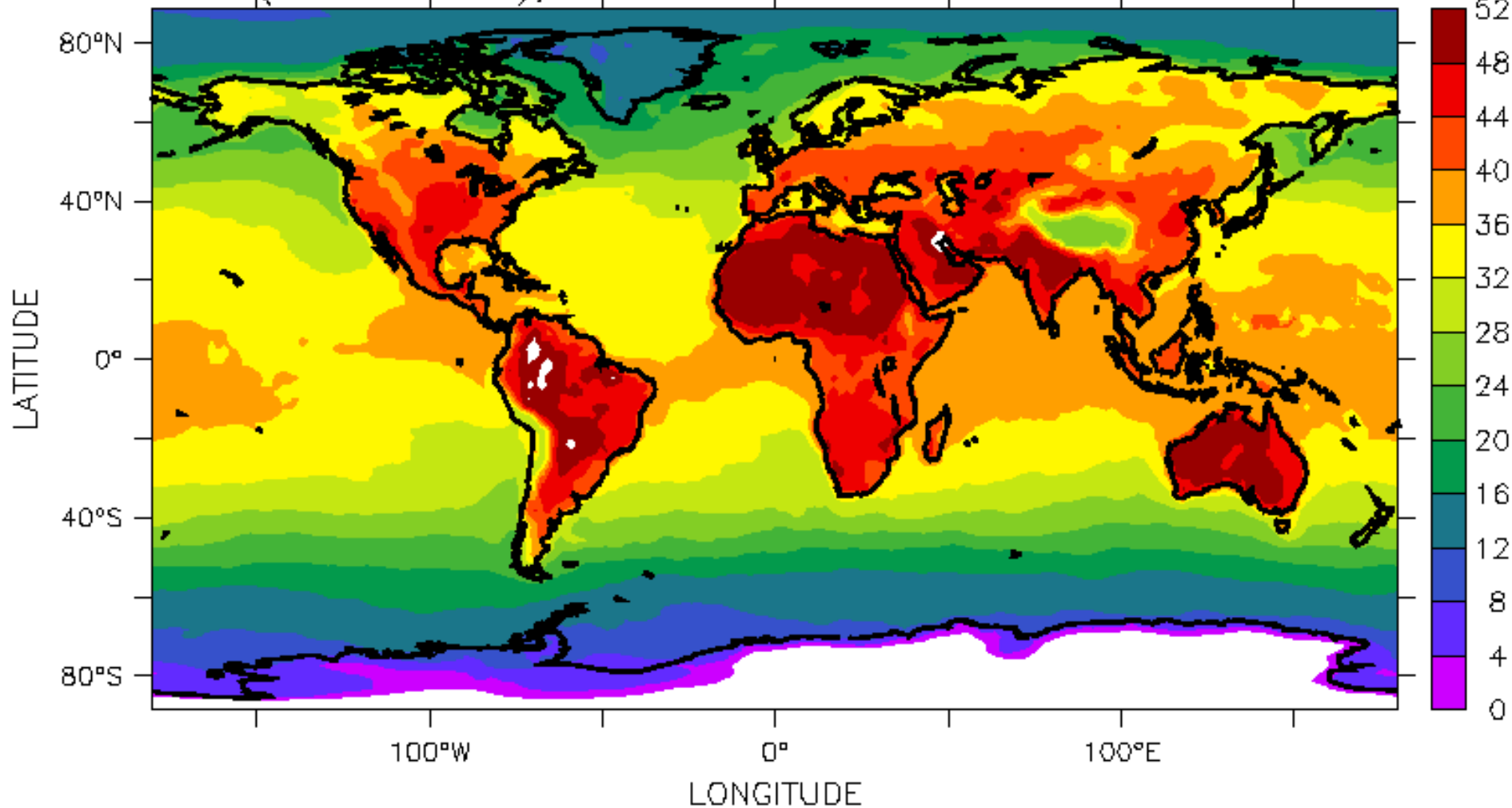
# Model bias

.....

$$T_{100}(\text{ESS}) - T_{100}(\text{ERA-40})$$



T100(2070-2100), bias corrected





## Dutch Delta Committee:

### What is the effect of global warming on

- maximum wind speed
- wind directions
- wave heights
- storm surge levels?

