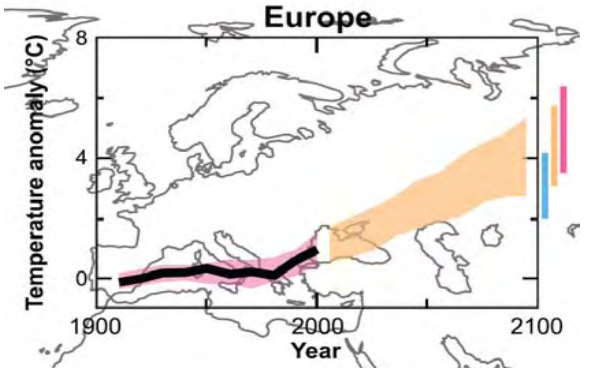
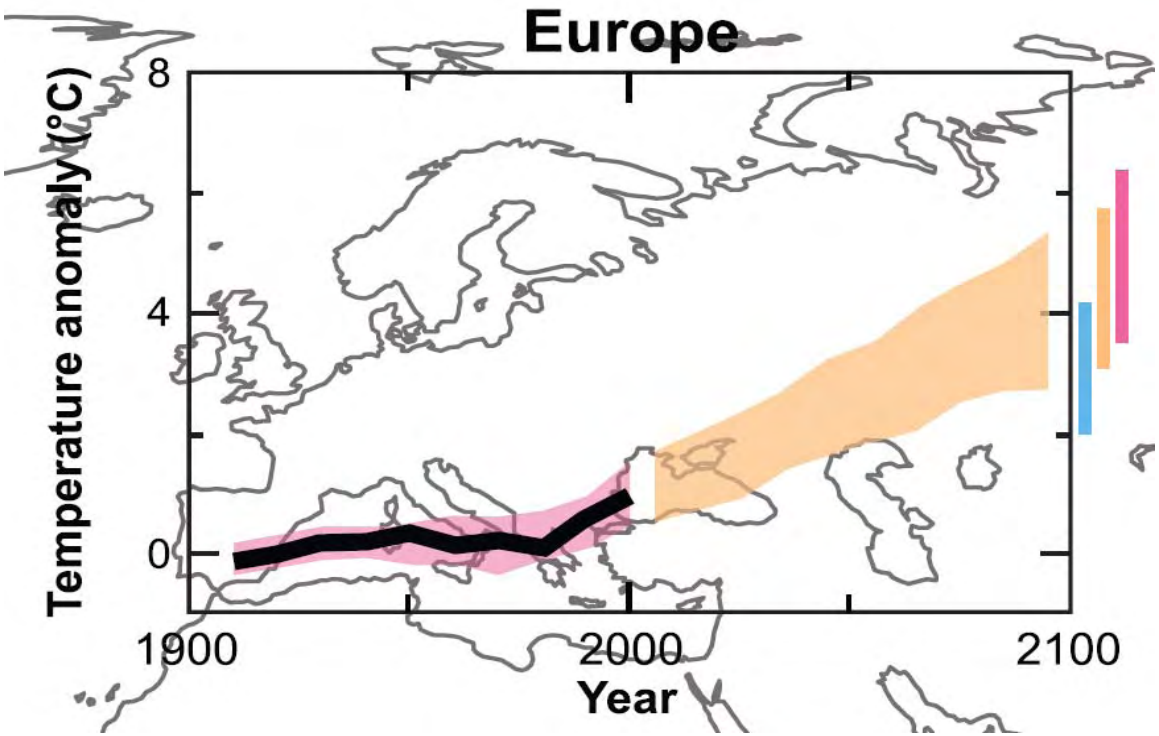
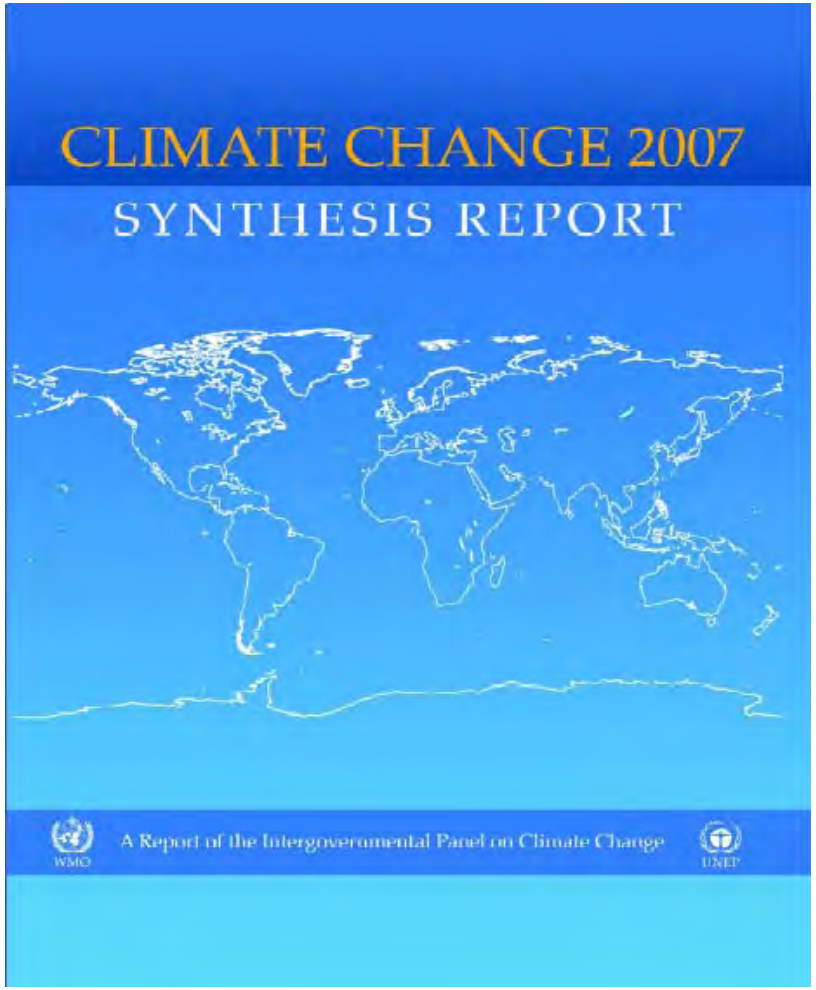
Predicting weather, climate and extreme events



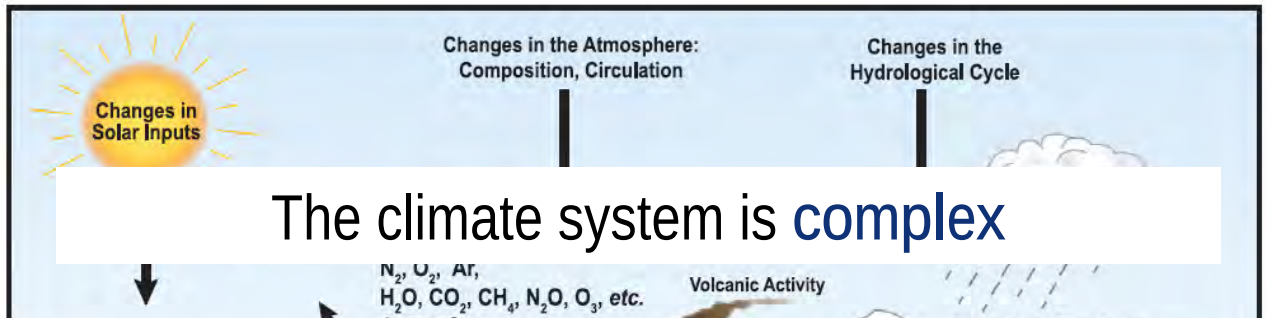
Alessandro Dosio
EC Joint Research Centre
Institute for Environment and Sustainability
Climate Change Unit


Europe
Temperature anomaly (°C)
8
4
0
1900
2000
2100
Year


CLIMATE CHANGE 2007
SYNTHESIS REPORT
A Report of the Intergovernmental Panel on Climate Change
WMO
UNEP

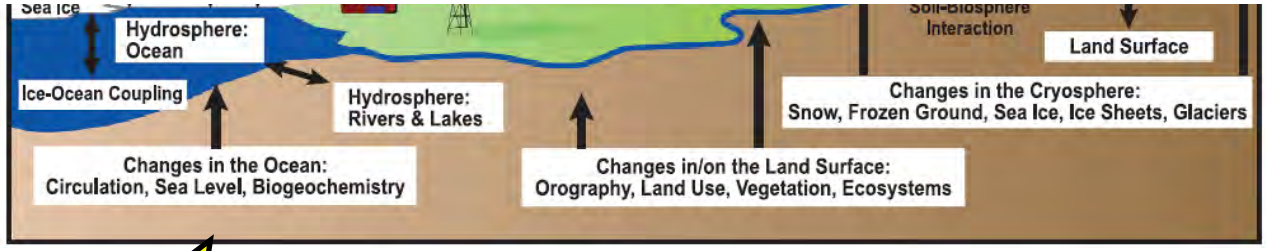
Is w ure?

