Probability of mild winters:

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

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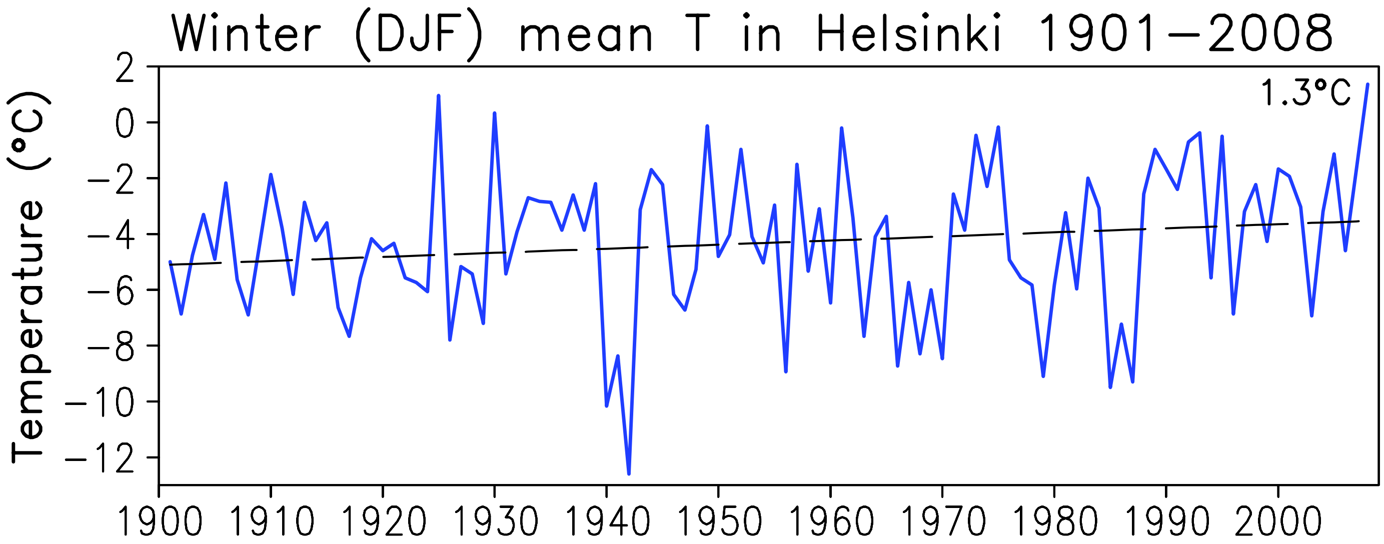
Recent new monthly-to-annual temperature records in Helsinki

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

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

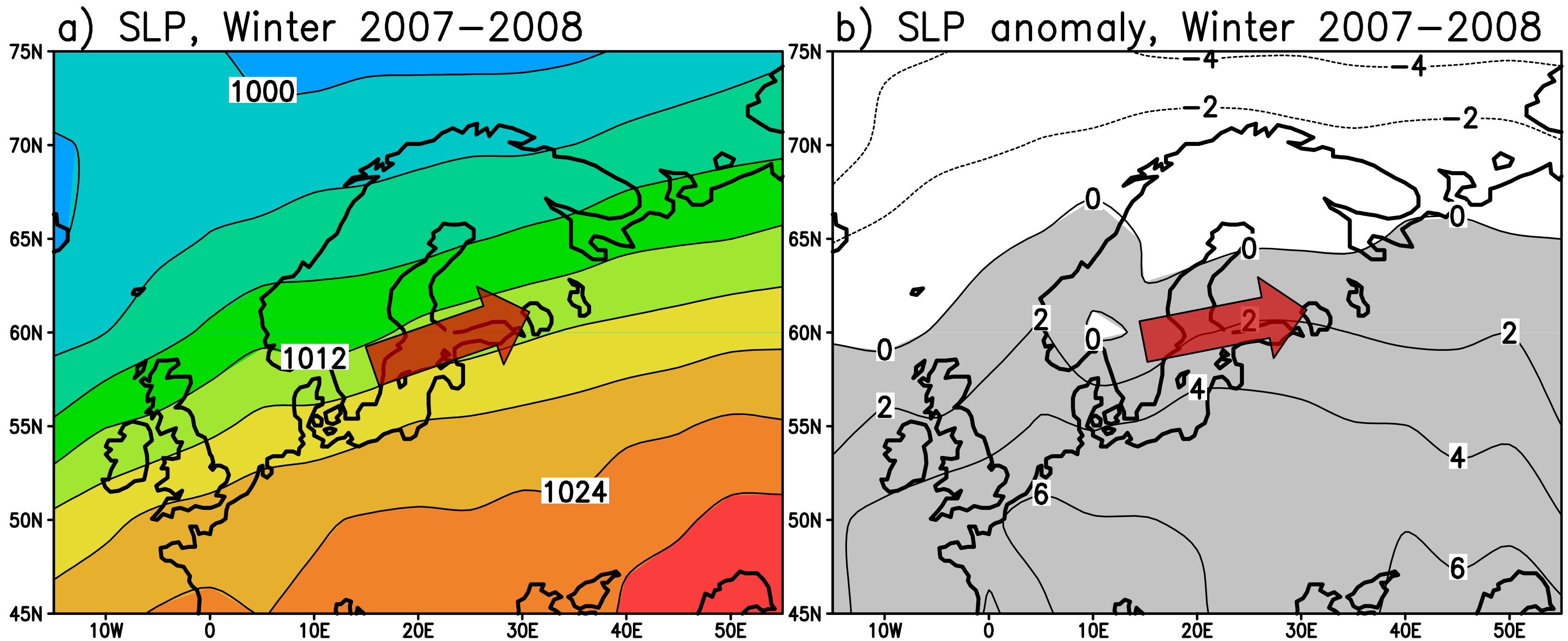
Winter (DJF) mean temperature in Helsinki, 1901-2008



