

Climate Change and its Possible Impact on Aviation

- What are the Consequences (Threats)? -

Uwe Wienert
Deutscher Wetterdienst

Contents

1. What do we know from the past?

→ measurements, observations

→ recent trends

2. The possible future development of our climate

global and regional climate projections

change of parameters affecting aviation

3. Extreme weather – a challenge to climate research

Despite a patchy network of weather stations and many other restrictions limiting continuous long-term records our knowledge of the climate during the last 150 years is mainly based on measurements and observations.

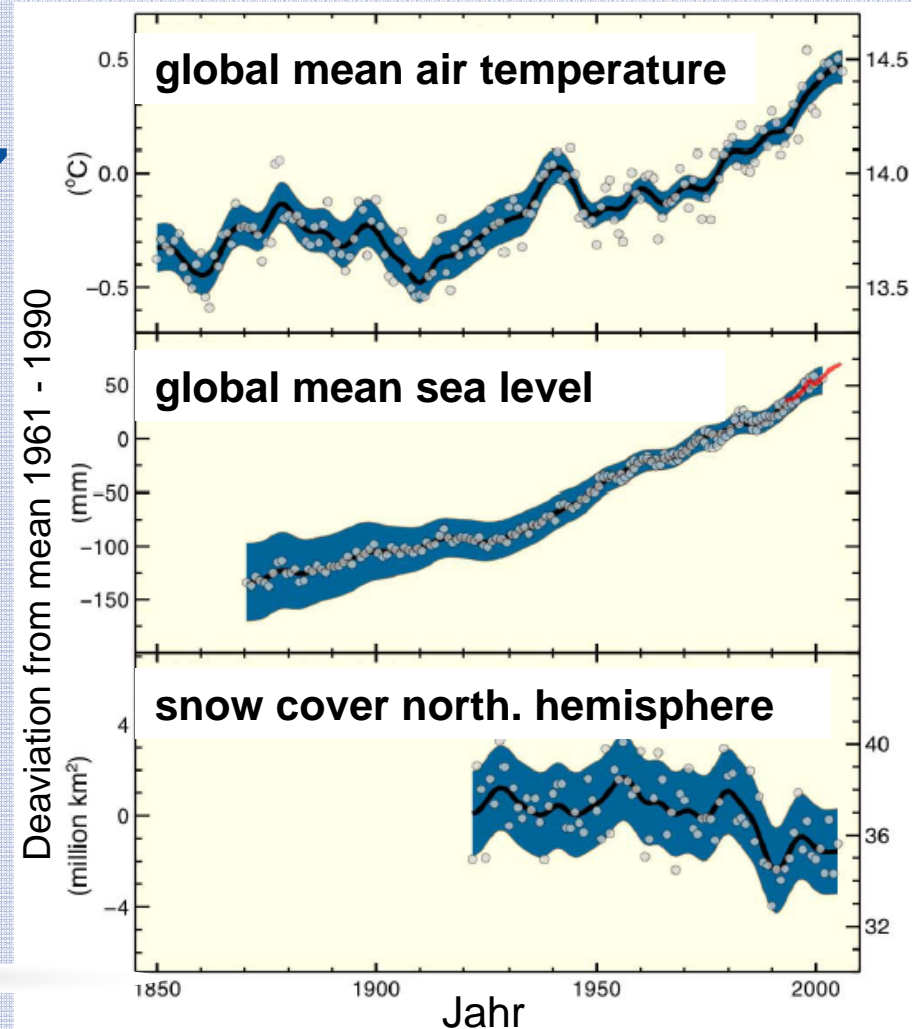
What are the most important climate changes that can be perceived today?



Global Changes according to IPCC 2007

- Increasing air temperature since 1850 (approx. + 0.9 K)
- Rise of sea level since 1870 (approx. 18 cm)
- Decrease of snow covered areas on northern hemisphere (approx. $-3 \cdot 10^6 \text{ km}^2$)

