

Probability of mild winters:

interpretation of recent observations
in the light of model results, and
projections for the future

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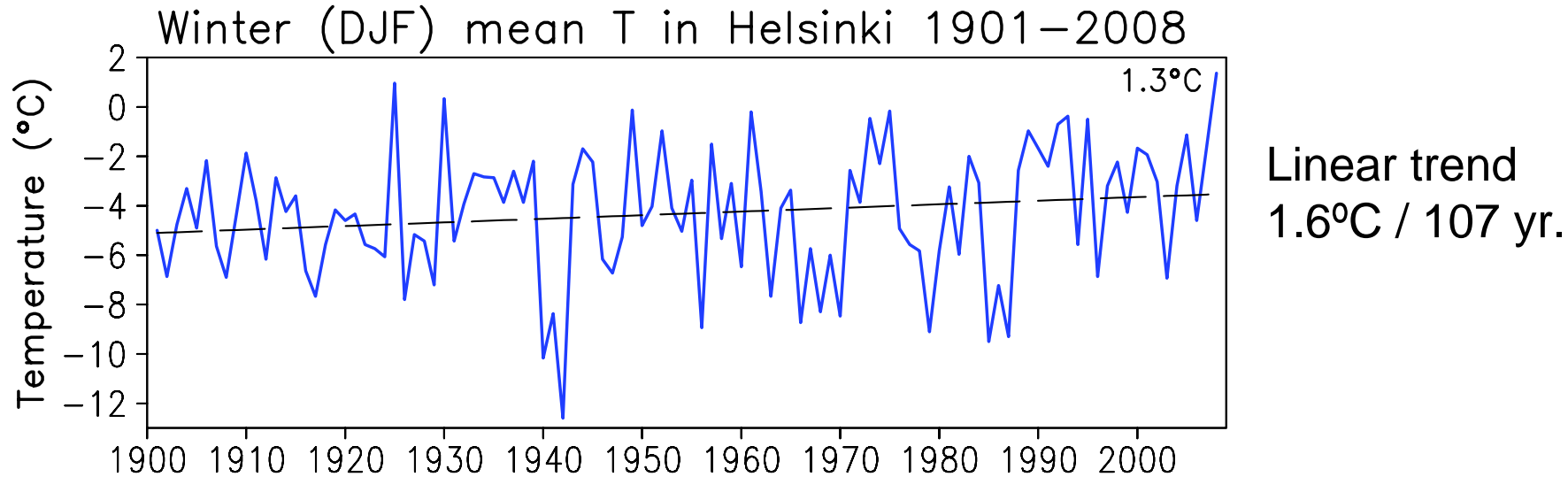
12.1.2009

Recent new monthly-to-annual temperature records in Helsinki

- December 2006: **+4.0°C** (1929: +2.9°C)
- March 2007: **+3.1°C** (1989: +2.0°C)
- Winter (DJF) 2007-08: **+1.3°C** (1924-25: +1.0°C)
- Year 2008: **+7.6°C** (1934: +7.2°C)

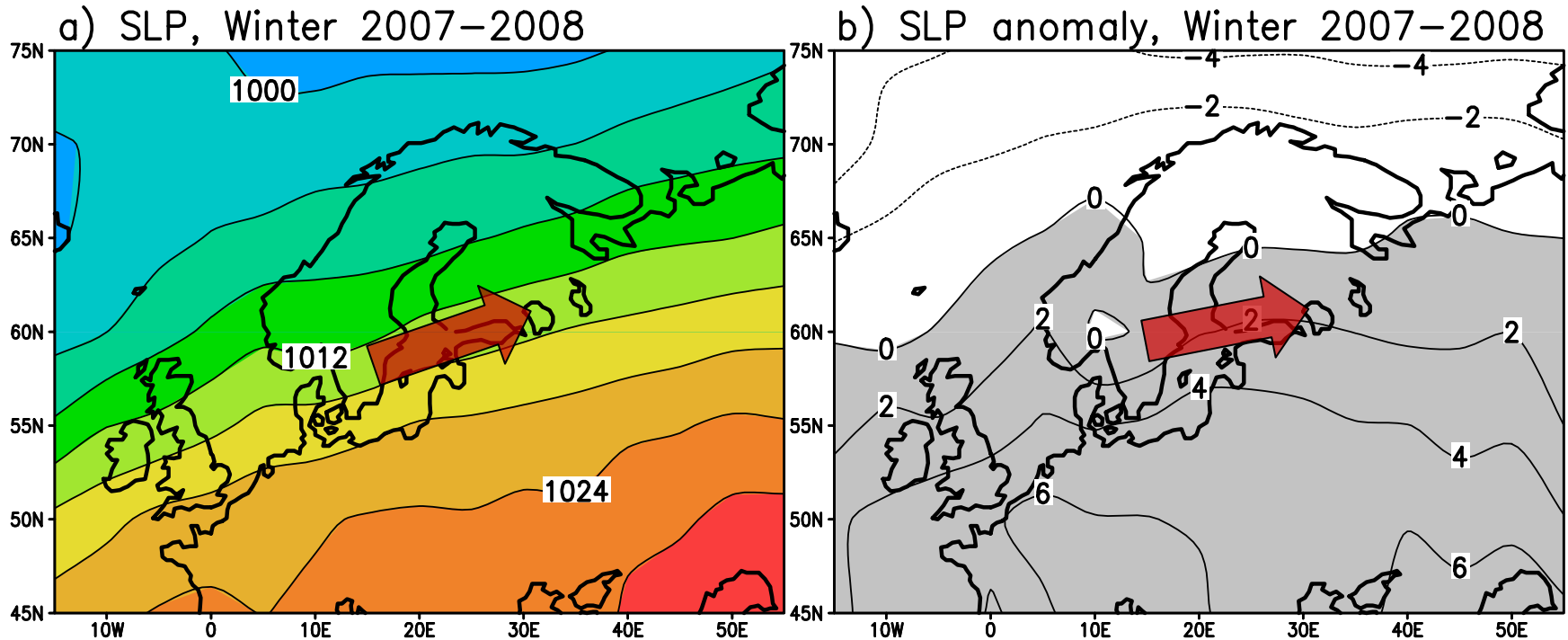
- **Are these warm events connected to the ongoing (largely greenhouse-gas-induced?) global warming, or are they just an expression of natural variability?**