Linear trend
1.6ºC / 107 yr.

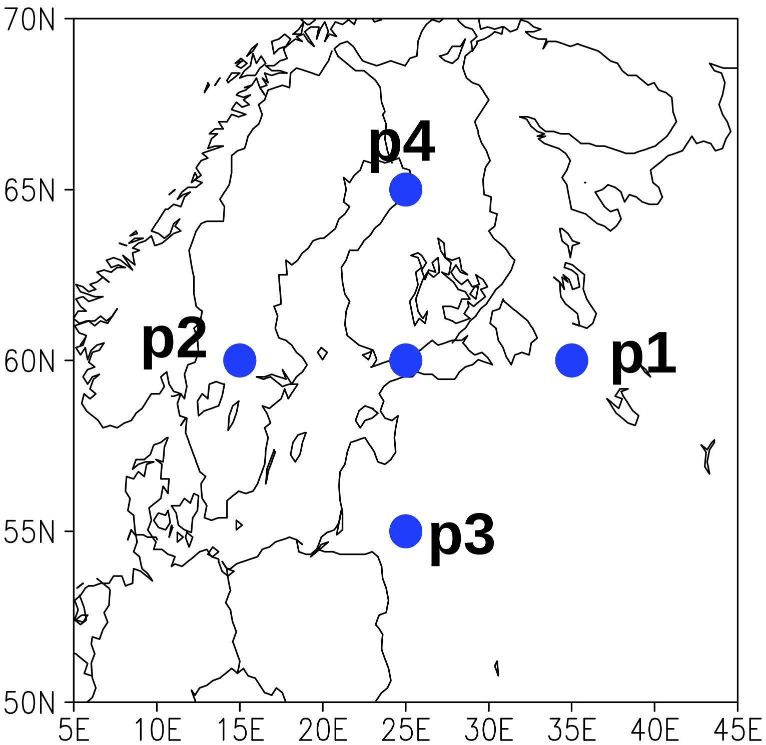
- **Systematic climate change still small compared with the large interannual variability**
- As measured in (ºC), any extreme warm anomaly must be mostly due to natural variability
- **Most of natural temperature variability in northern Europe is caused by atmospheric circulation**

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



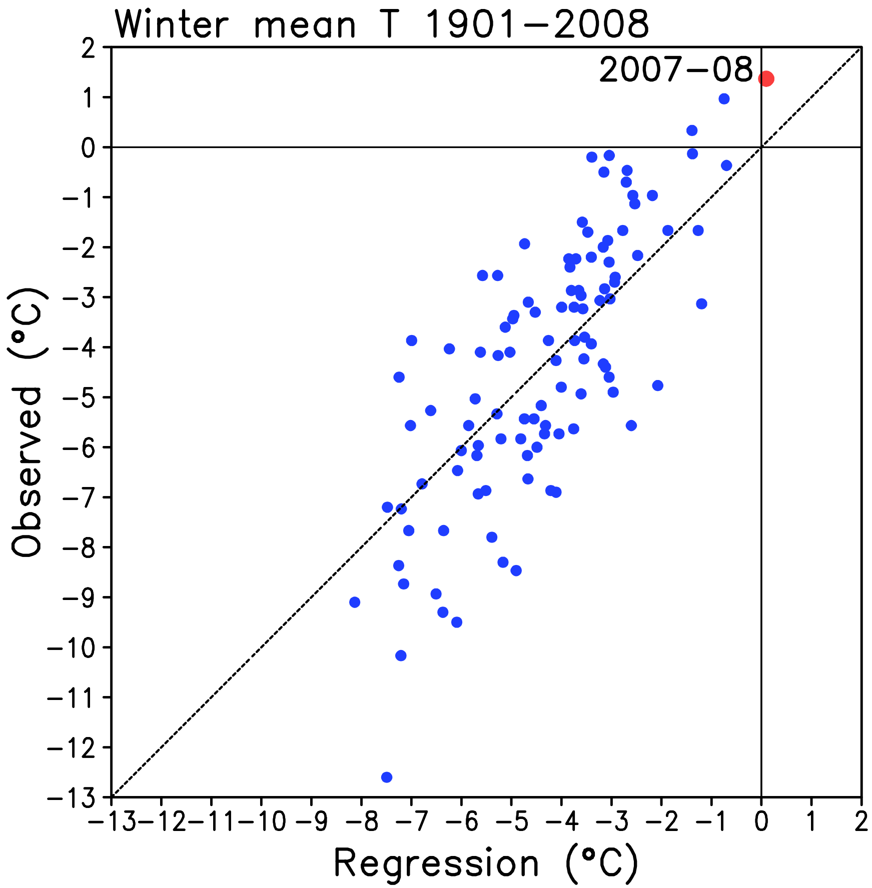
Two predictors:

1) **north-south pressure difference**
(p3-p4) → U = west component of geostrophic wind

2) **west-east pressure difference**
(p1-p2) → 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

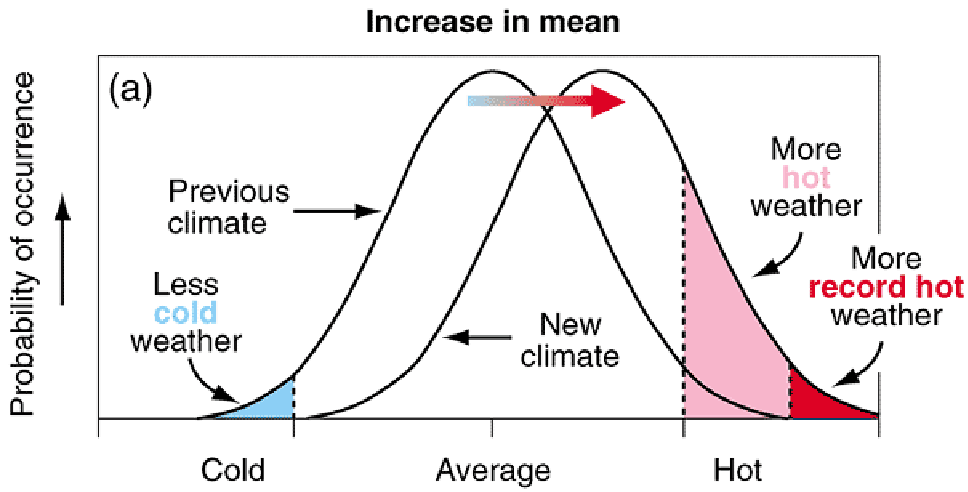


Winter 2007-2008:
Predicted = **0.1ºC(!)**,
Observed = **1.3ºC**

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** (≈ impossible) **to prove a connection between global climate change and a single mild winter based on observations alone!**
- **However:**

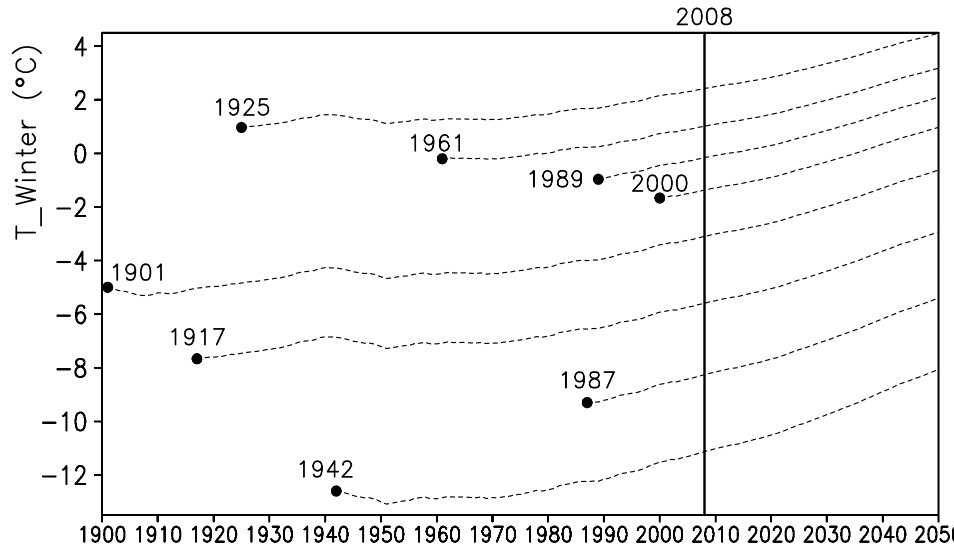


IPCC (2001)