The weather/climate system



There are multiple interactions (feedback) between its components

There is still an incomplete physical understanding of many components



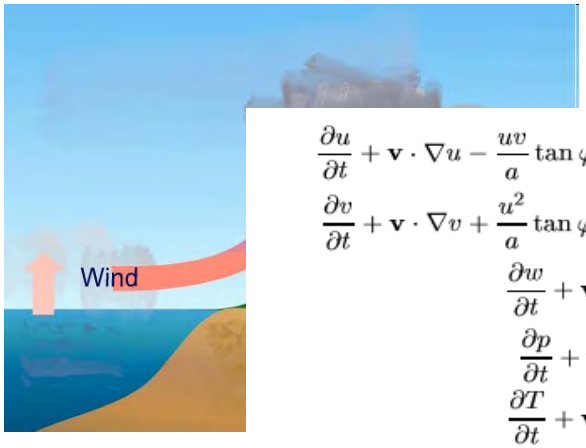
DISCLAIMER:

These factors impose limitations on our ability to understand fully the future course of Earth's global climate.

(IPCC 4AR, 2007)

A (very short and oversimplified) course in NWP

Physical process



(Wikipedia)

Mathematical representation

$$\frac{\partial u}{\partial t} + \mathbf{v}\cdot\nabla u - \frac{uv}{a}\tan\varphi - fv = -\frac{1}{\rho a\cos\varphi}\frac{\partial p}{\partial \lambda} + M_u$$

$$\frac{\partial v}{\partial t} + \mathbf{v}\cdot\nabla v + \frac{u^2}{a}\tan\varphi + fu =$$

$$\frac{\partial w}{\partial t} + \mathbf{v}\cdot\nabla w =$$

$$\frac{\partial p}{\partial t} + \mathbf{v}\cdot\nabla p =$$

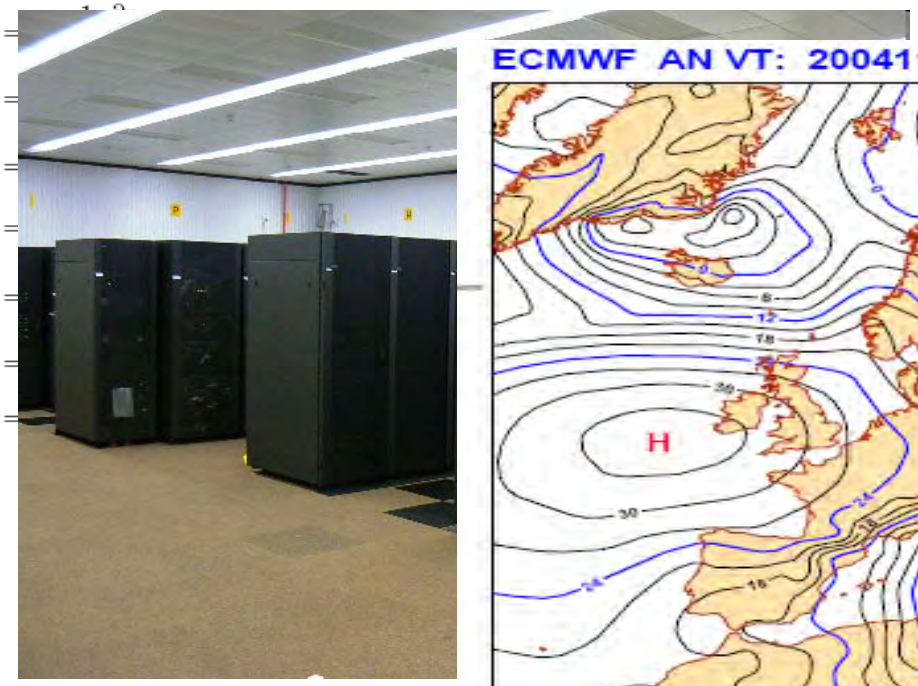
$$\frac{\partial T}{\partial t} + \mathbf{v}\cdot\nabla T =$$

$$\frac{\partial q^v}{\partial t} + \mathbf{v}\cdot\nabla q^v =$$

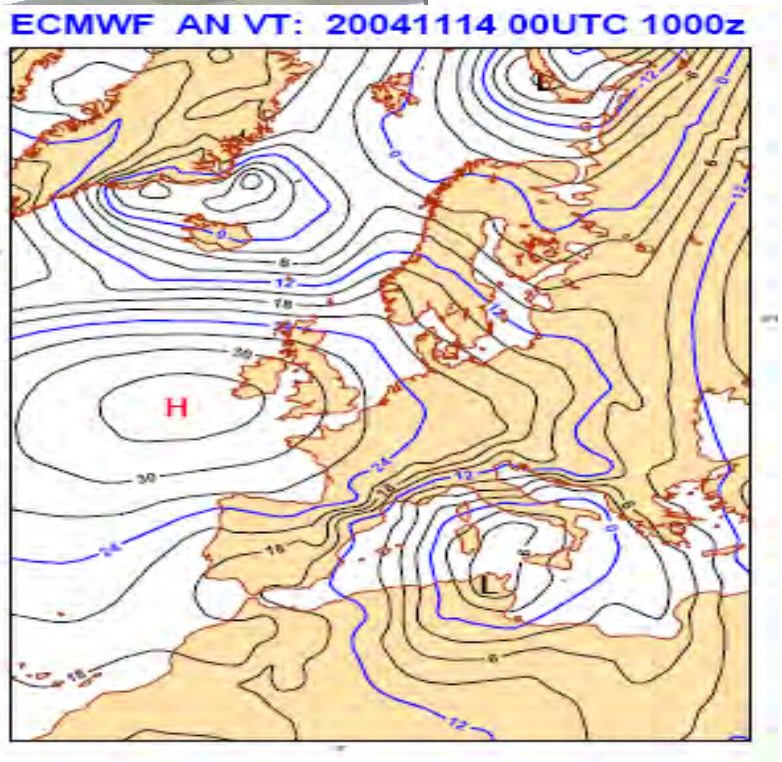
$$\frac{\partial q^{l,f}}{\partial t} + \mathbf{v}\cdot\nabla q^{l,f} - \frac{1}{\rho}\frac{\partial P_{l,f}}{\partial z} =$$