### Approach

- KNMI'06 scenarios
- other literature
- Essence + WAQUA



# Essence + WAQUA

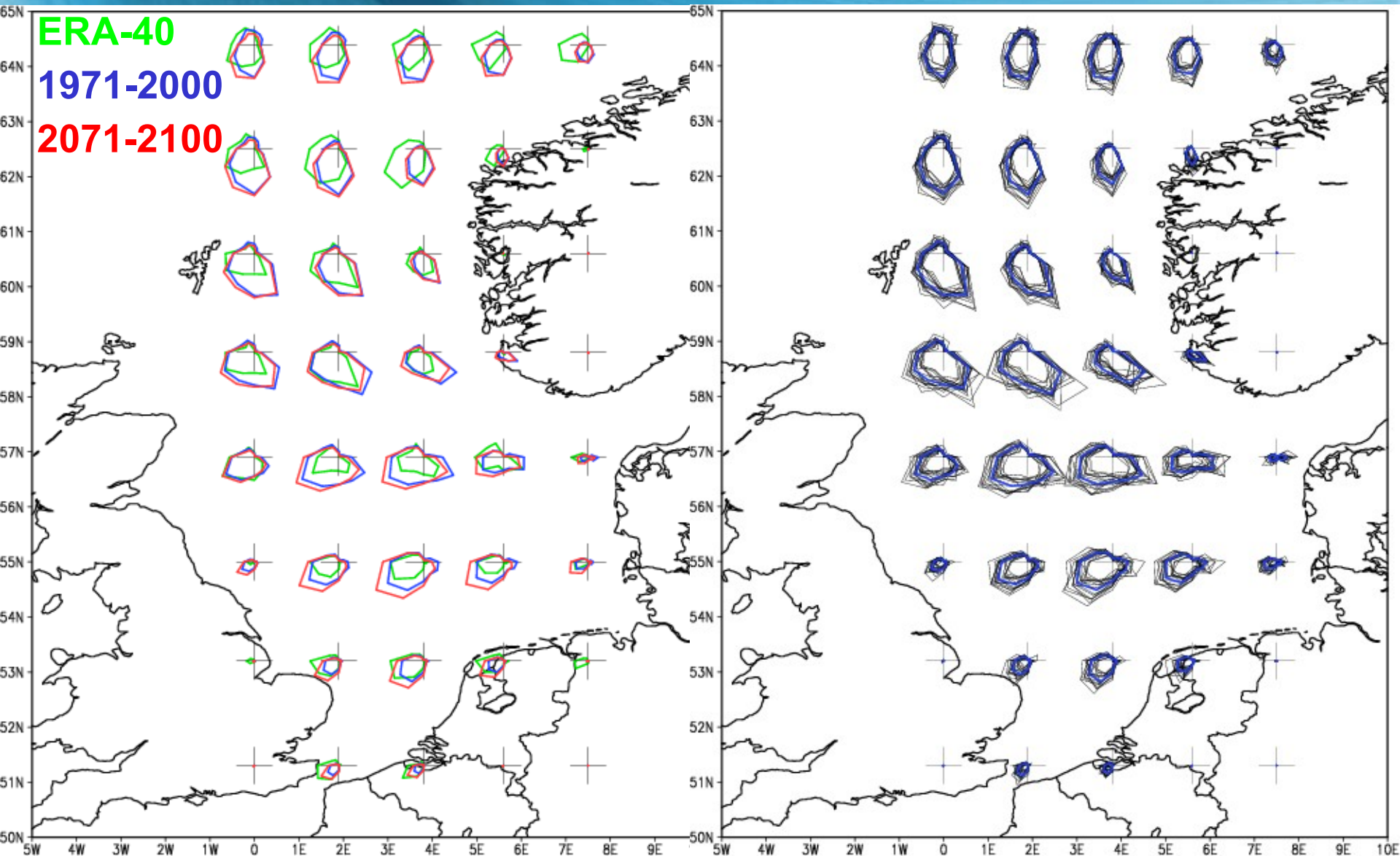
## Essence

- ECHAM5/MPI-OM