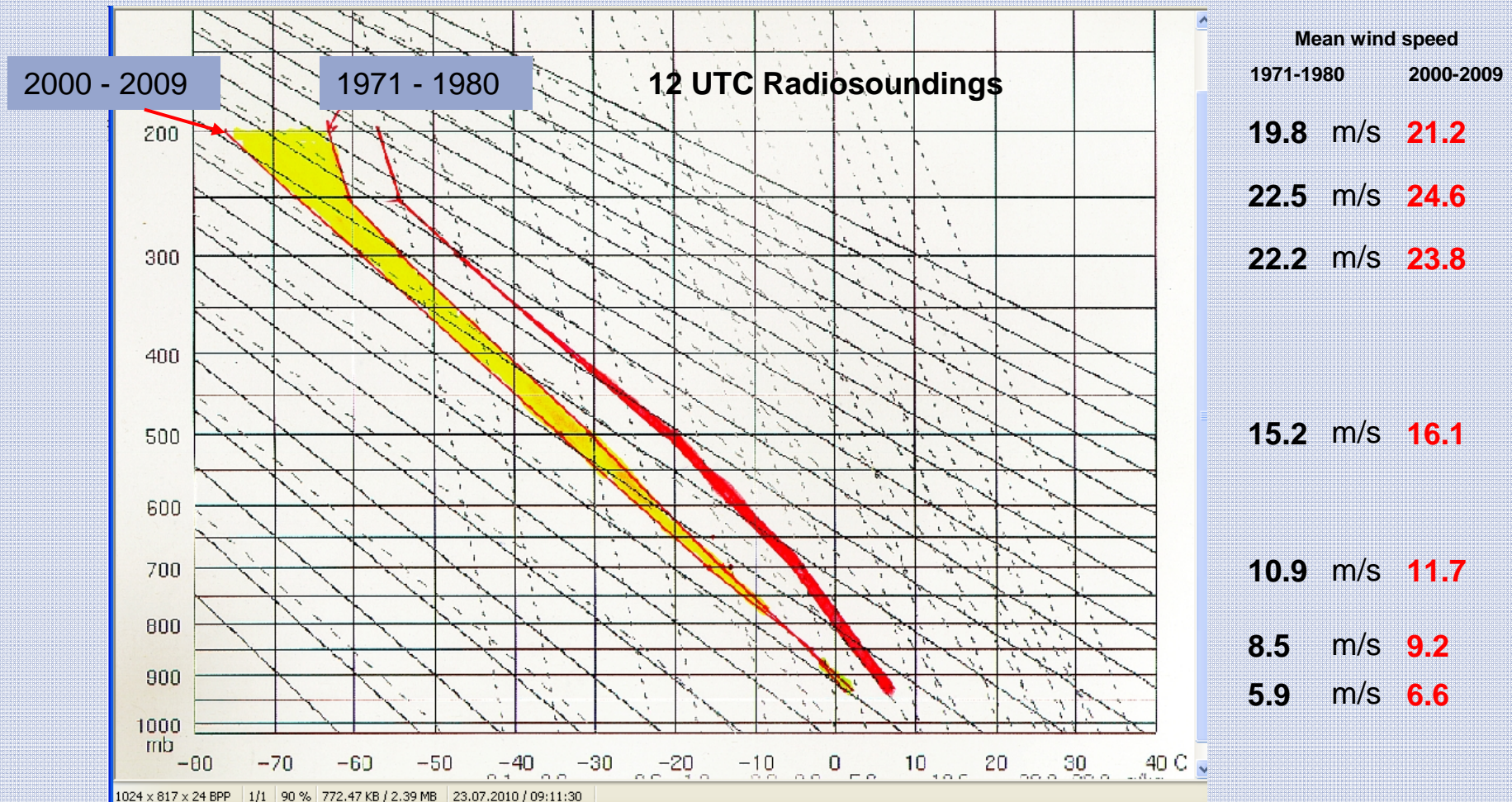
Source: IPCC 2007 (WGI-AR4, Summary for Policymakers, Feb. 2007)



Some climate trends from 1961 to 2009 at selected stations in Germany

Number of days with	1961 to 1970	2000 to 2009	Relative change
Tmax \geq 25 °C	31	47	+42 % to +83 %
Tmax \geq 30 °C	5	11	+92 % to +124 %
thunderstorm	27	27	-16 % to +11 %
freezing rain at the ground	5	11	+57 % to +127 %
snow cover \geq 1 cm	50	22	-64 % to -43 %
gusts > 40 kt	6 (1971 to 1980)	6	-23 % to +135 %

Vertical changes in air temperature, dew point and wind speed Aerological station Meiningen (50.56°N / 10.38°E)