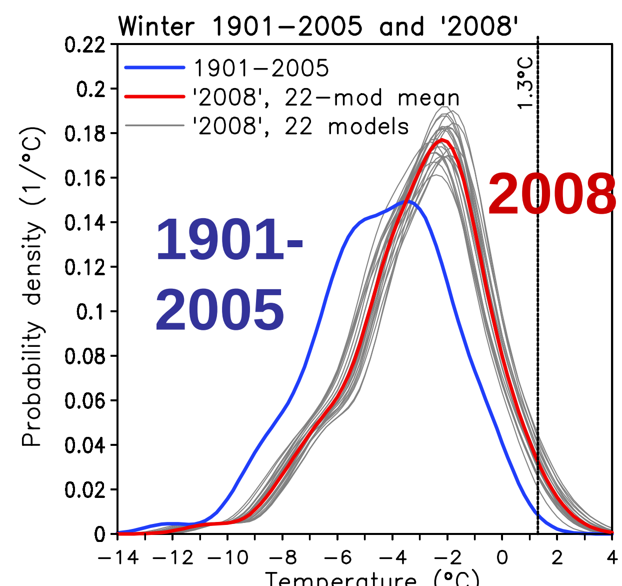
- **In the following, I'll try to put this idea in quantitative terms:** - <u>how much should the probability of very mild winters have increased this far, based on</u>
  (i) the observed global warming
  (ii) results of global climate models

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

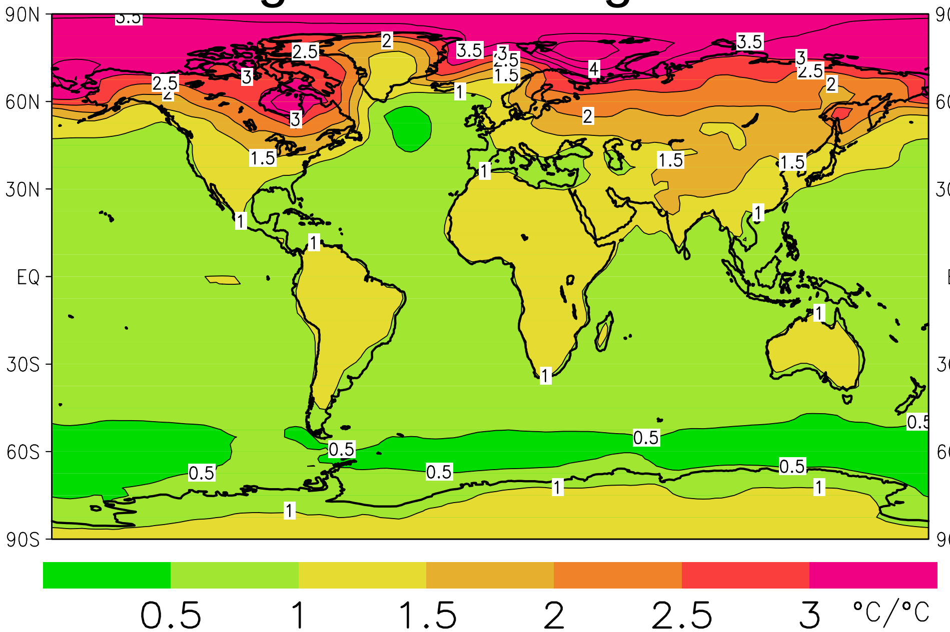
- **Regression coefficients for mean temperature and variability** (B, D) **derived from model simulations of anthropogenic climate change**:
  - 1901-2098 (21st Century with A1B scenario)
  - 22 models
  - In principle, the coefficients could also be derived from observations, but their signal-to-noise ratio would be much lower

- **”Climatological mean” global mean temperature G_0 = 11-year running mean of G**

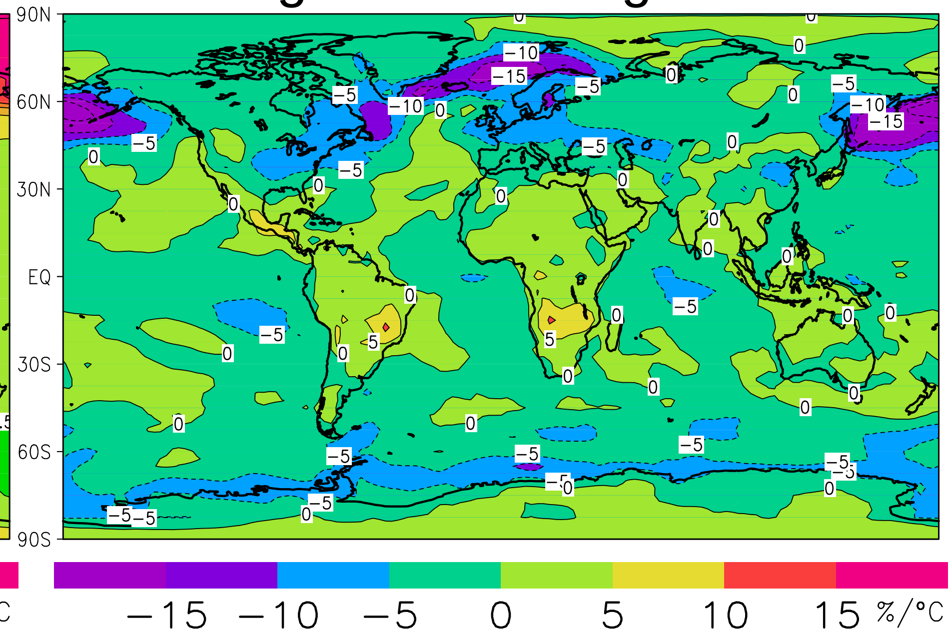
- **Global mean warming up to** 2002 **from observations, after** 2002 **from models**