- 17-member ensemble
- 1950-2100, SRES A1b

## WAQUA

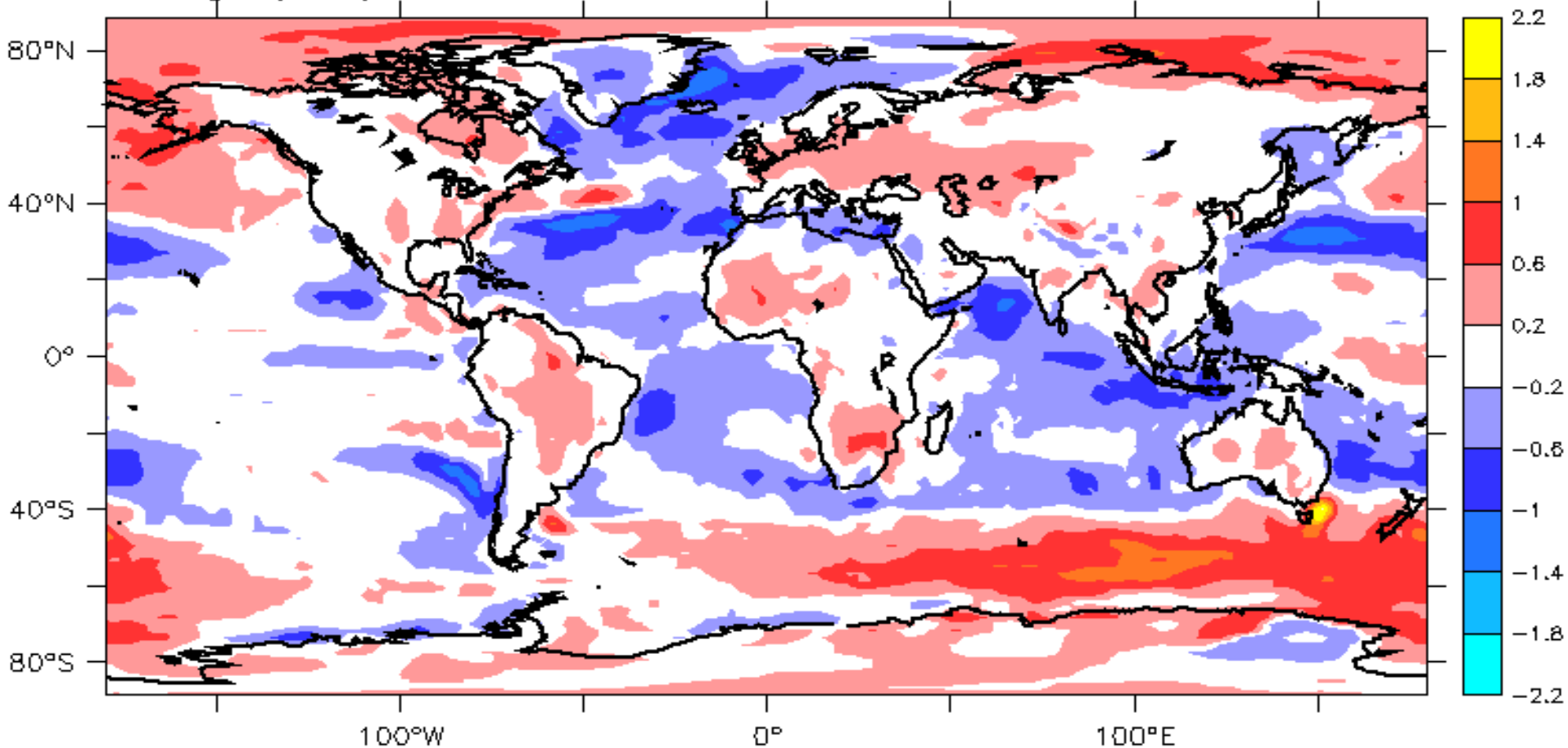
- storm surge model
- Northwest European shelf
- 8 km x 8 km
- output every 10 minutes