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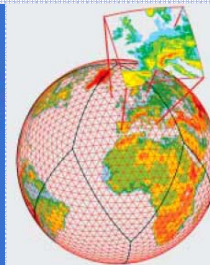
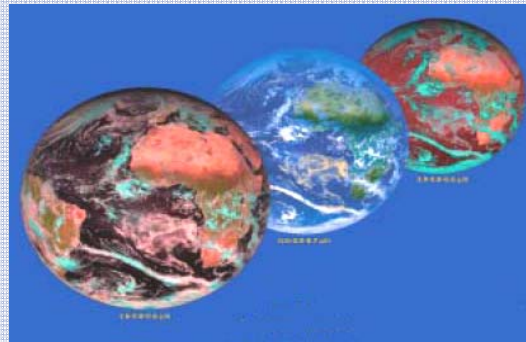
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Regional Climate Models in Germany

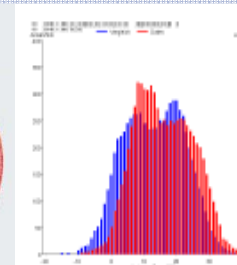
Measured
data

Global climate models
(not in DWD)

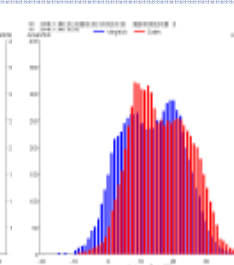
available regional climate models



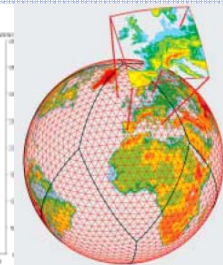
REMO



WETTREG



STAR



CLM

ECHAM-5

operated by : MPI-M
(Hamburg)

but origin of model ...

numerical

MPI-M
(Hamburg)



EM of DWD

statistical

CEC
(Potsdam)

statistical

PIK
(Potsdam)

numerical

CLM-Consort.
(Cottbus)

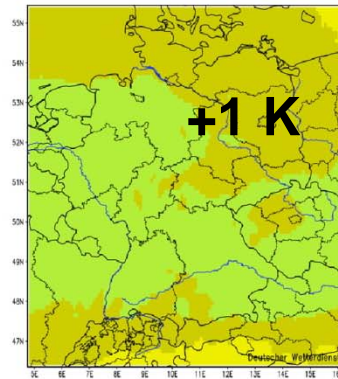


LM of DWD
(current mutual
development)

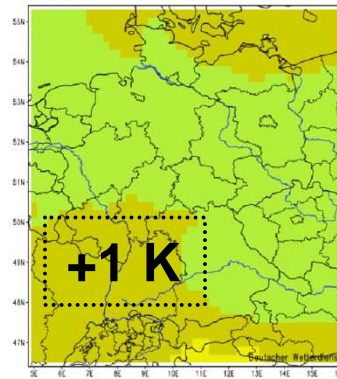
Annual mean temperature change w.r.t. the period 1971 - 2000