Winter (DJF) mean temperature in Helsinki, 1901-2008



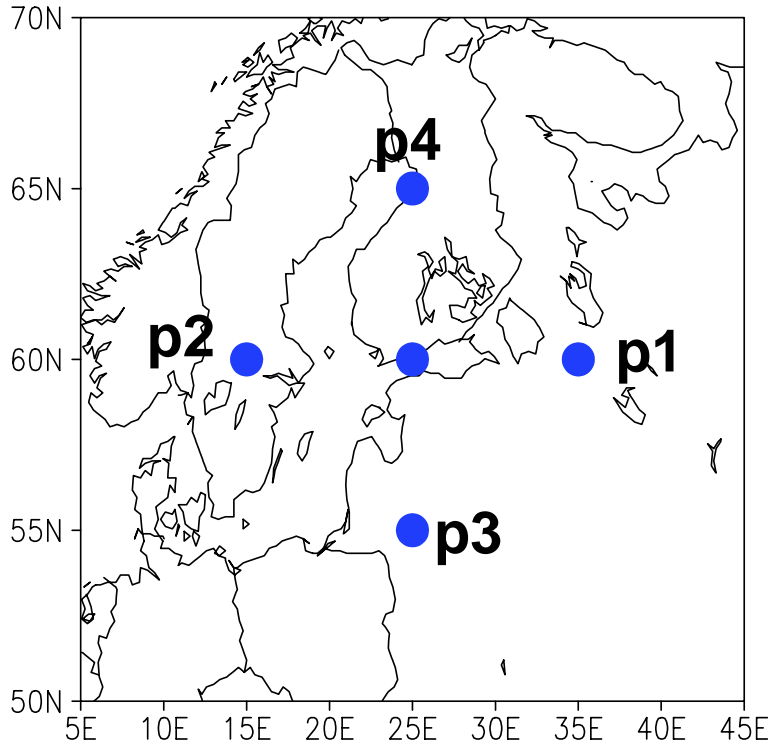
- **Systematic climate change still small compared with the large interannual variability**
- As measured in (°C), any extreme warm anomaly must be mostly due to natural variability
- **Most of natural temperature variability in northern Europe is caused by atmospheric circulation**

Sea level pressure: DJF 2007-2008



Anomalously strong westerly flow, as expected for a mild winter!

Effect on circulation anomalies on temperature in Helsinki: a very simple regression model

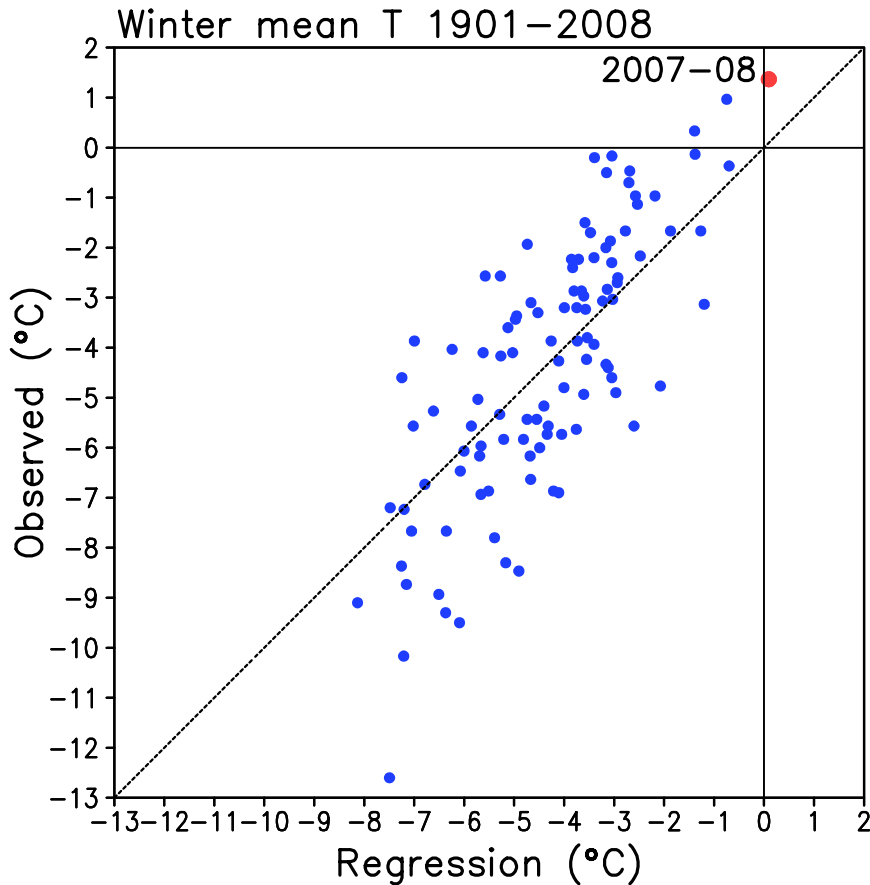


Two predictors:

- 1) **north-south pressure difference**
(p3-p4) \rightarrow U = west component of geostrophic wind
- 2) **west-east pressure difference**
(p1-p2) \rightarrow V = south component of geostrophic wind

This simple model explains (in leave-one-out cross-verification) slightly over **50%** of wintertime temperature variability in Helsinki.

Scatter plots between predicted (x-axis) and observed (y-axis) DJF mean temperatures



Winter 2007-2008:

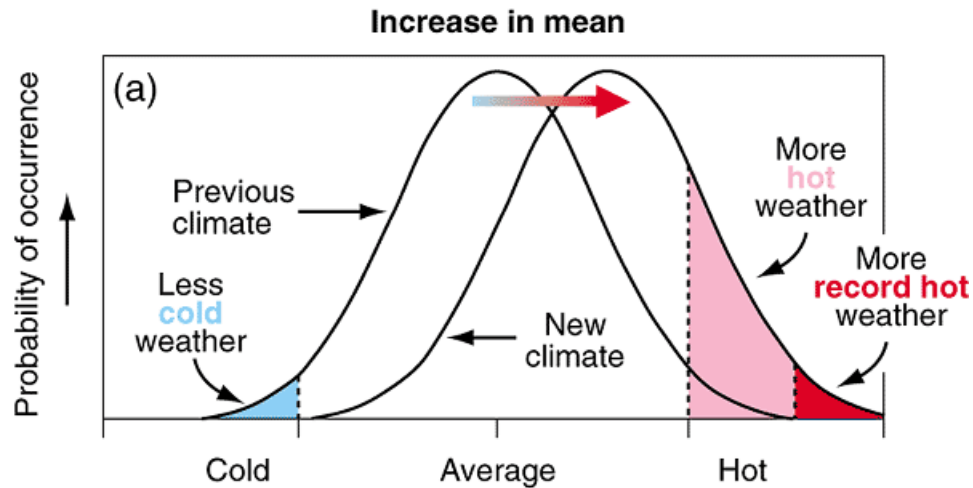
Predicted = **0.1°C(!)**,

Observed = **1.3°C**

Unfortunately, the effect of "global warming" cannot be quantified in this way:

- 1) large variability in regression residuals for other reasons
- 2) atmospheric circulation also potentially affected by global climate change

- It is very hard (\approx impossible) to prove a connection between global climate change and a single mild winter based on observations alone!
- However:



IPCC (2001)

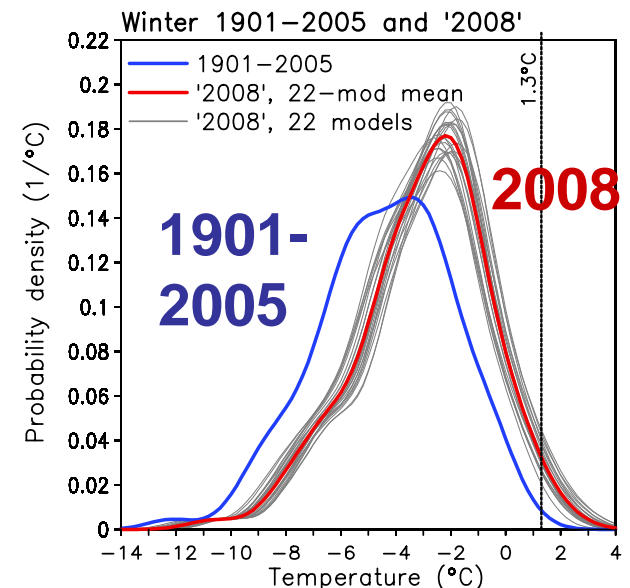
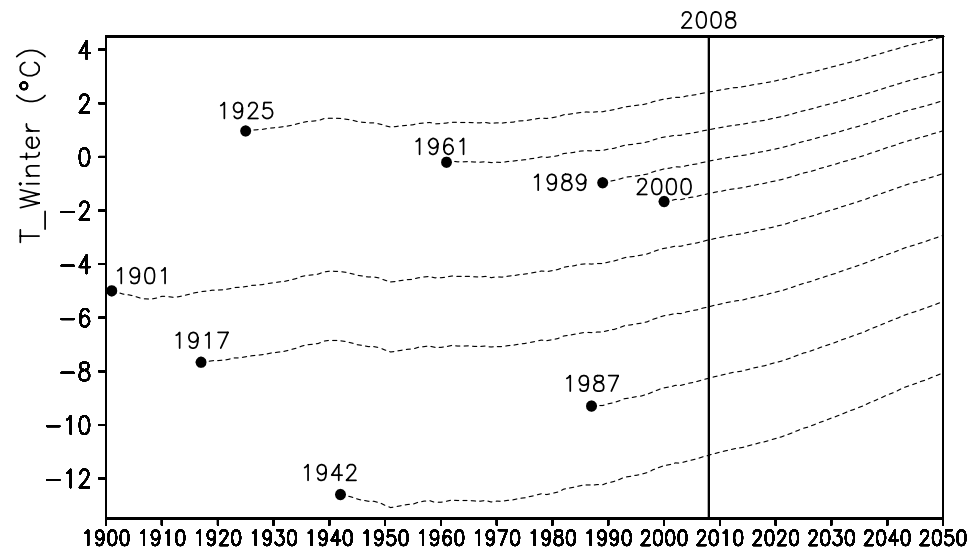
- In the following, I'll try to put this idea in quantitative terms: - how much should the probability of very mild winters have increased this far, based on
 - (i) the observed global warming
 - (ii) results of global climate models