# ...Will the wind change ?

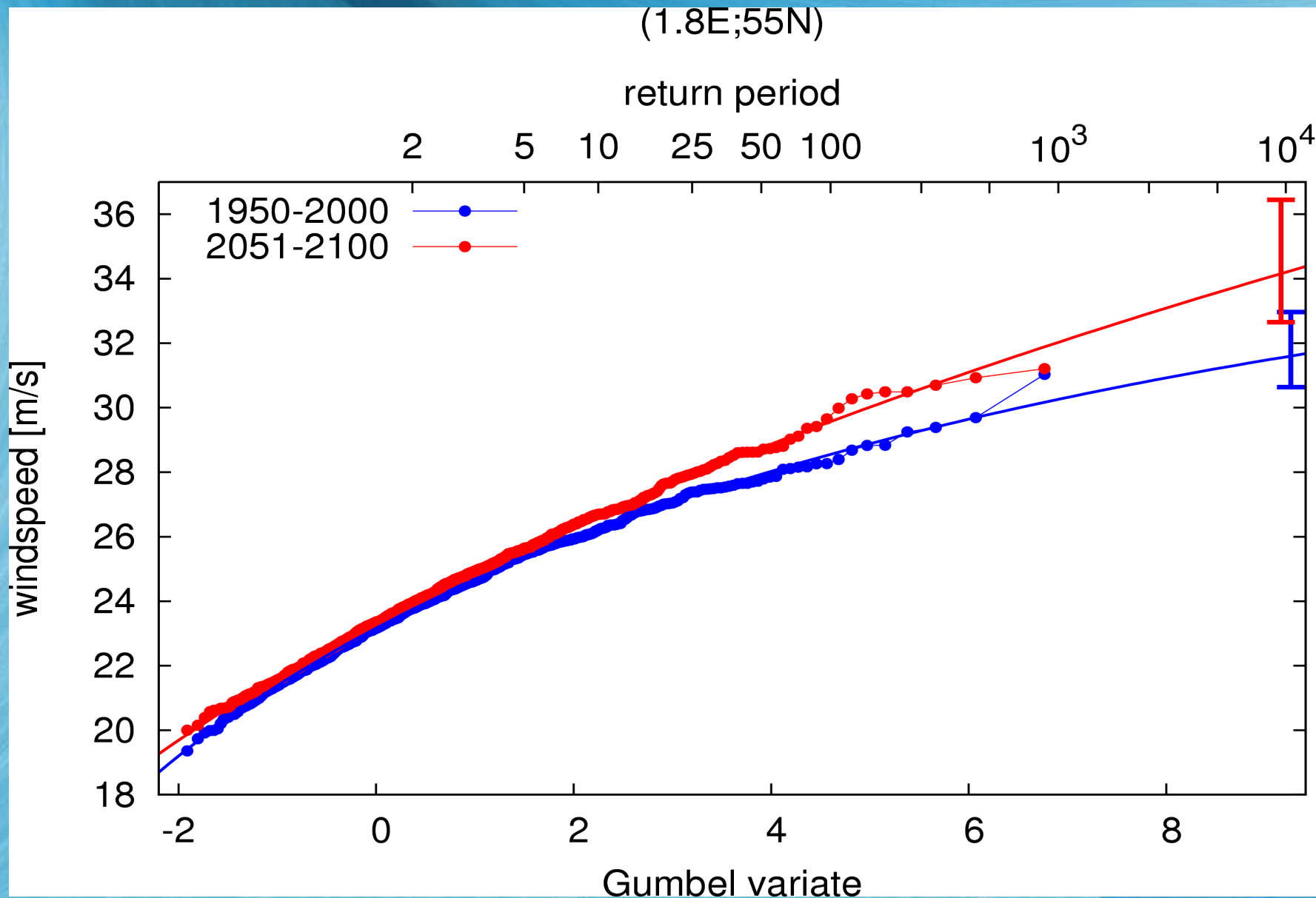


# Extreme winds

diff. sqrt( $\mu$ ), GEV fit to  $u \sim 2$