$$\rho =$$

Some (very fast) computer

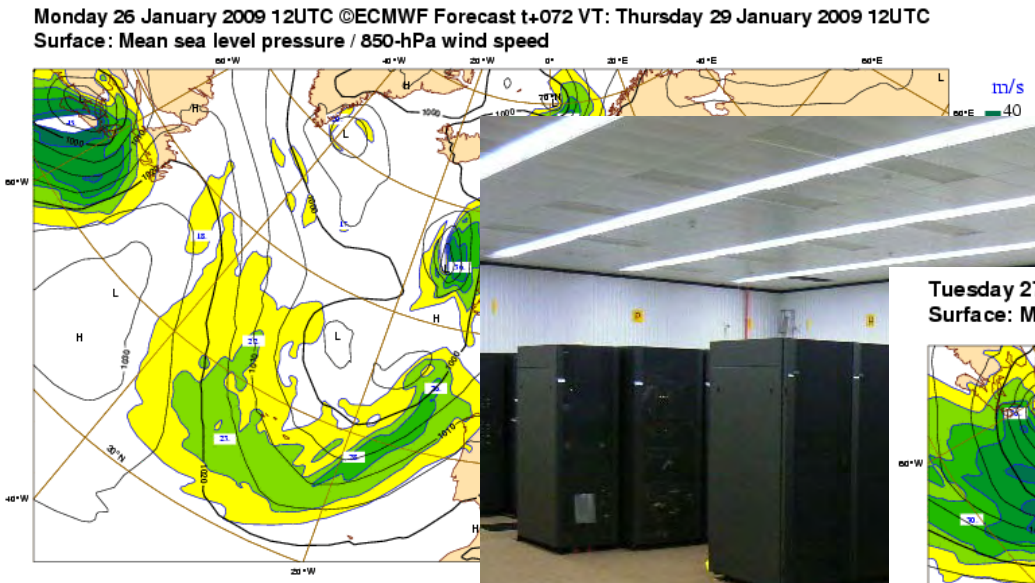


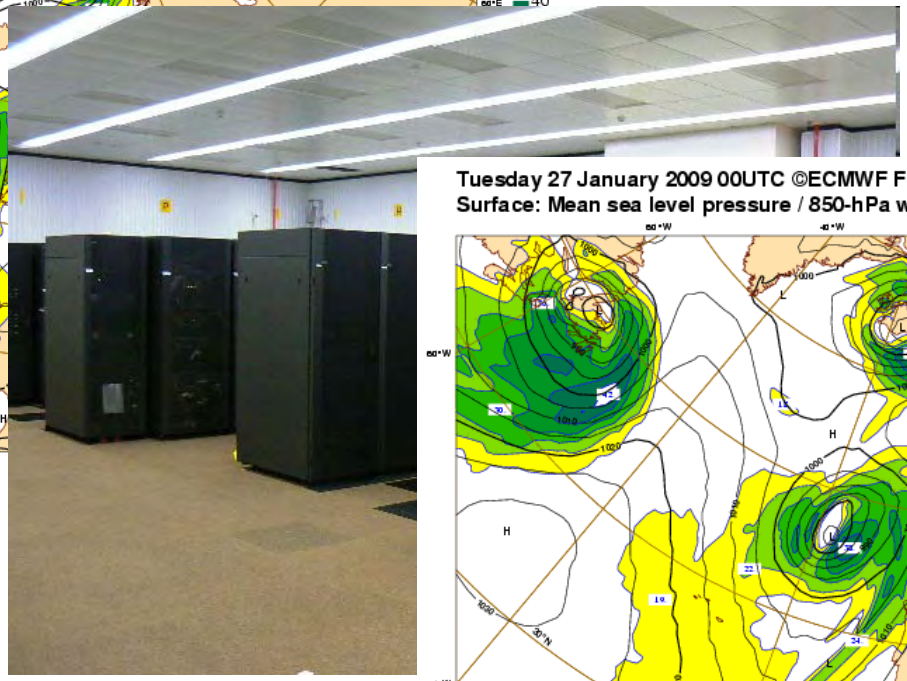
Future weather/climate



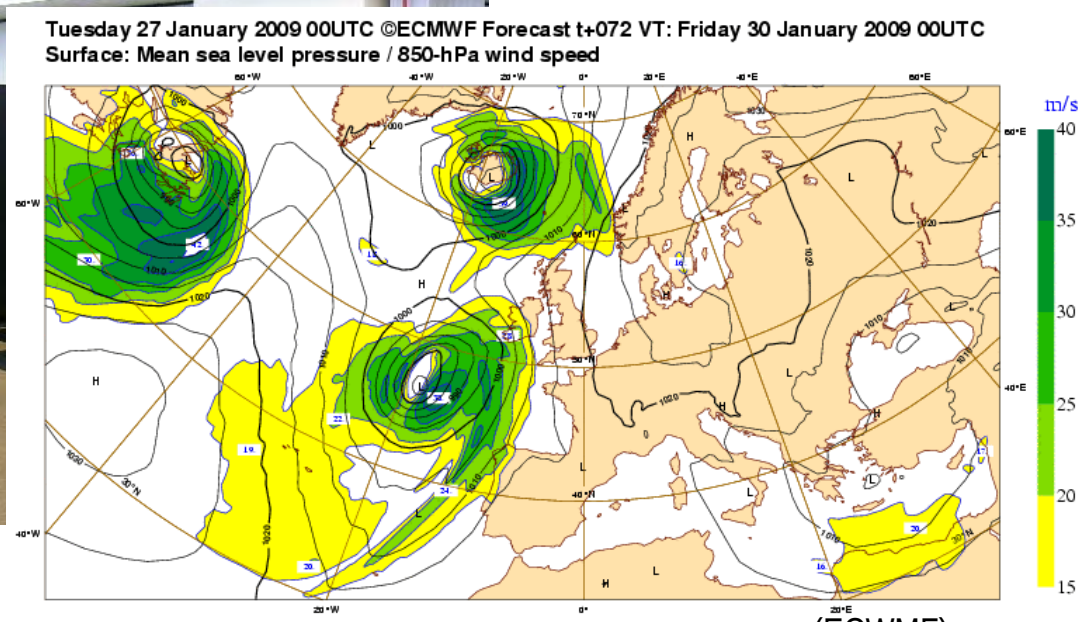
Weather forecast: an initial value problem

Today's weather (observations + model)





Tomorrow's weather



(ECWMF)

Why is this relevant?

Edward Norton Lorenz (1917 - 2

In the mid-1950s Lorenz was using a simple digital c to see
a sequence of data again and to save time he starte able
tout of the data correspo hich