2021-2050

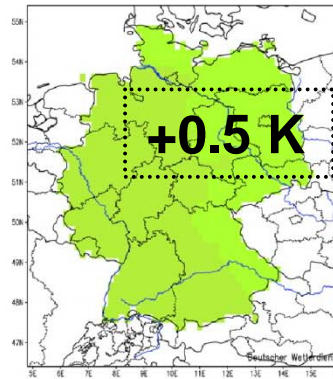
■ REMO



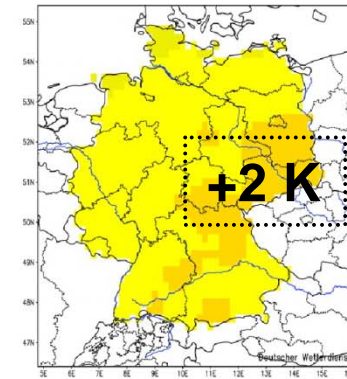
■ CLM



■ WETTREG

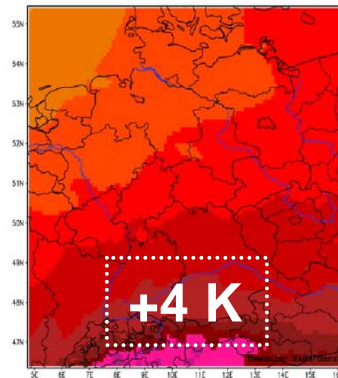


■ STAR

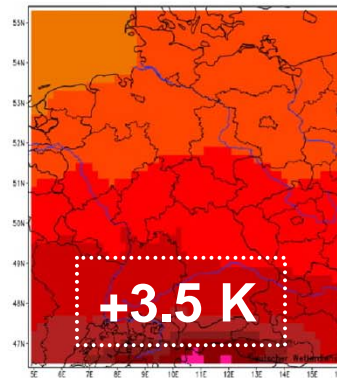


2071-2100

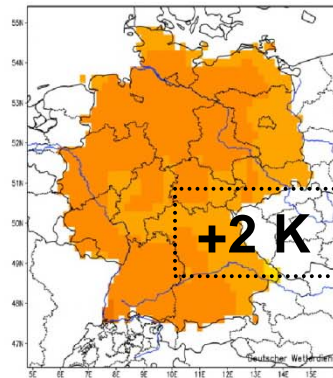
■ REMO



■ CLM



■ WETTREG



■ STAR

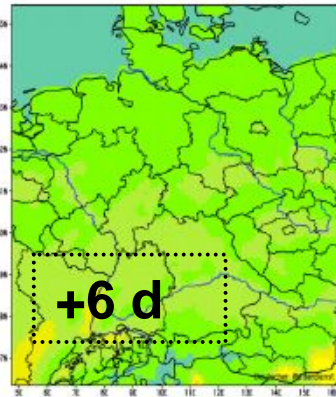
climate
projection
until 2055
only

Source: REMO: MPI-M i.A. des Umweltbundesamtes, 2006 | CLM: MPI-M/MaD i.A. des BMBF, 2007 | WETTREG: Meteo Research i.A. des Umweltbundesamtes, 2006 | STAR: PIK Potsdam, 2007

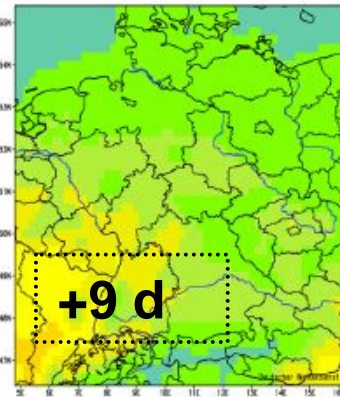
Change in number of hot days ($T_{\max} \geq 30^\circ\text{C}$) w.r.t. the period 1971 - 2000