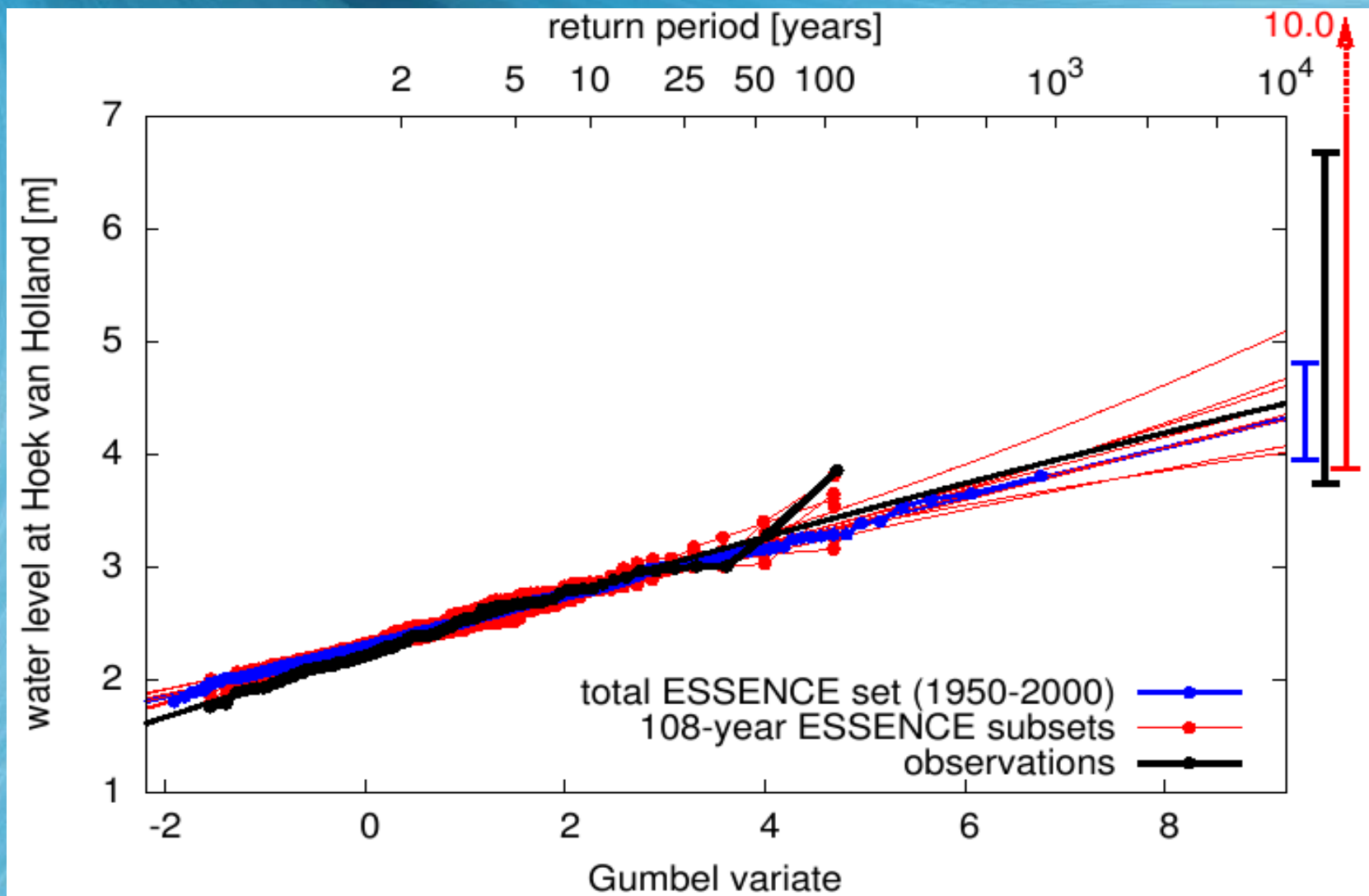
# ESSENCE winds



# Uncertainty present-day water levels



....