Estimating present temperature climate: a model-based approach

Step 1: past observations are extrapolated forward in time, using (A) observed changes in global mean temperature, and (B) model-simulated changes in mean temperature and temperature variability

Step 2: the distribution of the extrapolated temperatures is computed, and compared with the distribution of the observed temperatures

NEXT TO THE DETAILS...



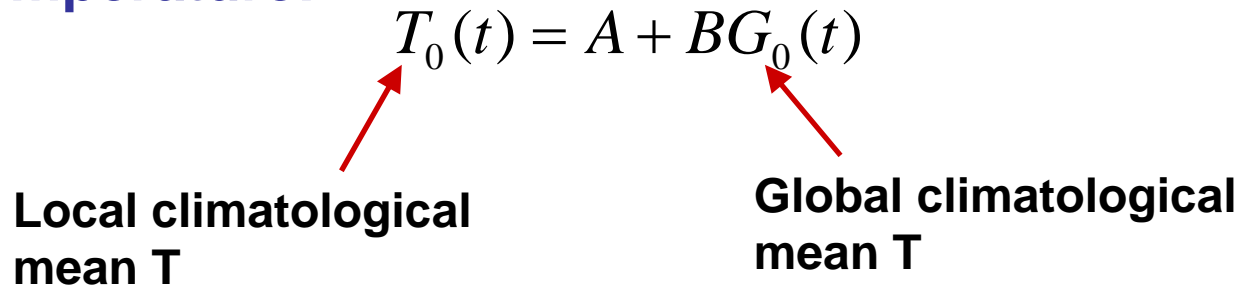
The basic assumptions

- 1) Local (e.g., Helsinki) 'climatological mean' temperature increases linearly with the global 'climatological mean' temperature:

$$T_0(t) = A + BG_0(t)$$

Local climatological mean T

Global climatological mean T



- 2) A similar linear equation holds for the amplitude of local interannual temperature variability:

$$\sigma_T(t) = C + DG_0(t)$$

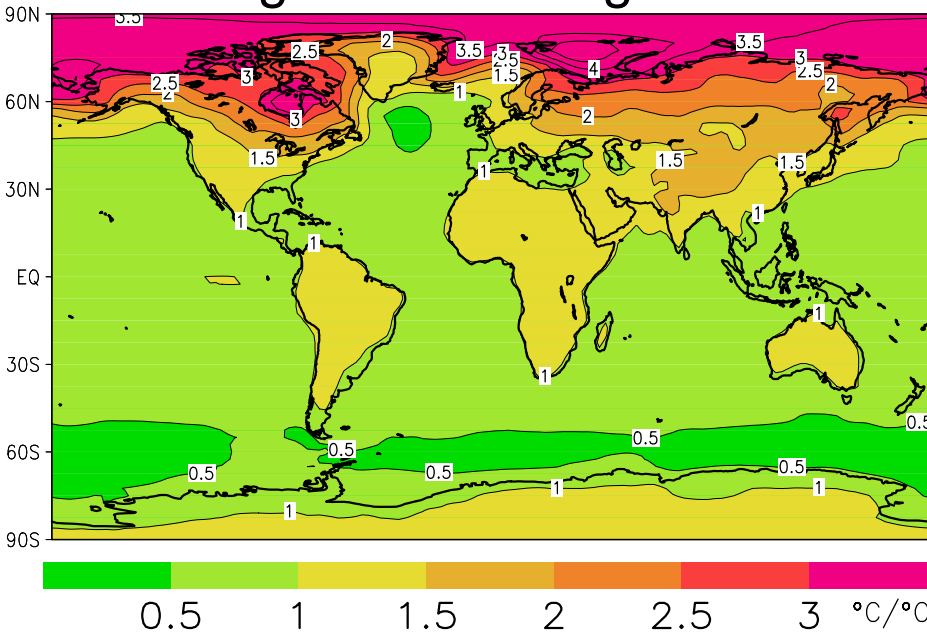
- 3) A simple running mean gives a reasonable estimate of the 'climatological' global mean temperature $G_0(t)$.