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

Change in local DJF mean T
for 1ºC global warming



Change in variability (%)
for 1ºC global warming



<u>Helsinki (60ºN, 25ºE):</u> On average, the mean winter temperature increases by **2.2ºC**, and the interannual standard deviation decreases by **6%,** when the simulated global mean T increases by 1ºC.

Regression coefficients for Helsinki

(60ºN, 25ºE): changes resulting from 1ºC global warming

DJF mean temperature: 22-mod. mean = **2.2ºC**, range = 1.3…3.1ºC
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!

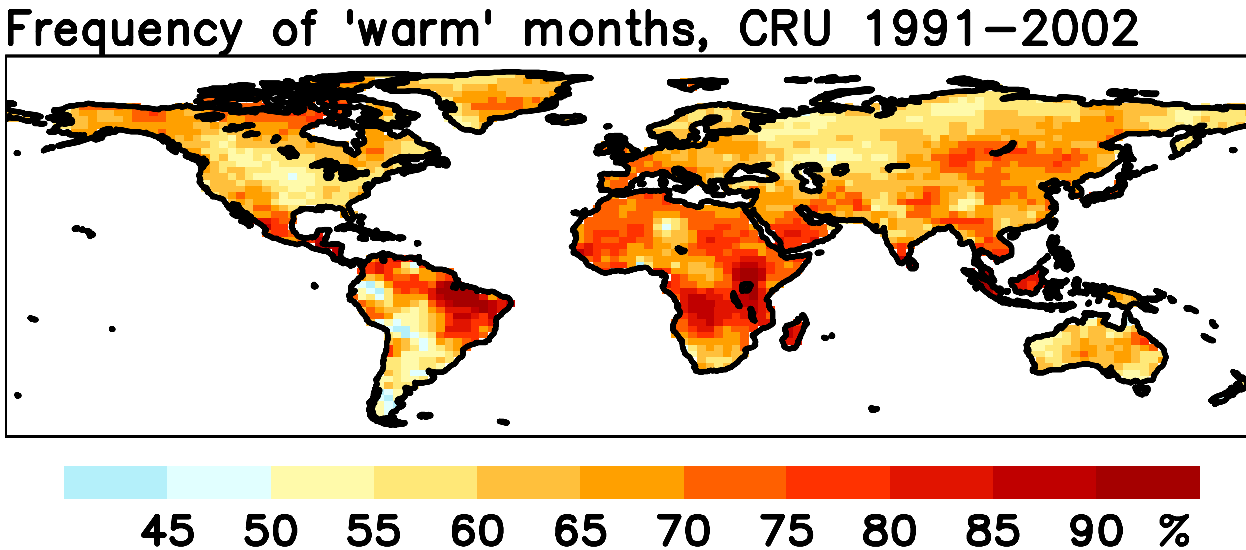
A global-scale hindcast test

- **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)