er that the mac ine beg

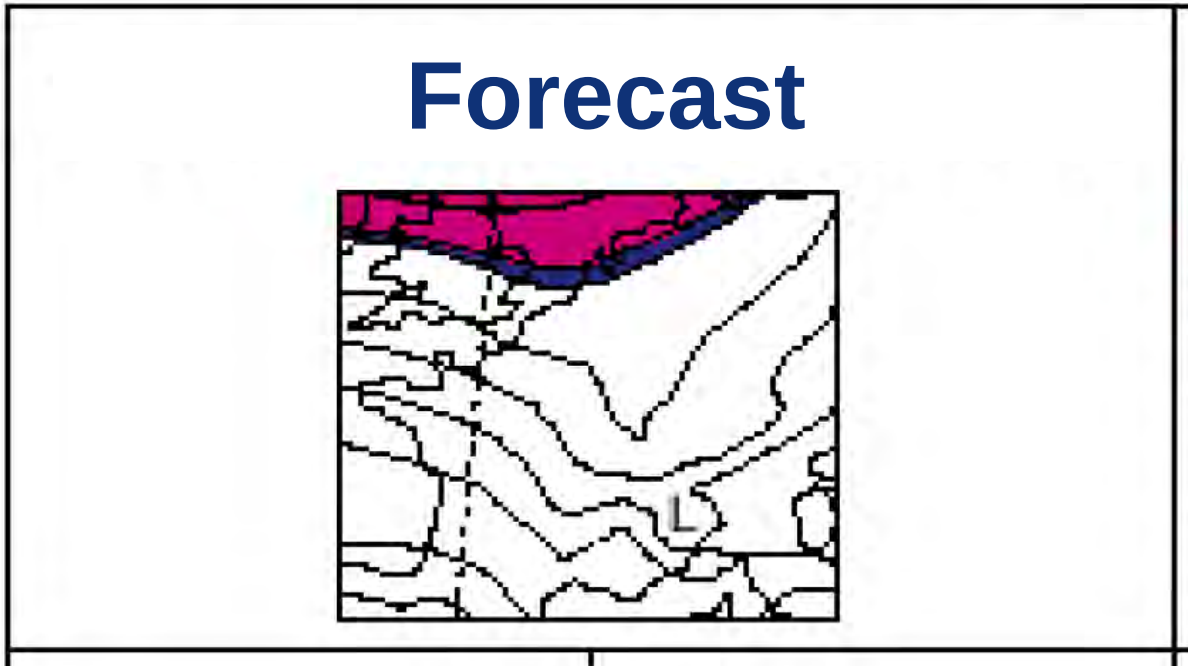
out.
, so
the t cally

condition of a e
he long term be

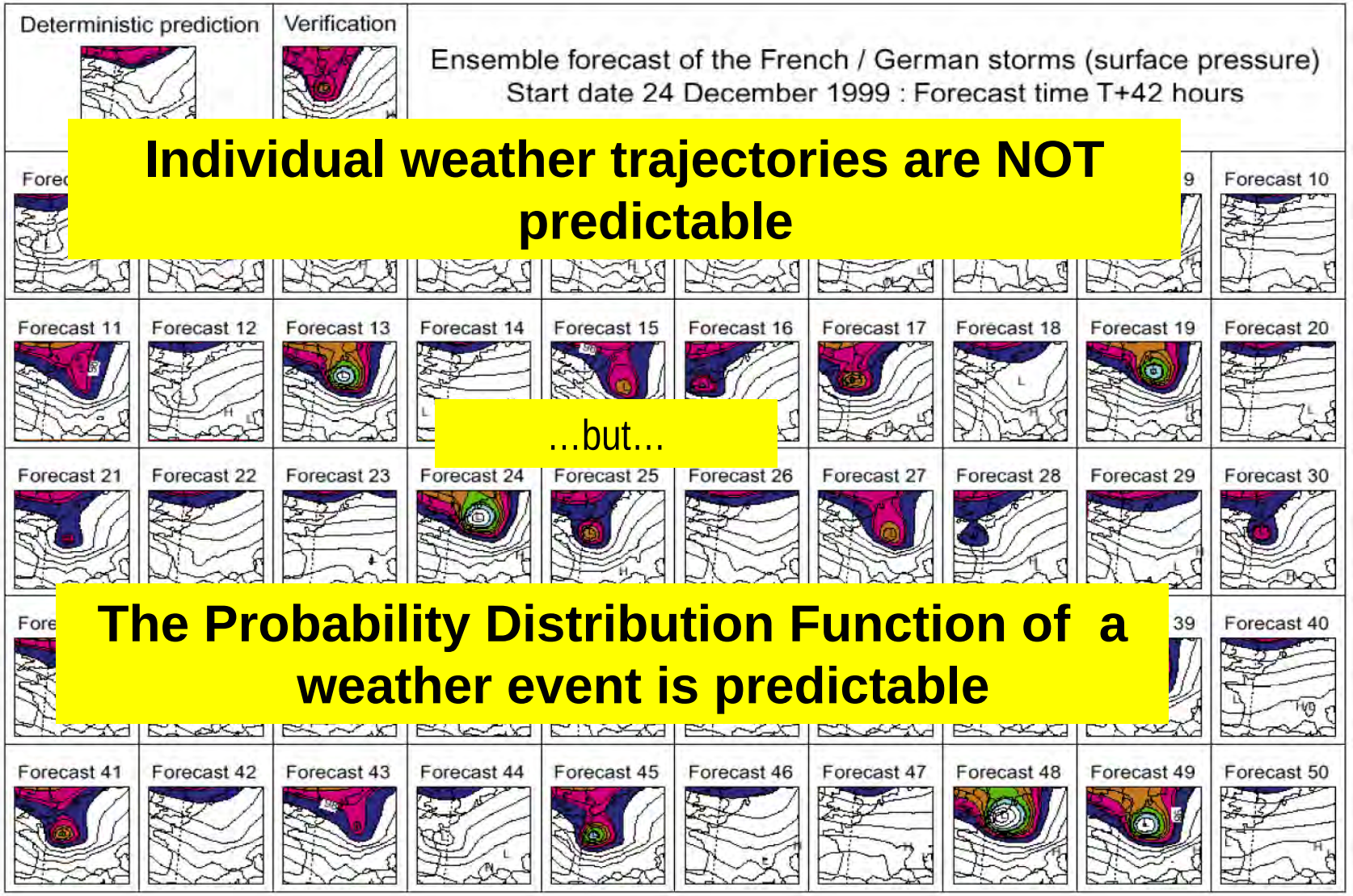
“Does the flap of a butterfly’s wings in Brazil set off a tornado in Texas?”
Lorenz, 1972

A real example: wind storm Lothar (December 1999)

Forecast



Then how can we predict the weather?



Individual weather trajectories are NOT predictable

…but…

The Probability Distribution Function of a weather event is predictable

T. Palmer et al, 2005

What about climate prediction?

Weather evolution is chaotic (i.e sensitive to initial condition). Max 10 days forecast.

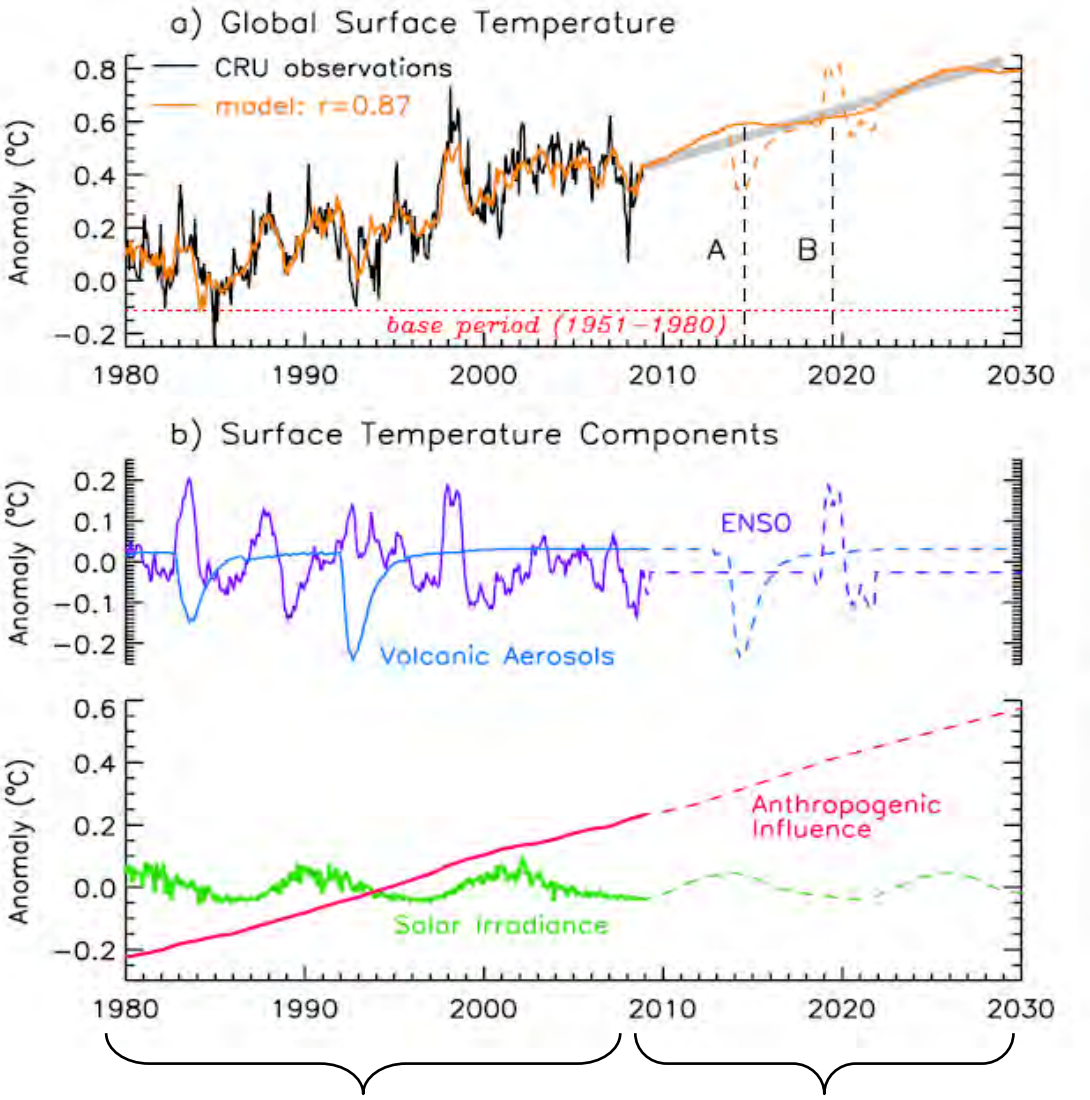
How is then climate predictable?

- **Low frequencies effects**, i.e. phenomena which vary on time scale much longer than the weather characteristics,

  Some seasonal/longer time scale phenomena are **systematic/predictable** (El Niño, etc) or **foreseeable/estimated** (e.g CO2 emissions scenario) → **FORCING**

  The long-term effect of these forcing on the atmospheric PDF can be predictable

- Climate **summarizes the average, range and variability** of weather elements (e.g. rain, wind, temperature) observed **over many years** at a location or across an area → Long term **STATISTICS**



Natural variability ("periodic")

Anthropogenic forcing (estimated)

Lean and Rind, 2009

Climate prediction is a boundary value problem:

… [climate] simulations initialized with **negligible differences** in initial conditions will result in **different sequences of weather events**.

On the other hand, the **long- term climate statistics will be the same for a given set of external boundary conditions**, and they will be **independent of the details of the initial state**.

(Laprise 2008)

Climate prediction in practice

I.C.