2021-2050

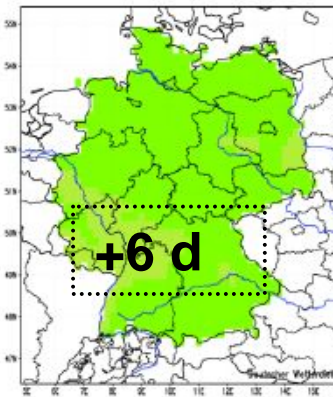
REMO



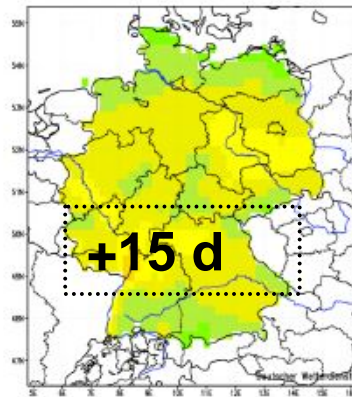
CLM



WETTREG

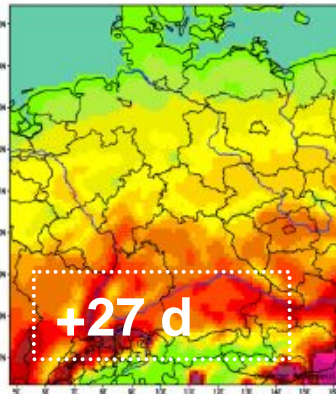


STAR

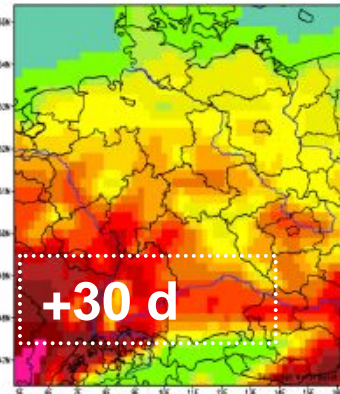


2071-2100

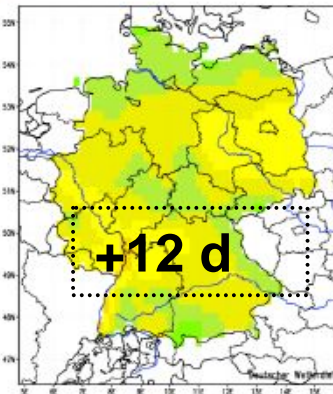
REMO



CLM



WETTREG



STAR

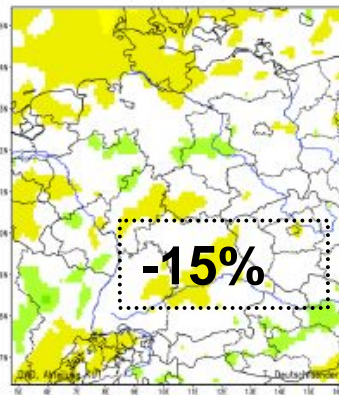
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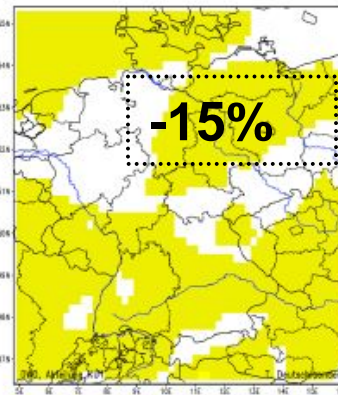
Mean summer precipitation change w.r.t. the period 1971 - 2000

2021-2050

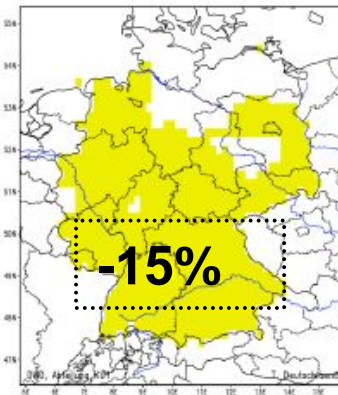
■ REMO



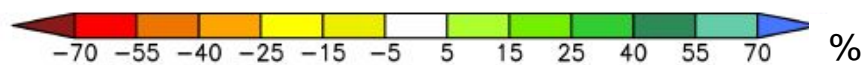
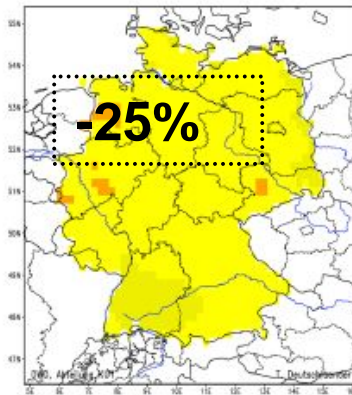
■ CLM



■ WETTREG

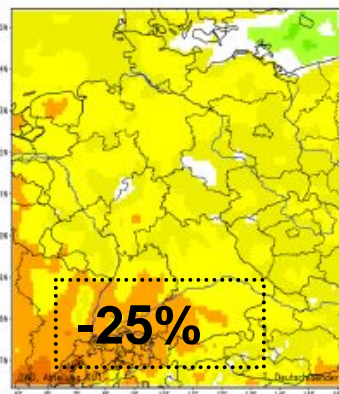


■ STAR

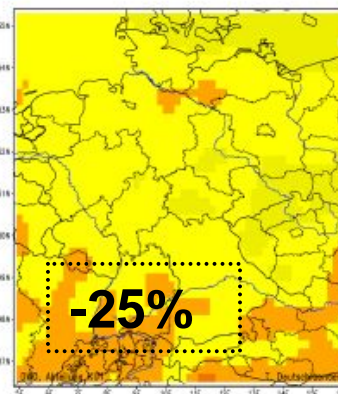


2071-2100

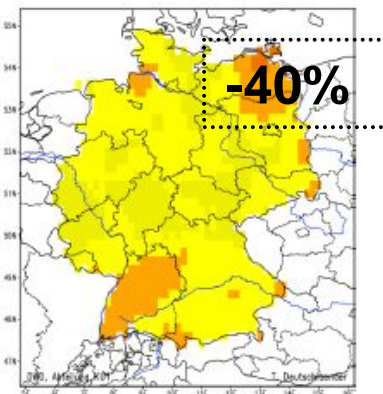
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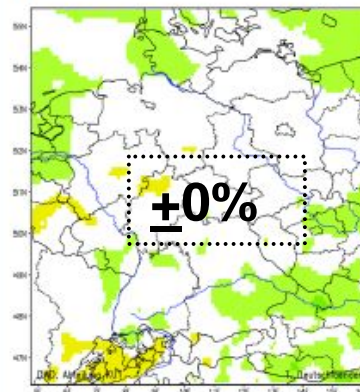
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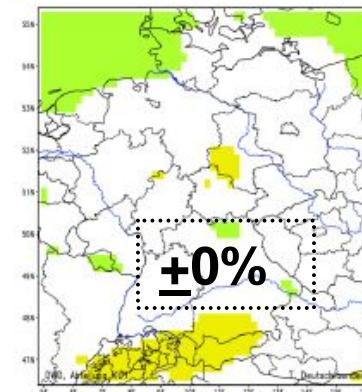
Mean winter precipitation change w.r.t. the period 1971 - 2000