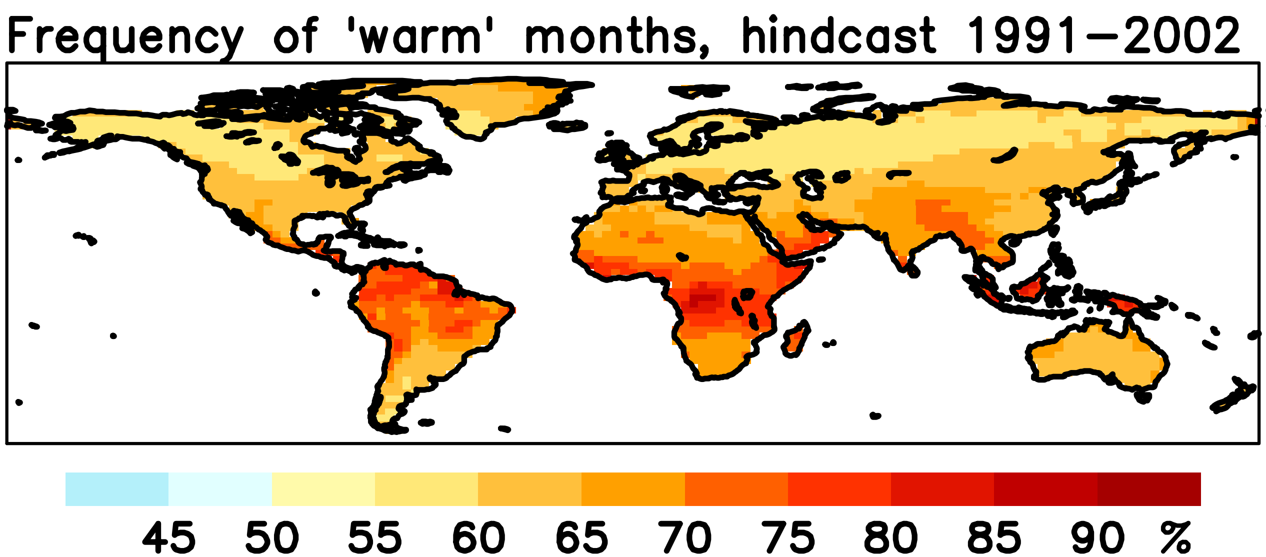
- **Two ways of estimating the probability distribution of monthly temperatures:**
  – Directly from observations for 1961-1990
  – Observations modifíed using model results

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

Observations
(mean = 67%)



Hindcast
(mean = 66%)



Spatial correlation: **r = 0.57**

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

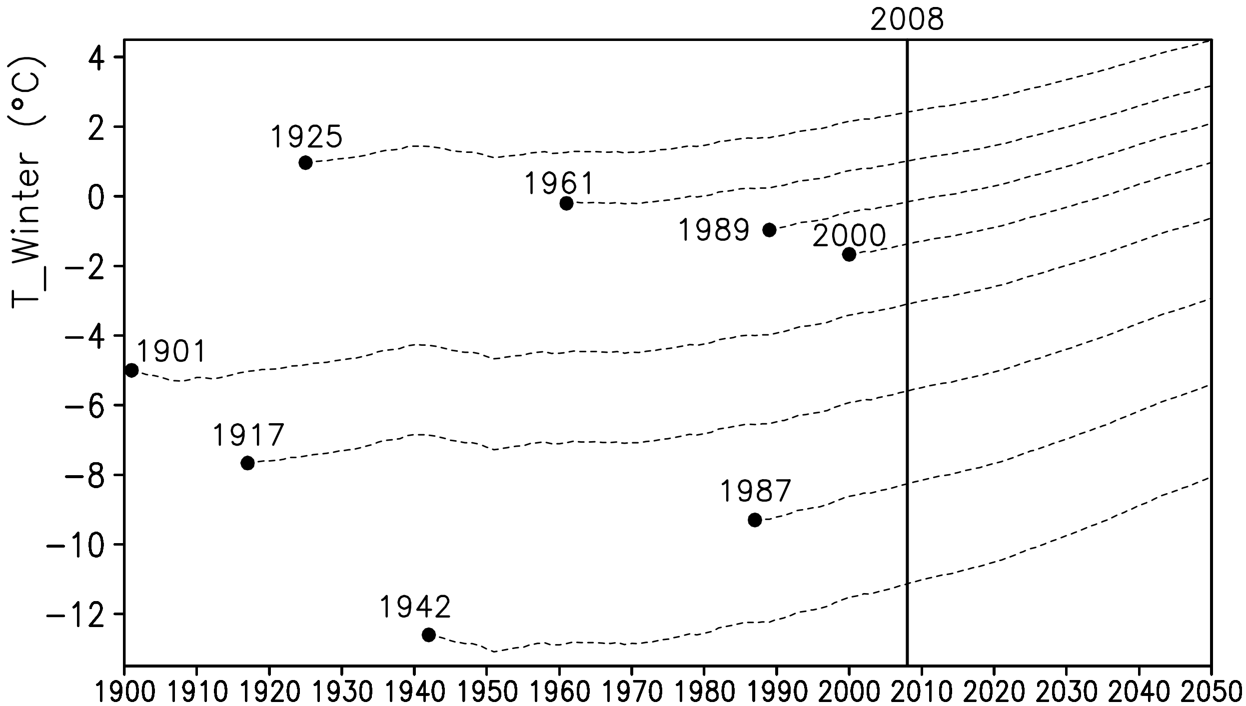
	Hindcast	Observed
Warm (top 50%)	66%	67%
Very warm (top 10%)	21%	20%
Very cold (bottom 10%)	5%	5%