Present climate

1950 2000 2050 2100

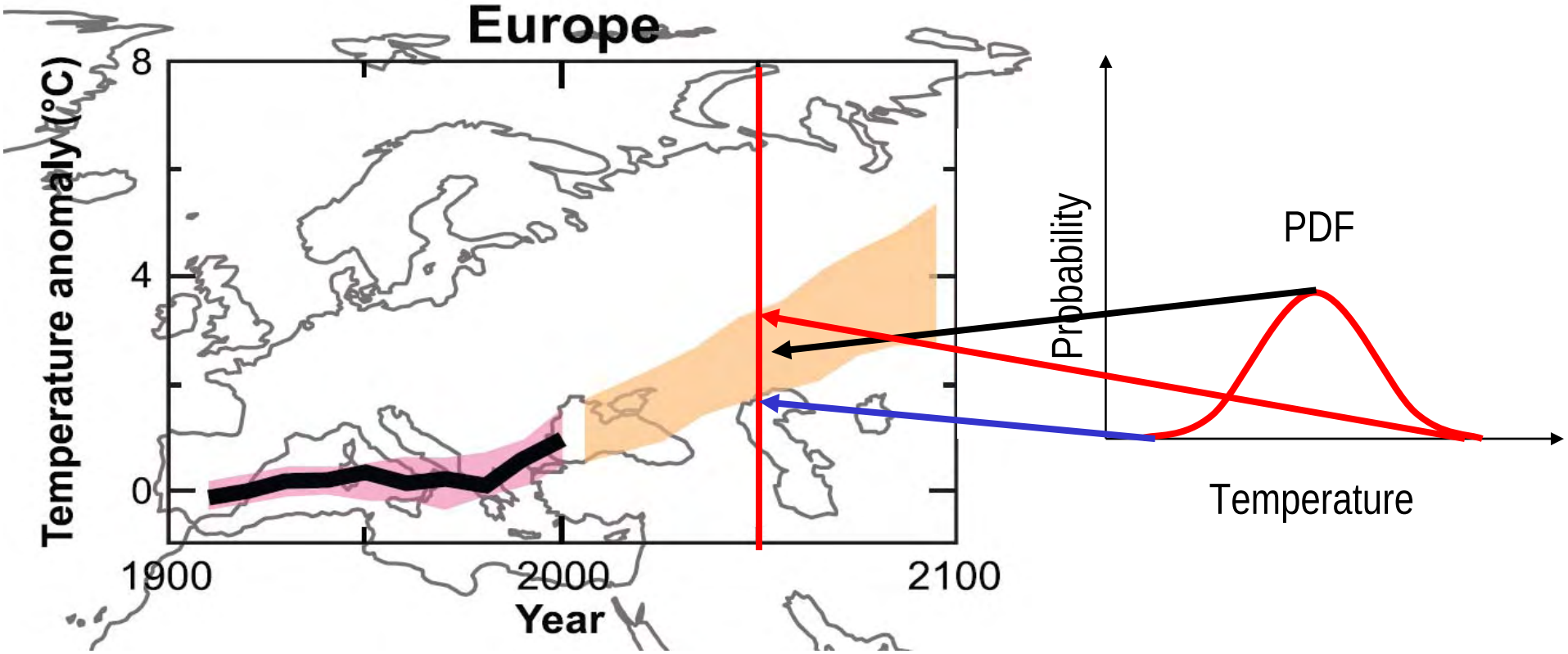
Realization 1
Realization 2
Realization 3
Realization n

Model 1
Model 2
Model n

Verification against observations

ong-term statsictis

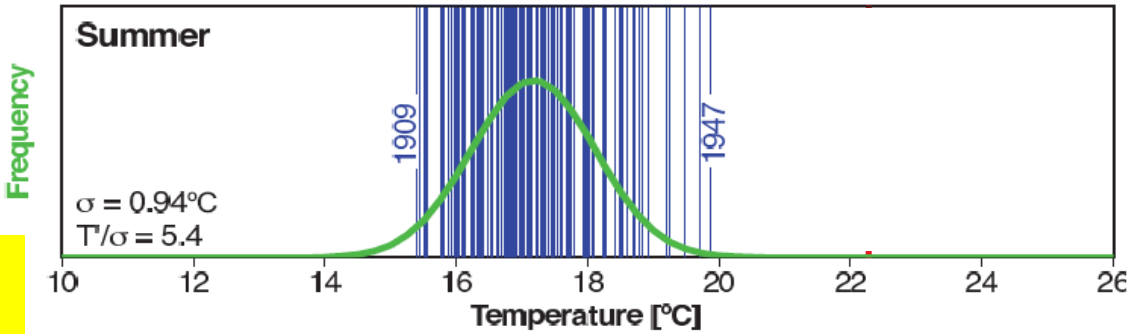
Climate prediction: a typical result



Result: multi model, multi-scenario ensemble (e.g., IPCC 4AR)

What is an extreme event? Observations

Switzerland: Summer



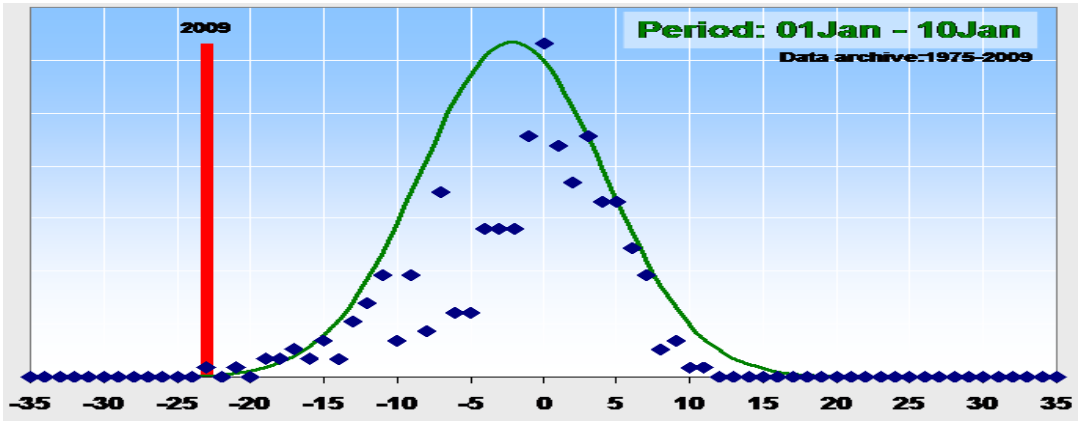
(Schär et al., 2004)

Extreme events are infrequent weather events that depart heavily from the average.