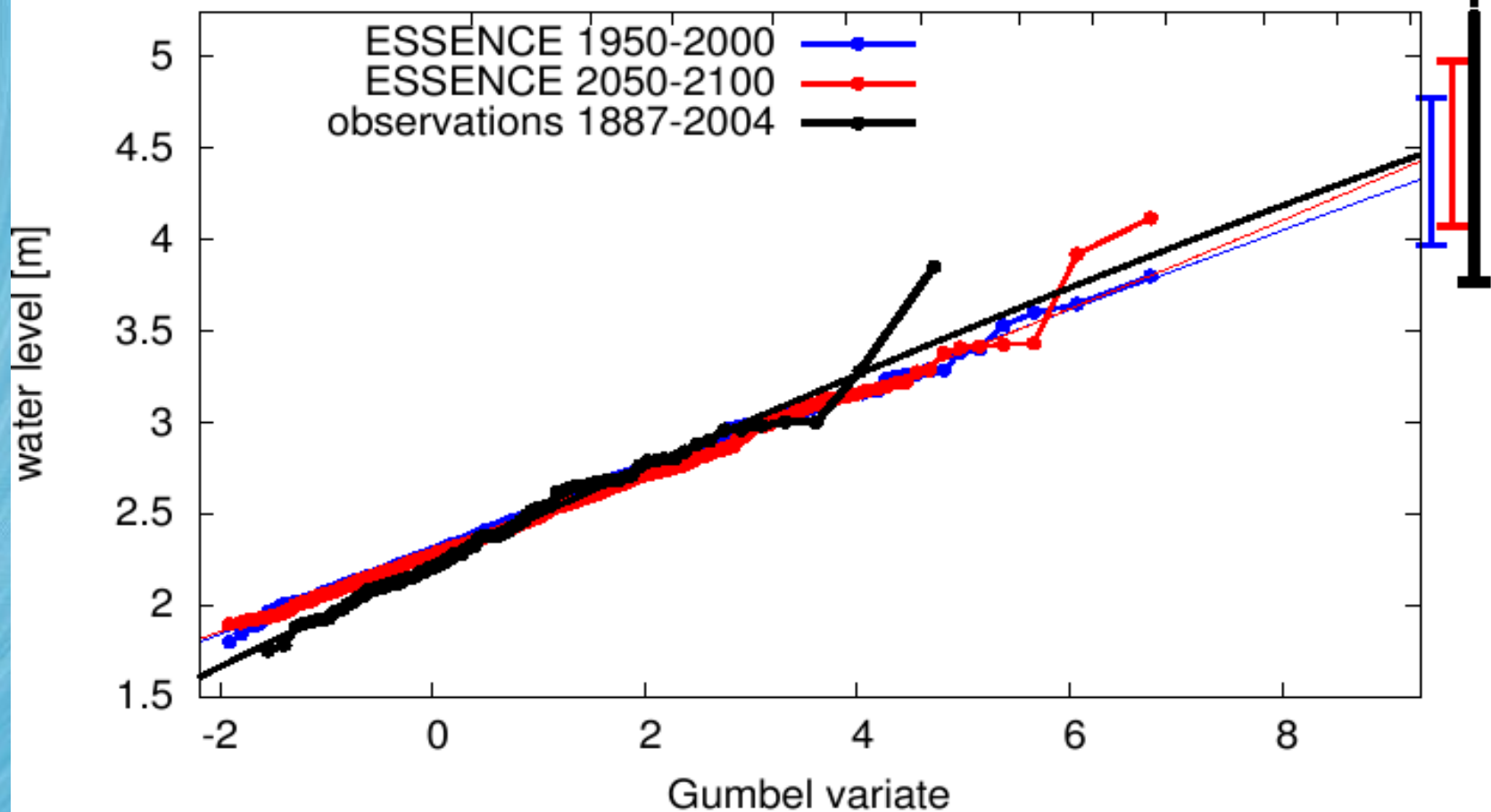
Andreas Sterl, SEAMOCS, Malt

# Future water levels

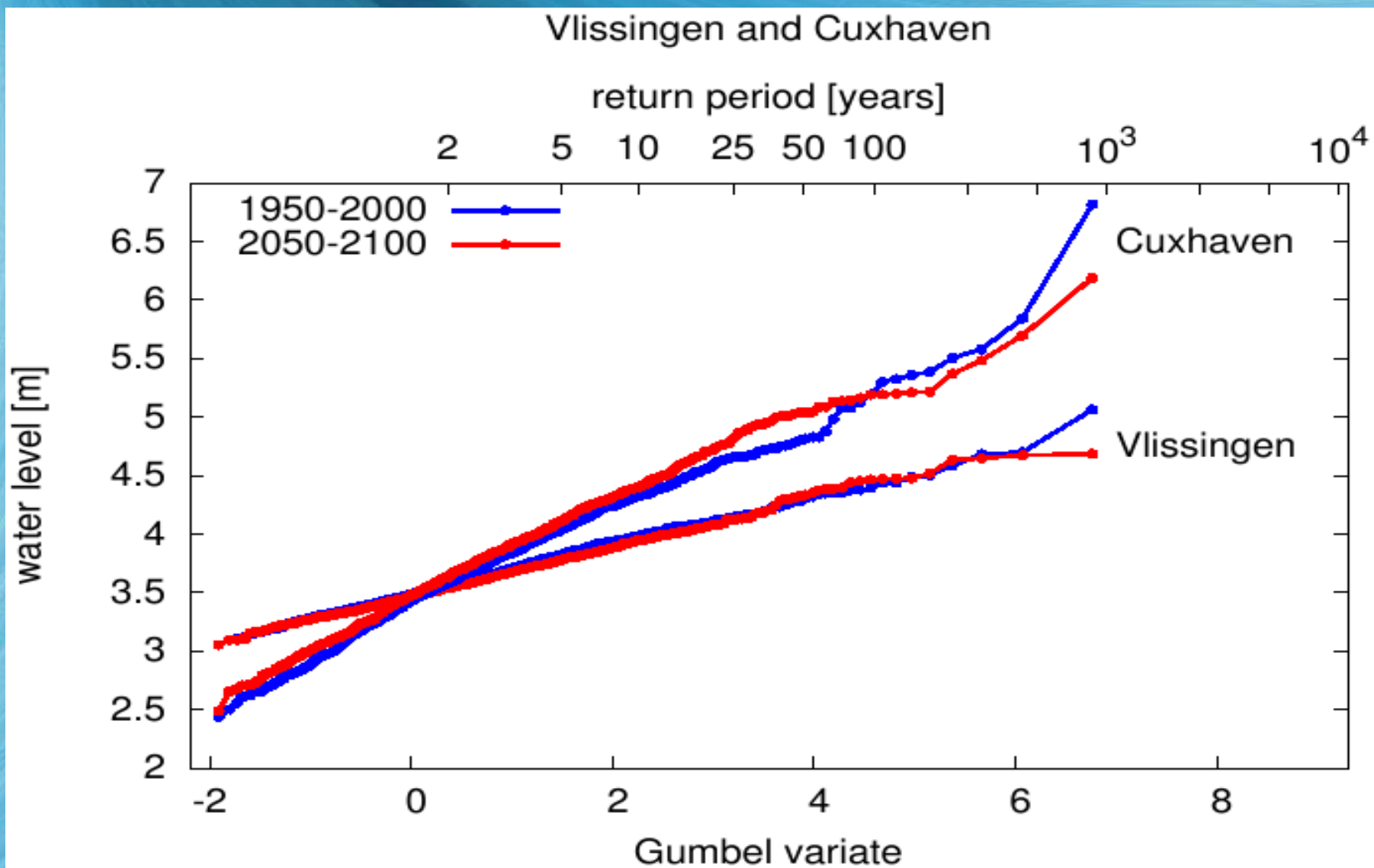
Hoek van Holland

return period

2 5 10 25 50 100  $10^3$   $10^4$



# Other stations



# Conclusions

- large ensemble => good statistical basis
- temperature extremes increase faster than the means ...
- ... and may reach dangerous levels within this century
- no change of **surge** heights along the Dutch coast, but ...
- ... **sea level** increases

# The End !!!

Andreas Sterl, SEAMOCS, Malt