2021-2050

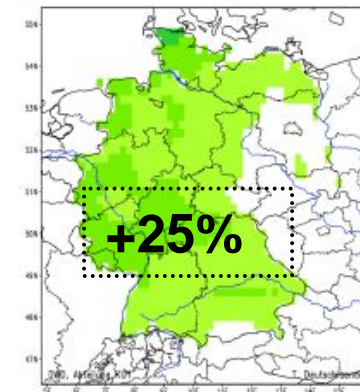
■ REMO



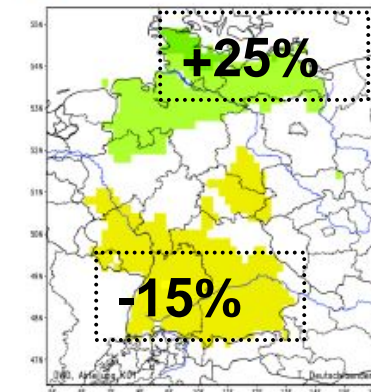
■ CLM



■ WETTREG

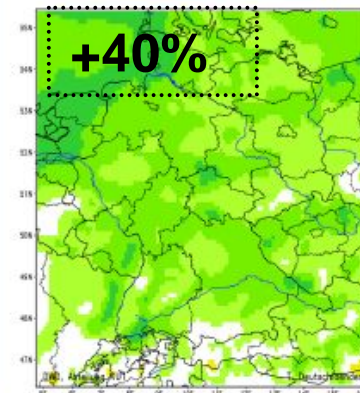


■ STAR

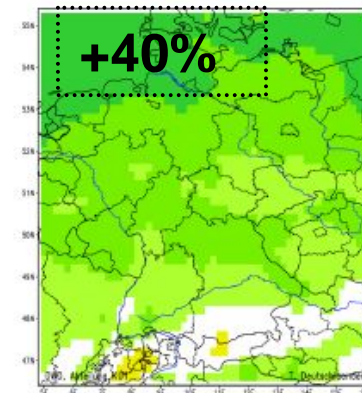


2071-2100

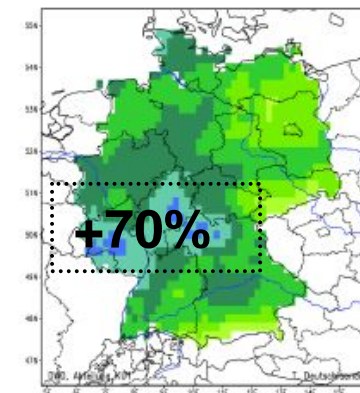
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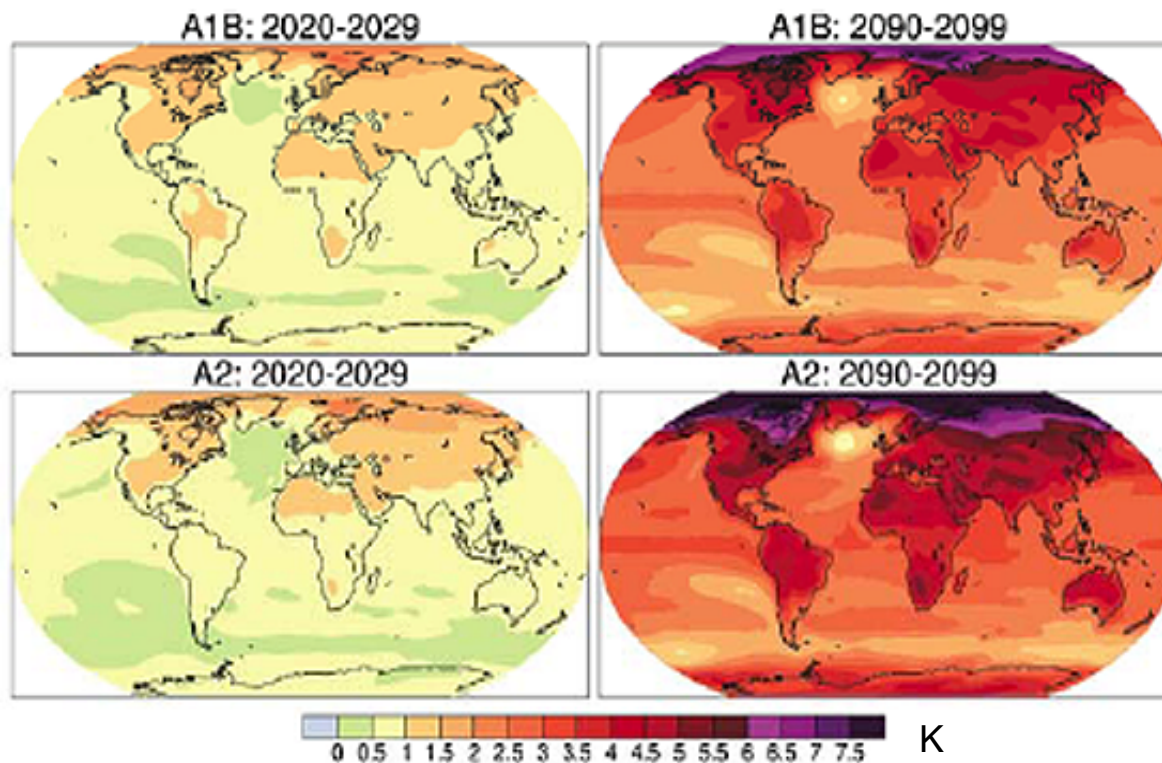
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Some large scale consequences for aviation