They are a result of the natural variability

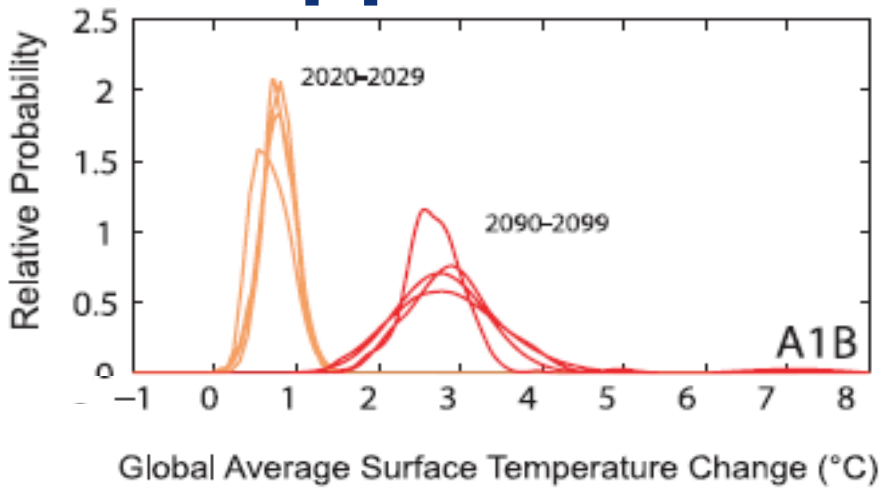
Germany: Winter

2009



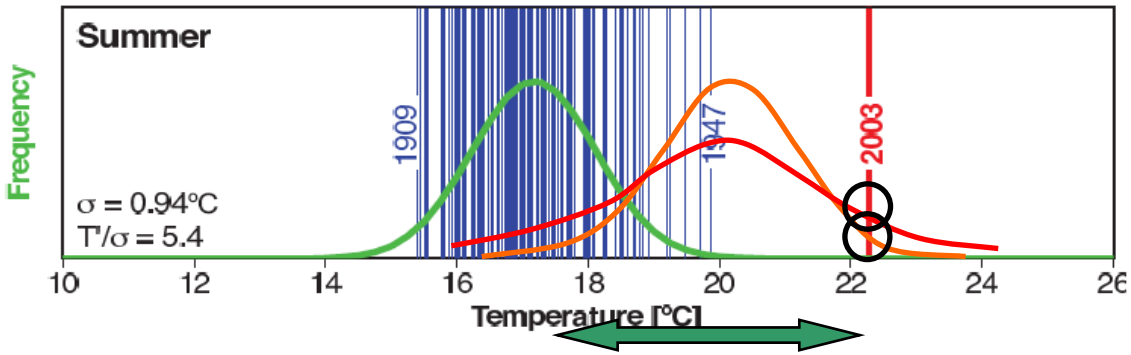
Extreme events: What happens if…

Model predictions



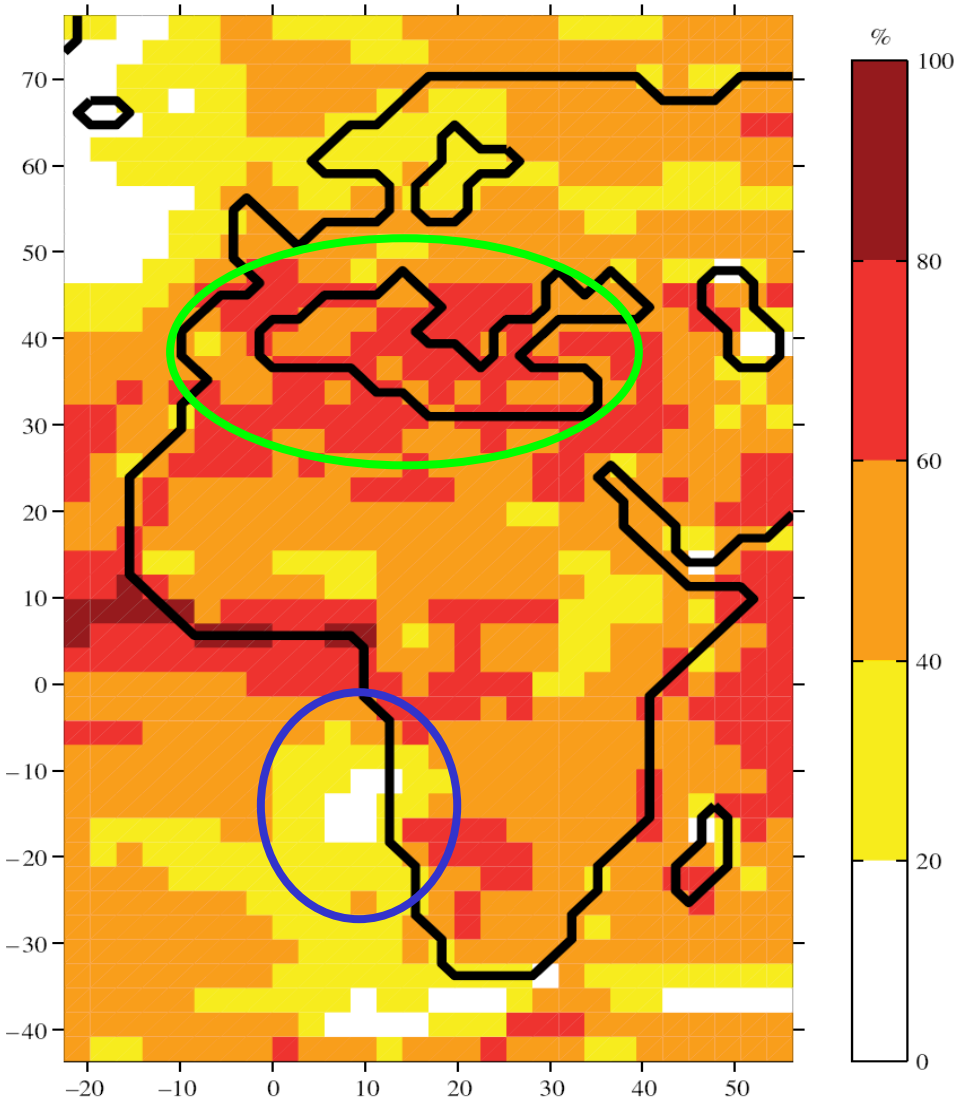
Shift of mean value

What it means in practice



Spread of variability

Probability of extremely warm (95th Percentile) summer temperatures in 2081–2100 based on a multi-model multi-scenario ensemble.



Over parts of the west coast of southern Africa, the probability of an extremely warm summer is predicted to increase from 5 to about 10%; that is such summers which occurred about once every 20 years in the twentieth century, can be expected to occur about **once every 10 years**.

On the other hand, there are regions (e.g. Mediterranean) where extremely warm summers are expected to occur with a probability of more than 60%. In these regions, such (twentieth century) extremes can be expected in at least **two seasons out of three**.

T. Palmer et al, 2005

The altered dices analogy

The situation of Climate Change is very analogous to an **altered set of dices** where the **sixes occur twice as often as normal**.

The “altering” of the climate system comes from the increase of greenhouse gases, and rise of the Earth’s temperature. This leads to an **increased probability of extreme weather events** in the future. Just like the altered dices would lead to an increased occurrence of sixes with every next roll.

Due to the **still random nature of the dices**, however, **we won’t be able to tell when the next six will occur.**

Extreme weather events behave in a very similar manner: even though **we can calculate their statistical frequency we still do not know when exactly they will occur**.

Furthermore the picture of the altered dices also emphasizes the fact that even though a certain occurrence has been observed before, it doesn’t tell you much about the dices quality or whether or not they have been manipulated in the first place: **half of the sixes would have occurred anyway**, even with two normal dices.

B. Schinke

To conclude…

An important question which scientists are trying to answer is whether **mankind's interference** with the climate system through the enhancement of the natural greenhouse effect will **increase the frequency or magnitude** of extreme weather events.

Given the **large natural variability** and the obvious **rarity of extreme** weather events it is **hard to ascribe the observed phenomena to the enhanced greenhouse effect** or even discern a definite trend in extreme event throughout this century.

What can be said with certainty, however, is that any change in climate will affect society mainly through extreme weather events. Of all aspects of climate variability, extreme events are likely to have greatest effect on human well-being in the decades to come.

(www.greenhouse-warming.org.uk)

Thank you!

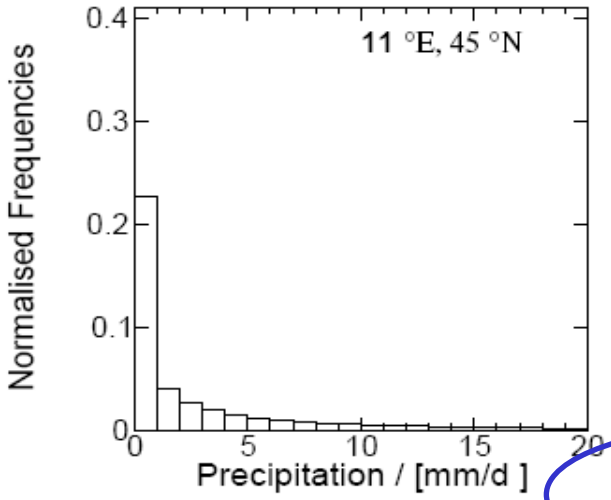
Extra material

Present and future precipitation

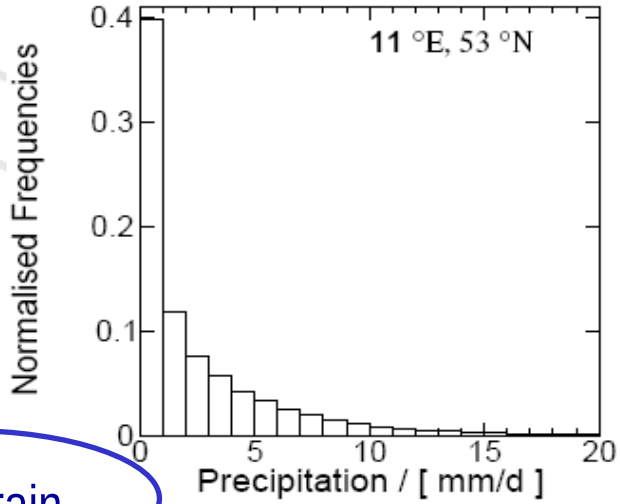
Present climate (1960-2000)