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

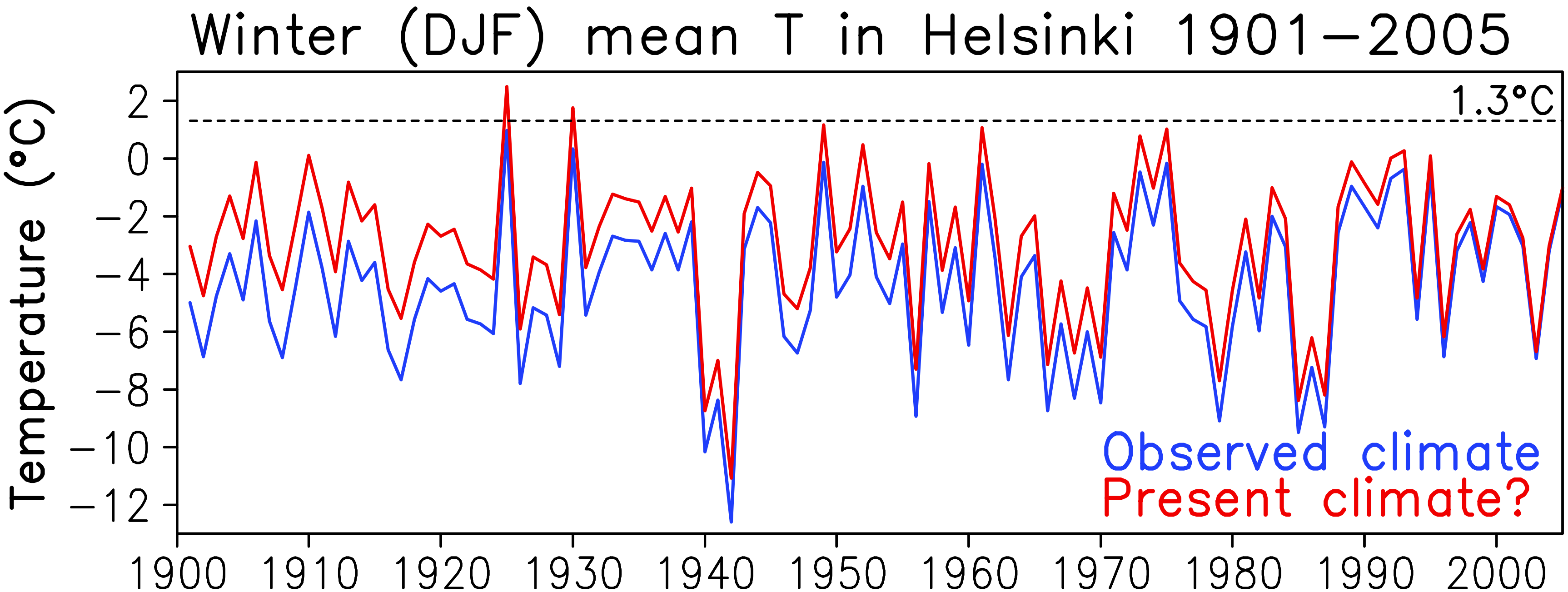


Other years excluded only for clarity
(are used in actual calculations)

Notes:

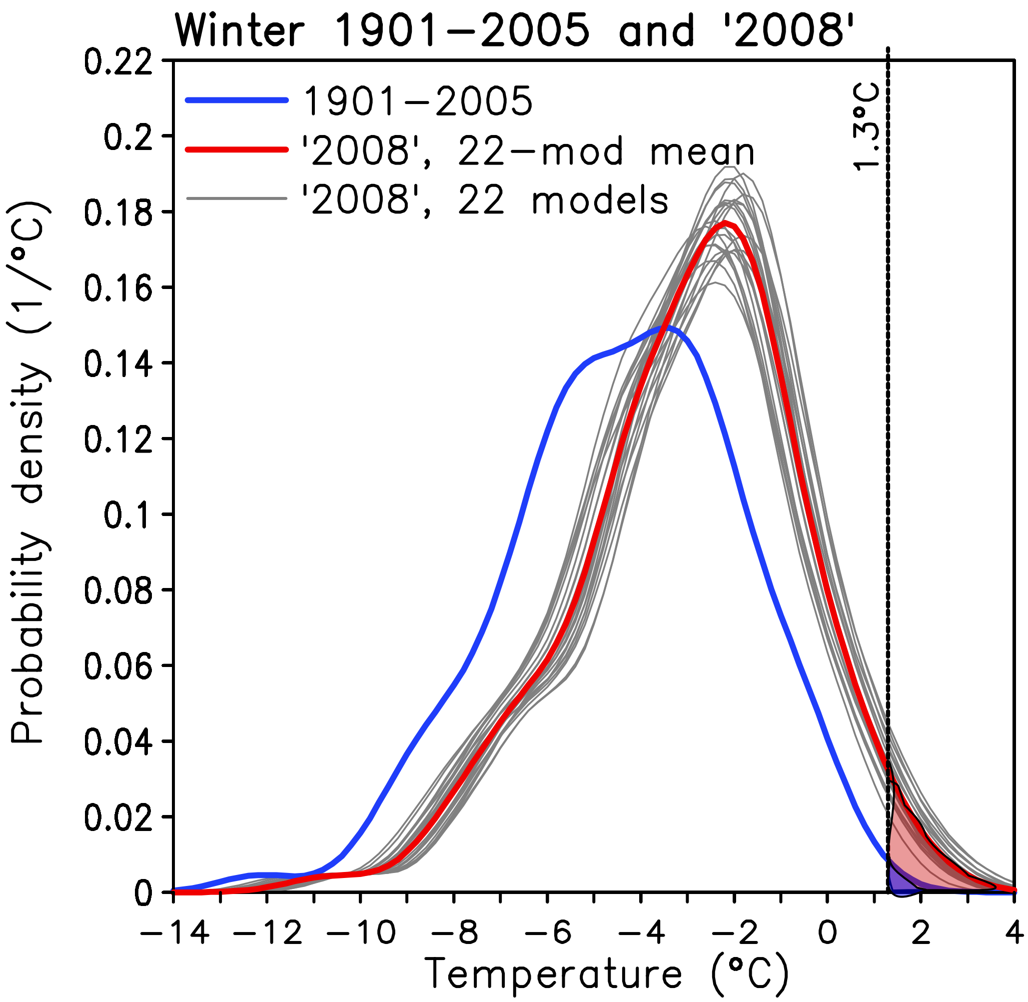
1) Hump at ~1940 ← observed maximum in global mean T
2) Slightly steeper slope for cold (e.g. 1942) than warm winters (e.g., 1925) ← decrease in variability
3) Only multi-model mean results shown in this figure.