Details of implementation

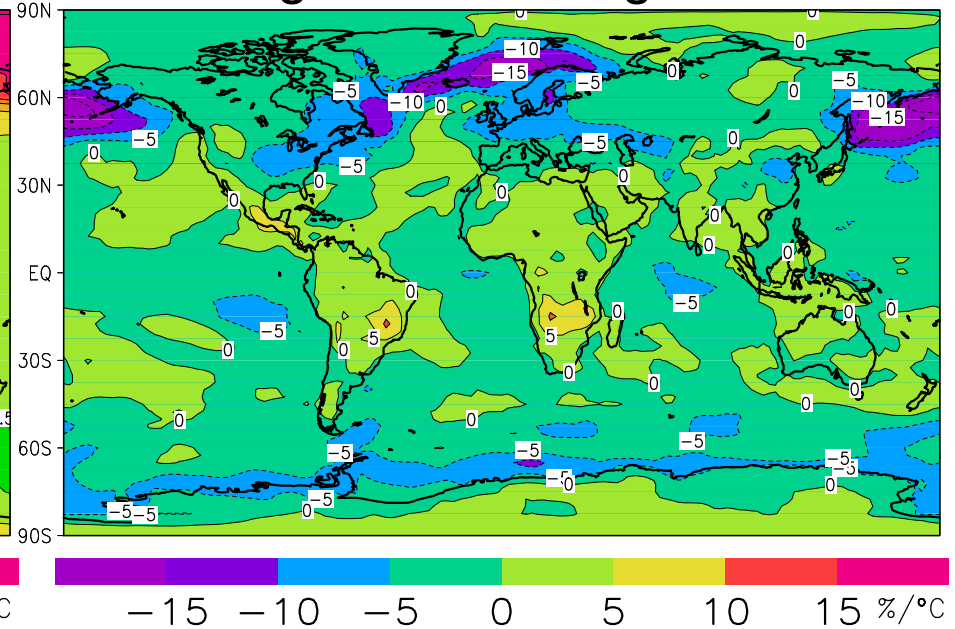
- **Regression coefficients for mean temperature and variability (B, D) derived from model simulations of anthropogenic climate change:**
 - 1901-2098 (21st Century with A1B scenario)
 - 22 models
 - In principle, the coefficients could also be derived from observations, but their signal-to-noise ratio would be much lower
- **”Climatological mean” global mean temperature G_0 = 11-year running mean of G**
- **Global mean warming up to 2002 from observations, after 2002 from models**

Regression coefficients for winter mean temperature (22-model mean)

Change in local DJF mean T for 1°C global warming



Change in variability (%) for 1°C global warming



Helsinki (60°N, 25°E): On average, the mean winter temperature increases by **2.2°C**, and the interannual standard deviation decreases by **6%**, when the simulated global mean T increases by 1°C.

Regression coefficients for Helsinki

(60°N, 25°E): changes resulting from 1°C global warming

DJF mean temperature: 22-mod. mean = **2.2°C**, range = **1.3...3.1°C**

DJF interannual StDev: 22-mod. mean = **-6%**, range = **-18%...+6%**

Fortunately: Changes in mean temperature are much more important for the results shown here than changes in variability!

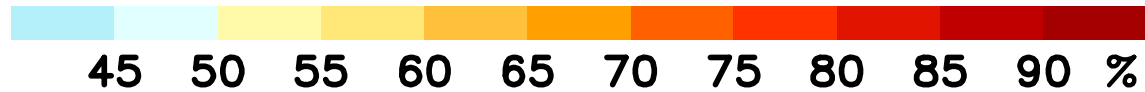
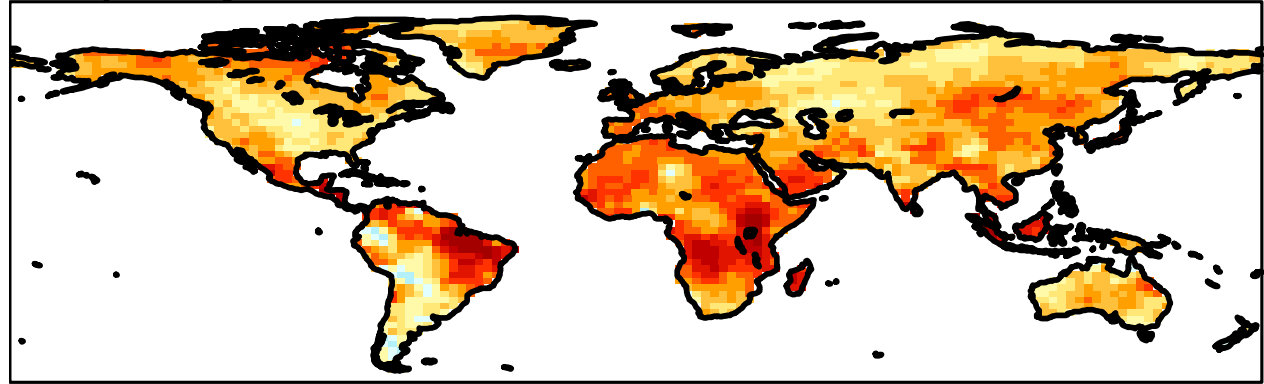
A global-scale hindcast test

- **Baseline period:** 1961-1990
- **Forecast period:** 1991-2002
- **Temperature data:** CRU TS 2.0 (land only)
+ Global mean T up to 1990 from Brohan et al. (2006)
- **Two ways of estimating the probability distribution of monthly temperatures:**
 - Directly from observations for 1961-1990
 - Observations modified using model results

Observed vs. hindcasted frequency of 'warm' months in 1991-2002 (above median of 1961-1990)