Scenario (A1B) – Present climate

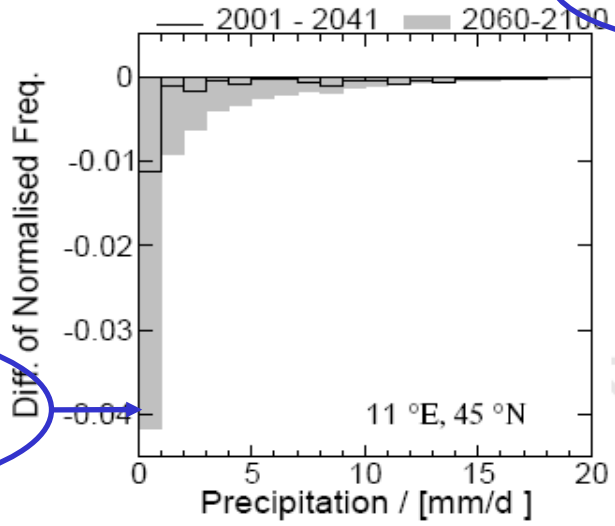
Northern Italy

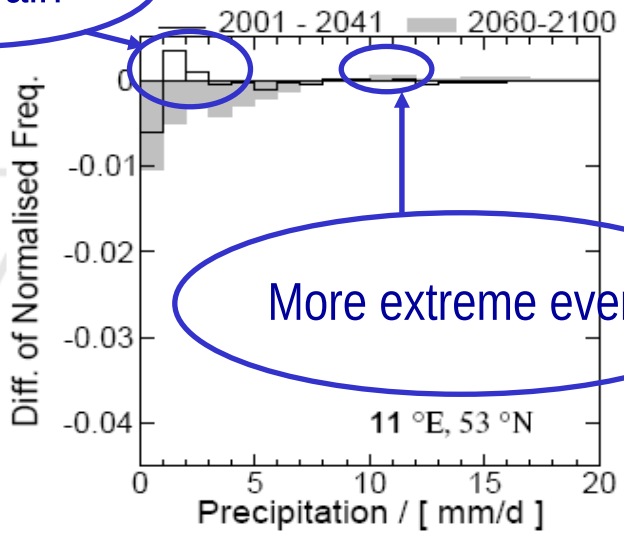


Northern Germany



More rain





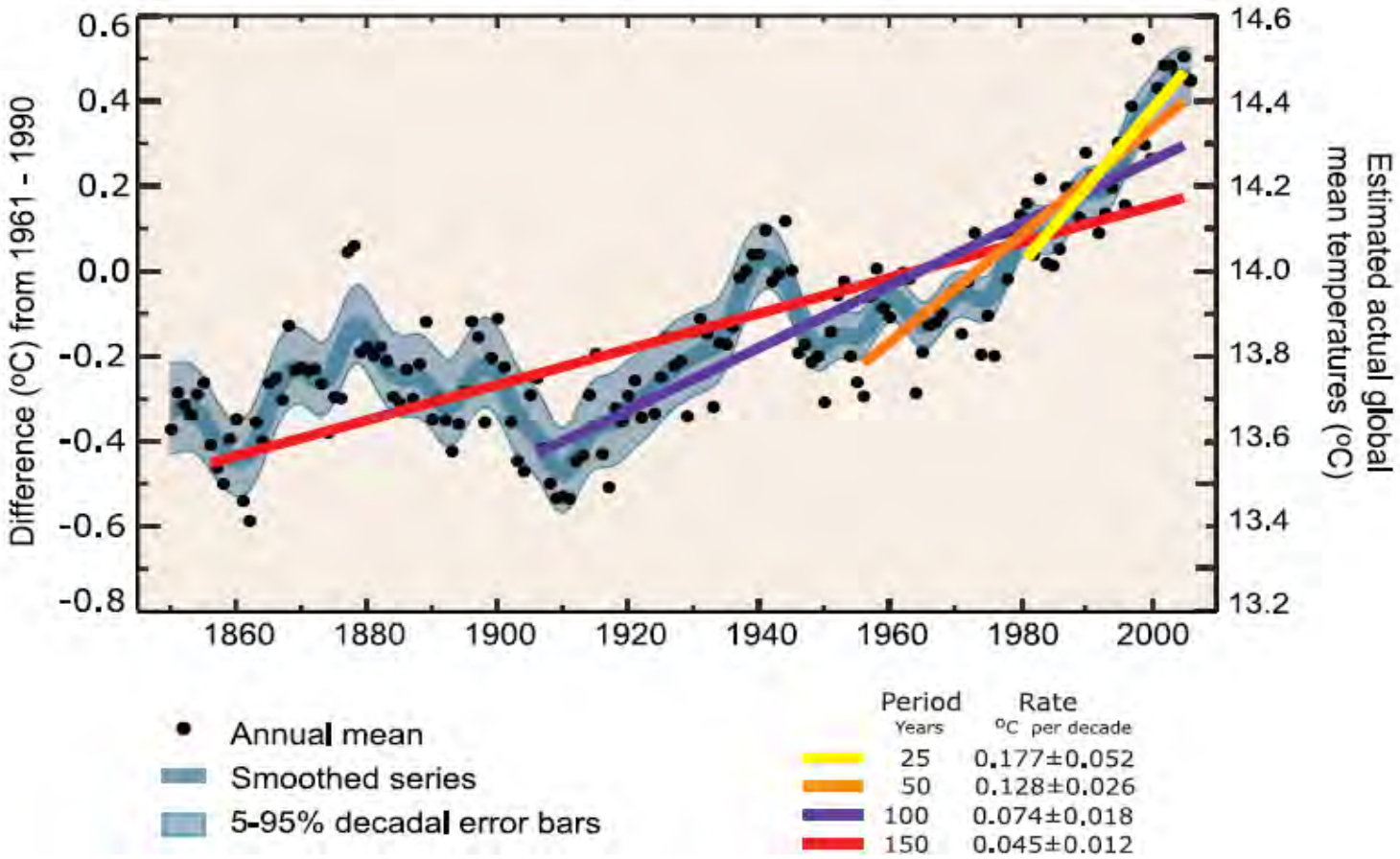
20 % less probable

More extreme events

Is climate changing?

Is climate changing?

Observations of climate change

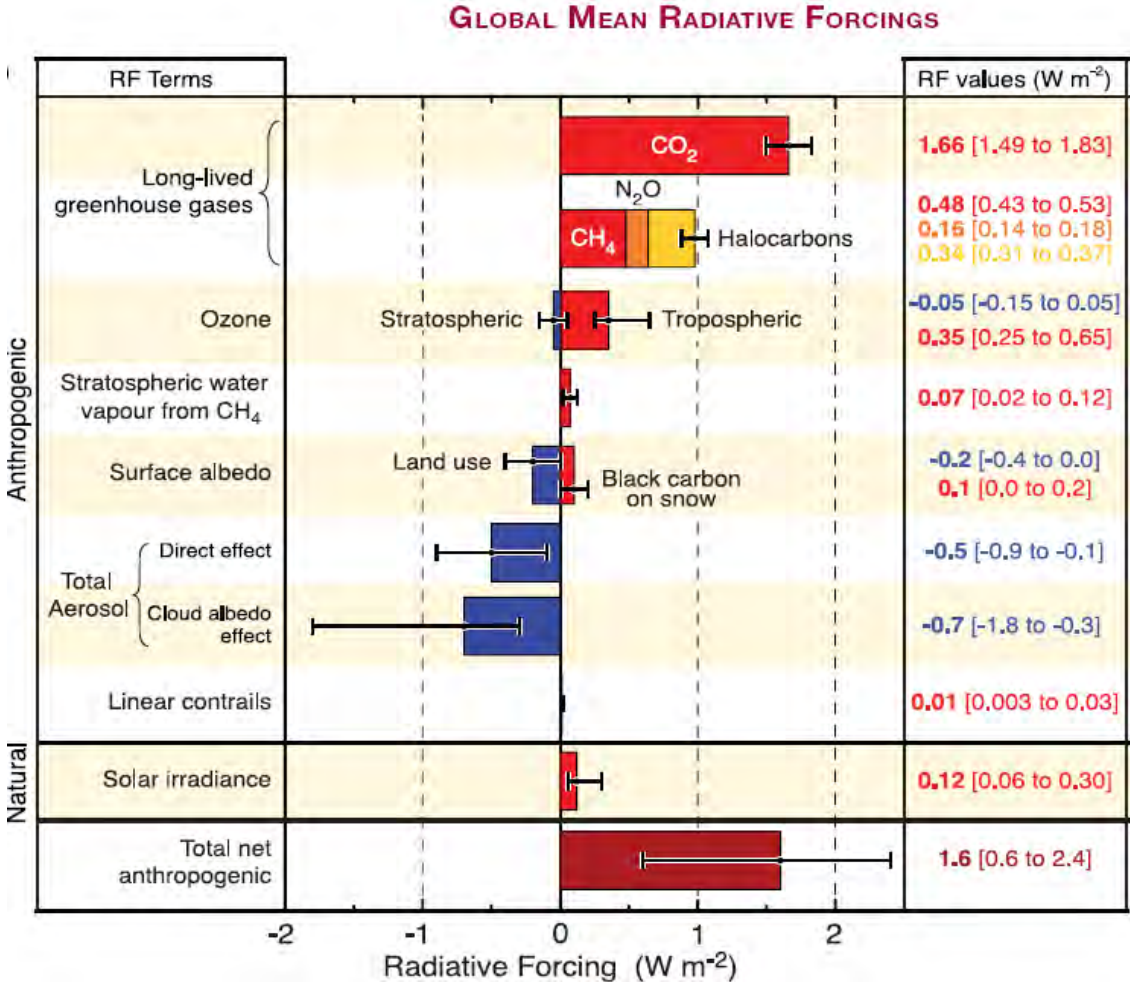


(IPCC AR4, 2007)

Why is climate changing?