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)



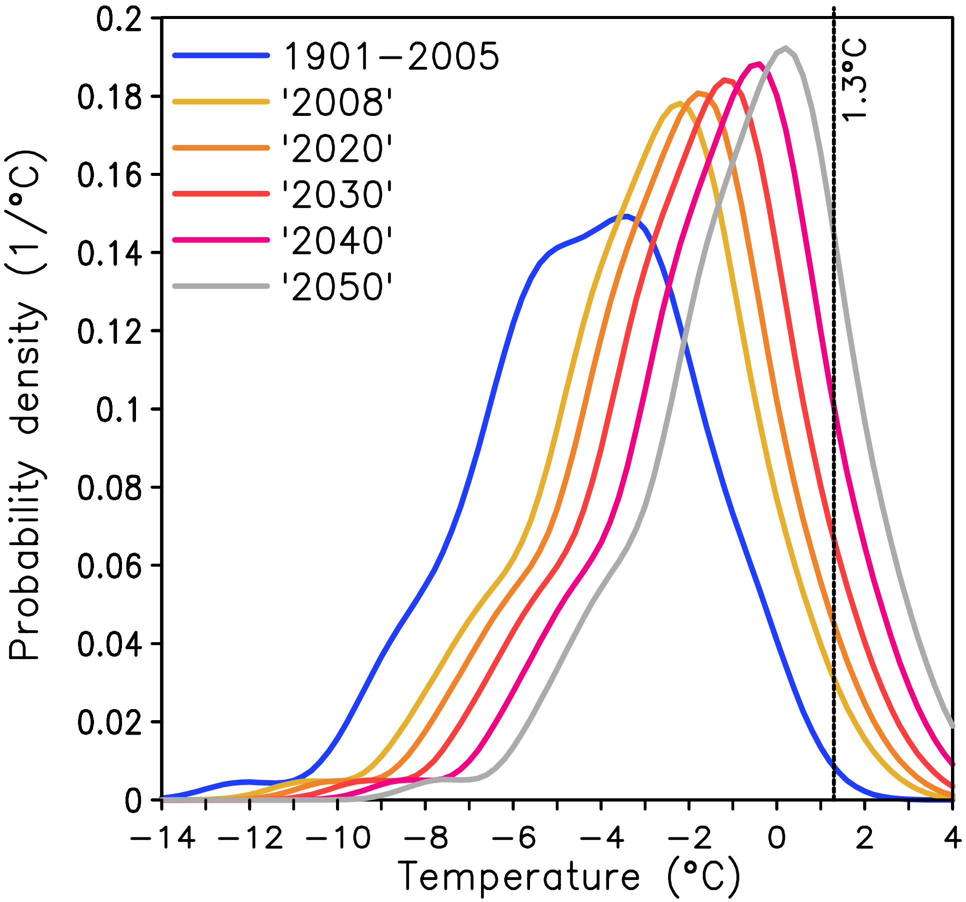
Estimated return period for $T_{DJF} \geq +1.3$ºC
(as observed in 2007-08):

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?



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

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**.

Conclusions

- It is impossible to prove a cause-effect relationship between climate change and individual extreme events.
- As measured in (ºC), 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/)**