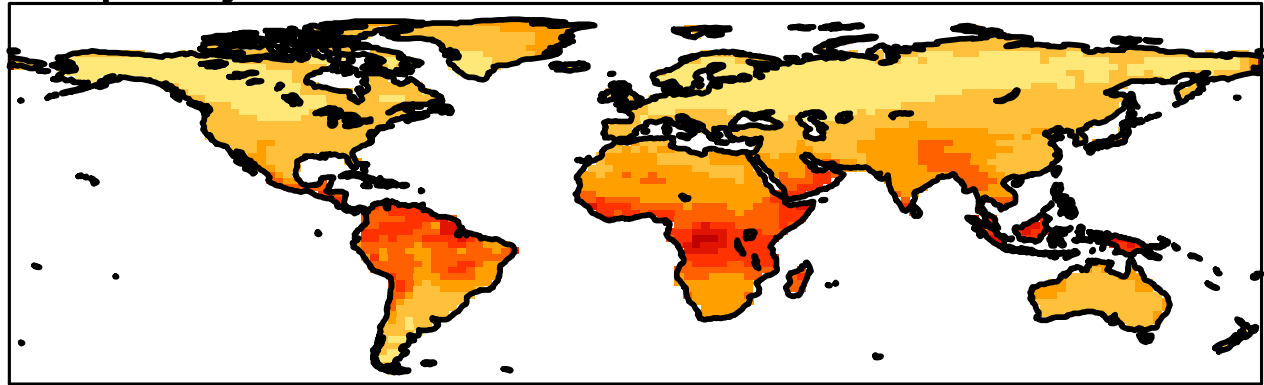
Observations
(mean = 67%)

Frequency of 'warm' months, CRU 1991-2002



Hindcast
(mean = 66%)

Frequency of 'warm' months, hindcast 1991-2002



Spatial correlation: **$r = 0.57$**

Frequency of monthly temperatures in 1991-2002, relative to the observed distribution in 1961-1990

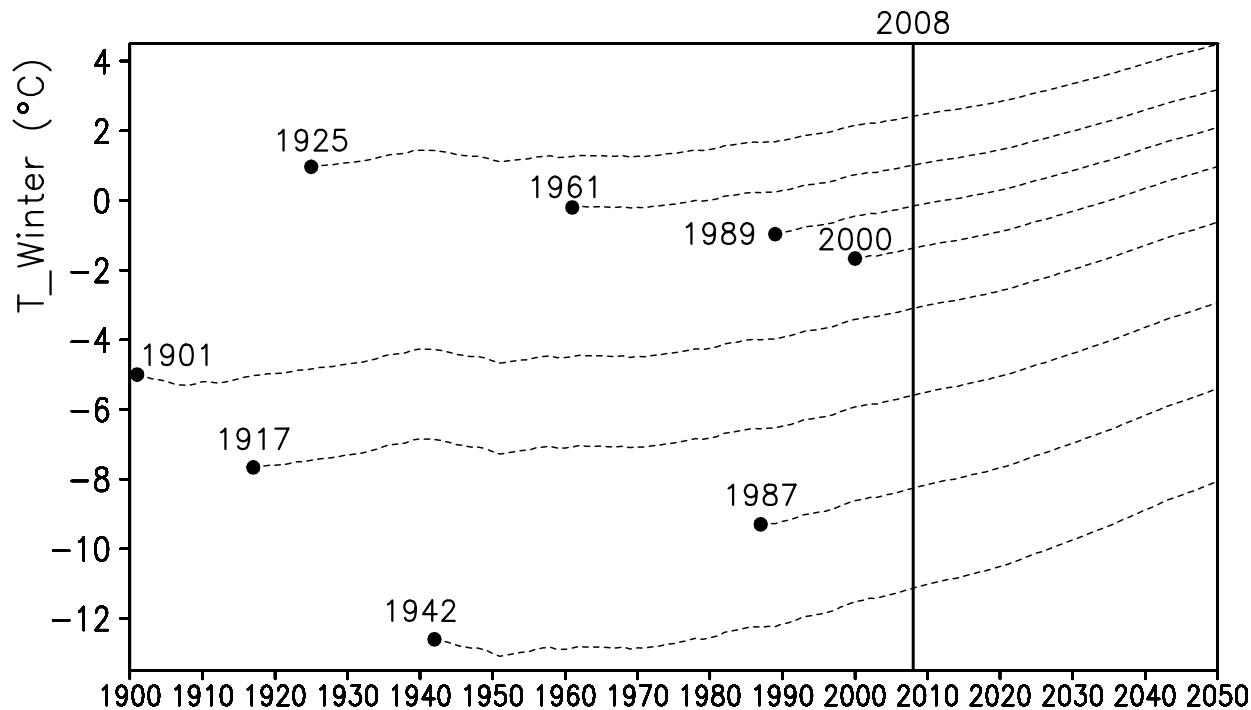
	Hindcast	Observed
Warm (top 50%)	66%	67%
Very warm (top 10%)	21%	20%
Very cold (bottom 10%)	5%	5%

Numbers averaged over the global land area (excluding Antarctica) and the whole 144-month period.

More on this: Räisänen & Ruokolainen (2008), *Climate Dynamics*, 31, 573-385

NOW BACK TO HELSINKI ...