Why is climate changing?

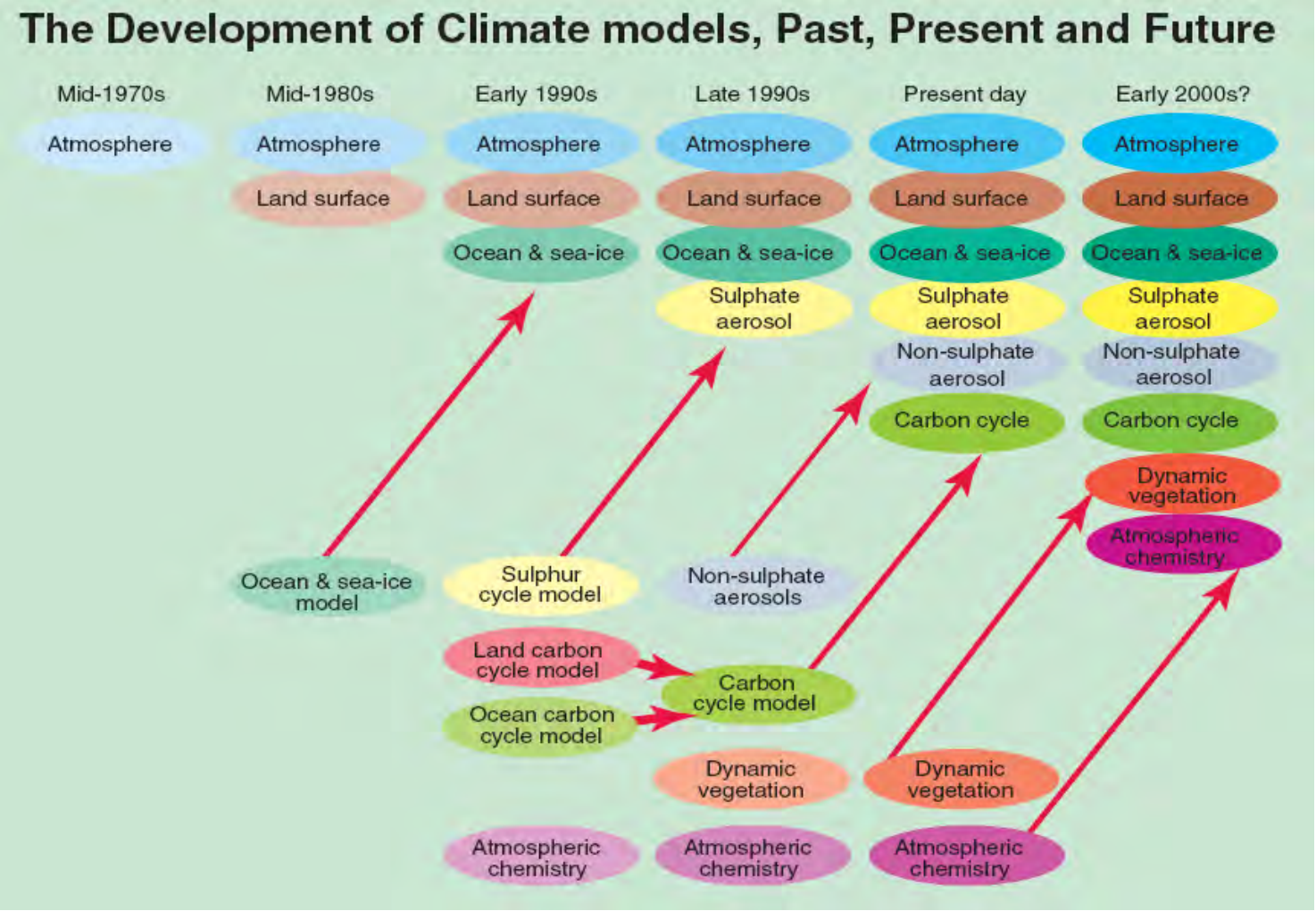
Changes in natural and human drivers of climate:



(IPCC AR4, 2007)

There is *a **very high confidence*** that the effect of human activities since 1750 has been a **net positive forcing** of +1.6 [+0.6 to +2.4] W m–2.

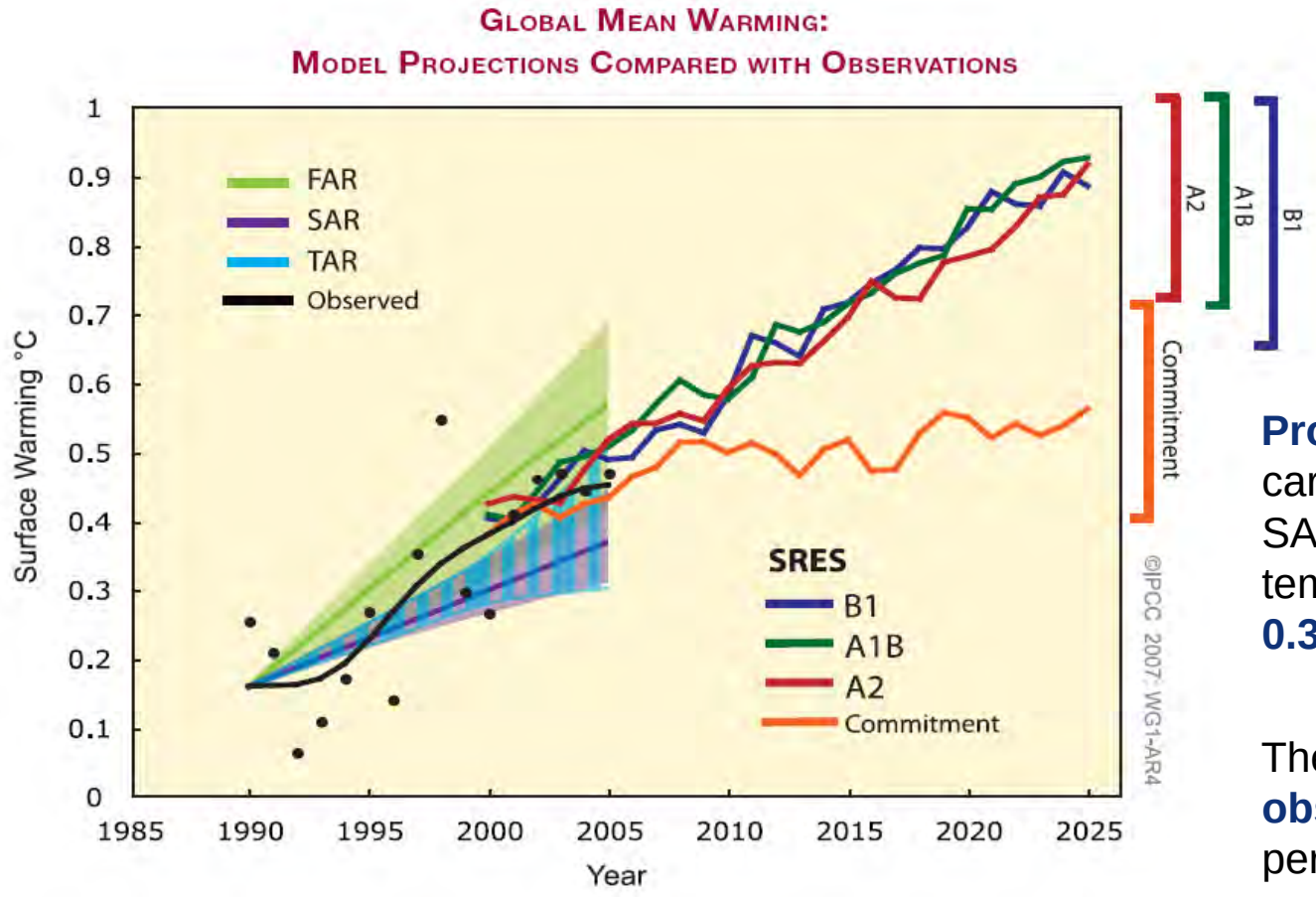
Development of climate models



(IPCC AR3, 2001)

Do models work?

Do models work?



Projections for 1990 to 2005 carried out for the FAR and the SAR suggested global mean temperature increases of about **0.3°C** and **0.15°C** per decade,

These results are comparable to **observed values of about 0.2°C** per decade.