Expected changes in air temperature for the emission scenarios A1B and A2



A stronger warming of high latitudes might lead to:

- a weakening frontal zone
- a northward shifting of the polar front
- lower wind speeds in jet stream
- a more northerly position of jet stream

For aviation such a situation could mean:

- less turbulence
- less often severe CAT
- changes in fuel consumption
- new flight routes

Source: IPCC 2007 (WGI-AR4, Summary for Policymakers, Feb. 2007)

Possible consequences for aviation



air temperature:

very likely:

+ 0.5 K to + 2.0 K until 2021-2050

(w.r.t. 1971 to 2000)

some risks:

- worsening of engine performance
- reduction of payload
- changing flight routes vertically

Possible consequences for aviation



precipitation:

likely:

- drier in summer
- wetter in fall and winter
- more rain than snow
- individual events more intensive

(compared to present)

some risks (and advantage):

- more icing situations in winter
- less restrictions of ground operations by snow
- flooding of runways by heavy rain more frequently

Possible consequences for aviation in Central Europe



thunderstorms:

possible:

more intensive and more frequent
(compared to present)

increased risks through



- heavy rain
- hail
- severe icing
- gusts and turbulence
- lightning
- tornados

Possible consequences for aviation



(winter-)storms:
possible:

- **Tendency for more violent storms**
- **Tendency for less frequent storms**
- **Tendency for changing storm tracks**