Extrapolation of winter mean T in Helsinki

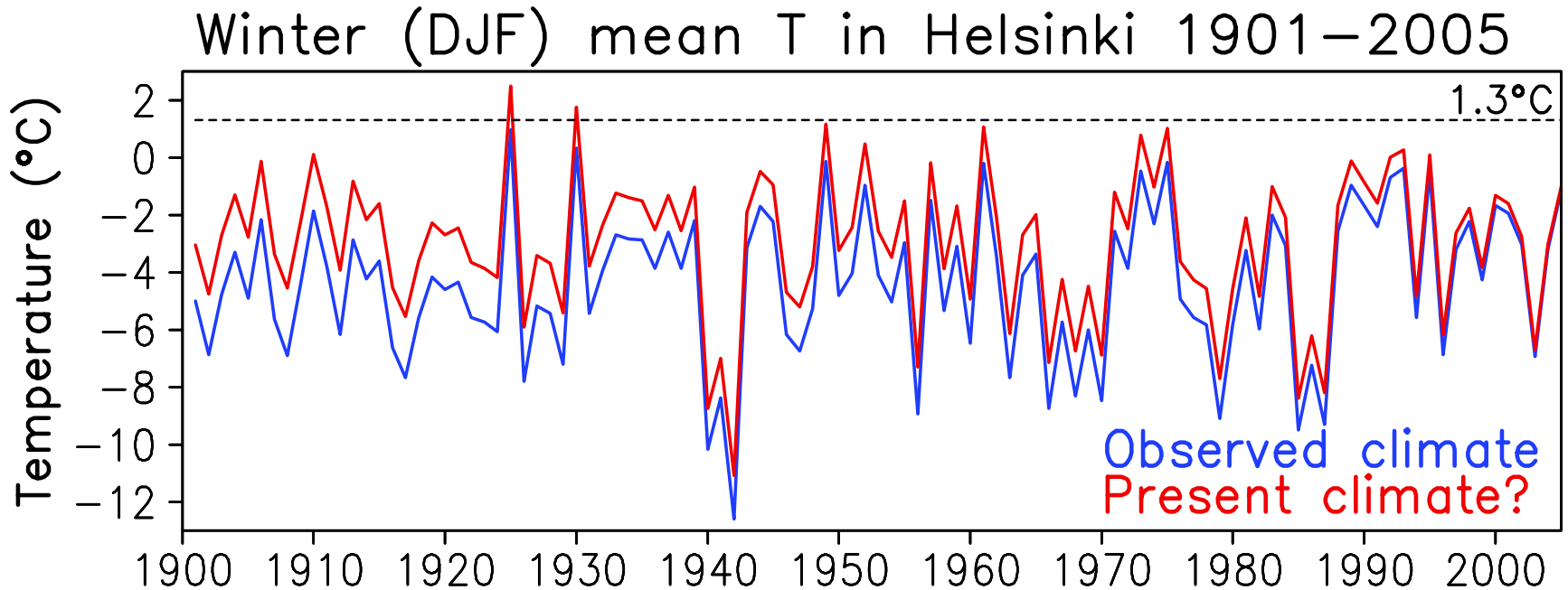


Other years excluded only for clarity (are used in actual calculations)

Notes:

- 1) Hump at ~1940 ← observed maximum in global mean T
- 2) Slightly steeper slope for cold (e.g. 1942) than warm winters (e.g., 1925) ← decrease in variability
- 3) Only multi-model mean results shown in this figure.

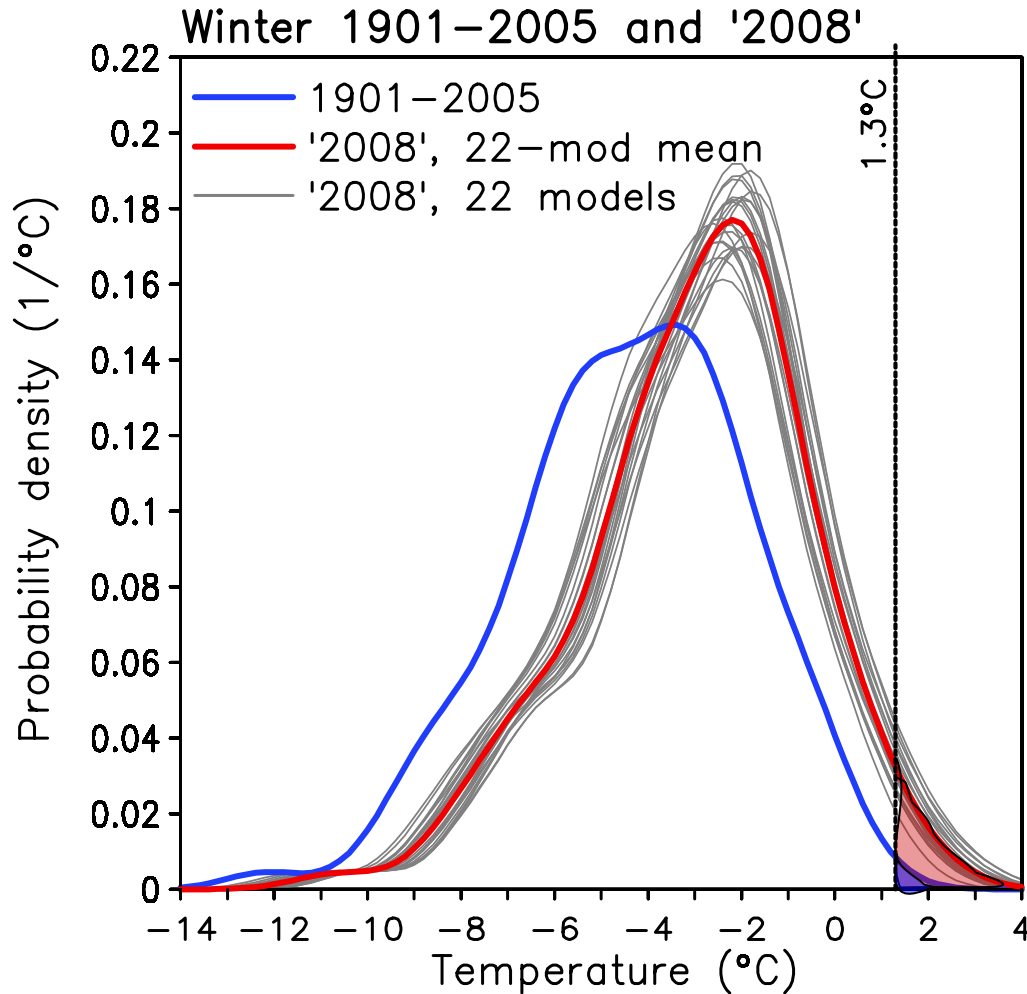
Winter mean temperatures in Helsinki in 1901-2005: as **observed** and as **extrapolated to present-day conditions**



Only multi-model mean results are shown here for clarity, in reality the “correction” varies between the 22 models

Resulting probability distributions

(using gaussian Kernel smoothing)



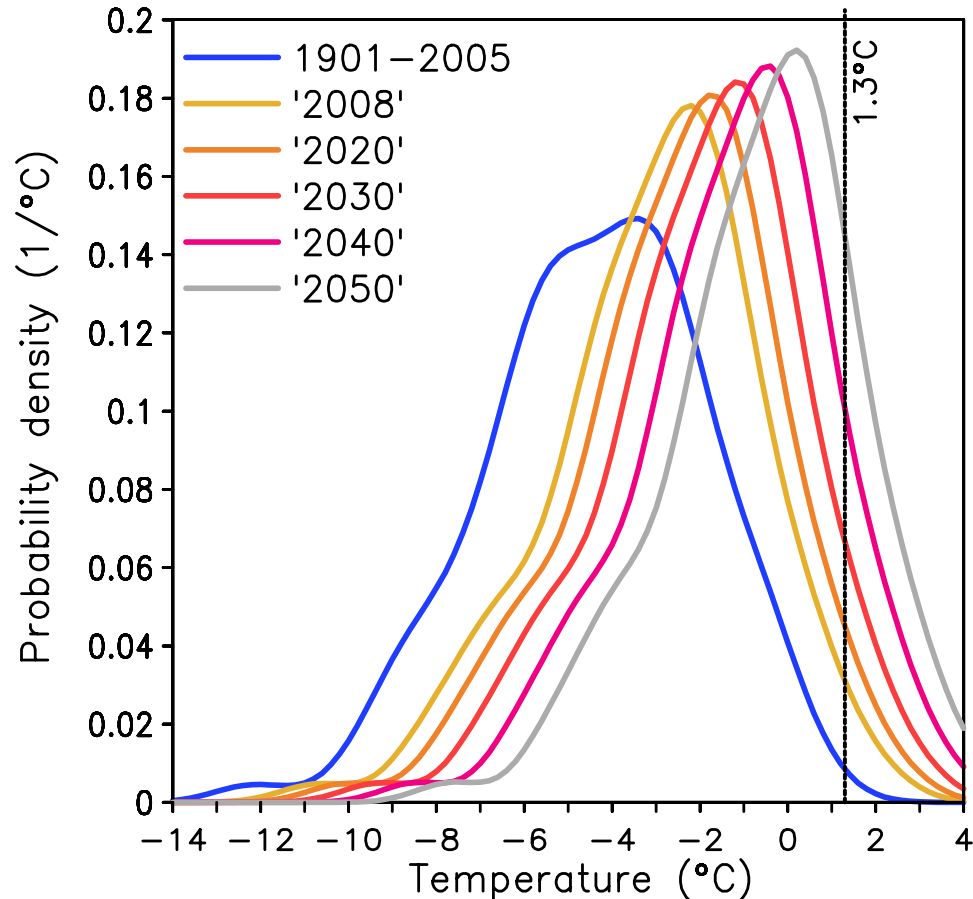
**Estimated return period
for $T_{DJF} \geq +1.3^{\circ}\text{C}$**
(as observed in 2007-08):

**Observations 1901-2005:
> 200 years**

**Present climate:
Best estimate: 35 years
Range between models:
20-80 years**

Note: probability ~ area

Future: warmer climate → more mild winters?



If climate change proceeds according to the best estimate from the models, then winters as mild as (or milder than) 2007-2008 should occur approximately

once in **15** years around **2030**,
and
once in **5** years around **2050**.

Probability distribution of DJF mean temperature under the A1B emissions scenario, as averaged over the 22 models

Conclusions

- It is impossible to prove a cause-effect relationship between climate change and individual extreme events.
- As measured in ($^{\circ}\text{C}$), climate change is still small compared to the natural interannual variability of winter temperatures.
- Still, in the light of the model results, this small warming is large enough to make extremely mild winters substantially more probable than they were before.
- **”Return period” of extremes is a potentially misleading term in a changing climate!**

References

- Räisänen, J. & L. Ruokolainen, 2008: Estimating present climate in a warming world: a model-based approach. *Climate Dynamics*, 31, 573-585.
- Räisänen, J. & L. Ruokolainen, 2008: Ongoing global warming and local warm extremes: a case study of winter 2006-2007 in Helsinki, Finland. *Geophysica*, 44, 45-65. (<http://www.geophysica.fi/>)