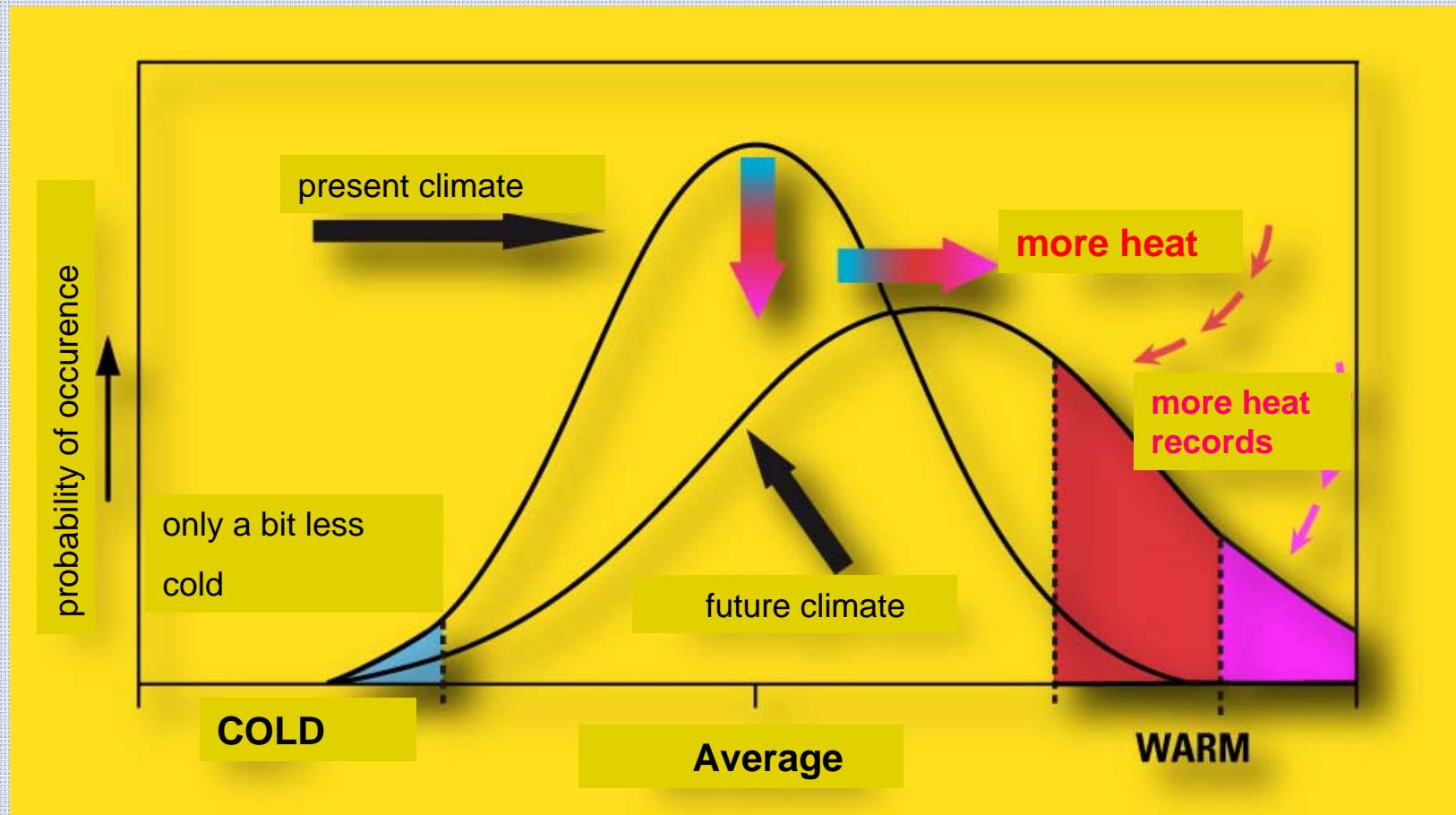
some risks (and advantage):

- . in distinct storms more severe turbulence but overall less frequent
- . damage of airport installations and aircraft on the ground
- . adaptation of flight routes to a change in storm tracks

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Climate Change Altering Extreme Values



mean warming! increased variability?

Selection of Climate Monitoring Parameters

Temperature

- CFD Maximum # of consecutive frost days
- FD Frost days
- ID Ice days
- CSDI Cold-spell duration index
- TG10p Cold days
- TN10p Cold nights
- TX10p Cold day-times
- SU Summer days
- WSDI Warm-spell duration index
- TG90p Warm days
- TN90p Warm nights
- TX90p Warm day-times



Precipitation

- CDD Maximum # of consecutive dry days
- CWD Maximum # of consecutive wet days
- R10mm Heavy precipitation days
- R20mm Very heavy precipitation days
- RX1day Highest 1-day precipitation amount
- RX5day Highest 5-day precipitation amount
- R95p Days with RR > 95th percentile of daily amounts
- R95pTOT Precipitation fraction due to very wet days



Wind

- 90th percentile of winter 10-m wind speed
- 95th percentile of winter 10-m wind speed
- 10th percentile of winter sea-level pressure
- # of exceedances of 90th wind-speed percentiles
- # of exceedances of 95th wind-speed percentiles
- # of exceedances of Beaufort 8
- # of exceedances of Beaufort 10



Project „Extreme Values“- an Overview

An analysis of changes in the extremes of air temperature, precipitation, and wind speed based on regional climate projections for Germany

- Results for the **year** as well as for meteorological **seasons**
- Time resolution at least on a **daily basis**
- Determination of the **change signal** (projection minus control period)

Start of project: June 2010

Summary

Since the end of the 19th century a global rise in air temperature has been observed together with a rising sea level and a decreasing snow cover.

A further warming of the atmosphere (lower troposphere) throughout this century is very likely to happen.

A warmer atmosphere will possibly bring about changes in:

- global circulation pattern
- precipitation regime
- frequency and intensity of extreme weather events

This may affect flight safety at the ground as well as in the air.

To quantify the effects of a changing extreme weather pattern more research has to be done.

A large, vibrant, orange and yellow cumulonimbus cloud dominates the background, set against a dark blue sky. A small silhouette of an airplane is visible flying through the lower right portion of the cloud.

**Thank you very much for
your interest**