



**Barcelona
Supercomputing
Center**

Centro Nacional de Supercomputación



What are climate anomalies and why are they important

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Guemas, Chloé Prodhomme, Louis-Phillipe Caron
and the Climate Forecasting Unit**

26 May 2015

Definition anomaly

« What is an anomaly?

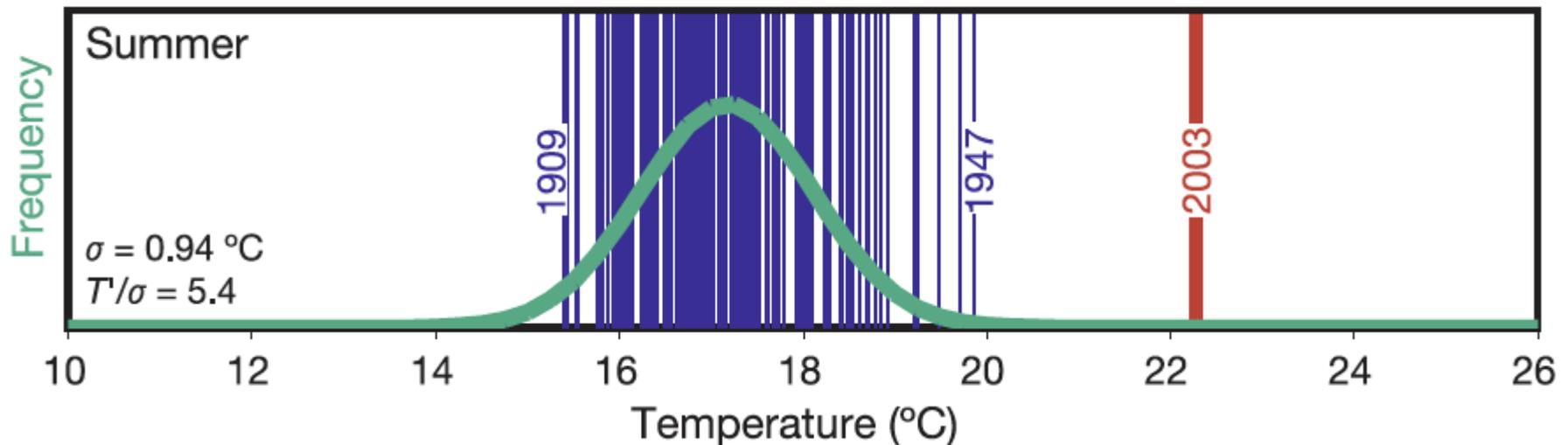
Deviation from the expectation / mean. Depends on the application (~70 Wikipedia definitions)



Definition climate

- Climate defined by the average weather conditions over a long period

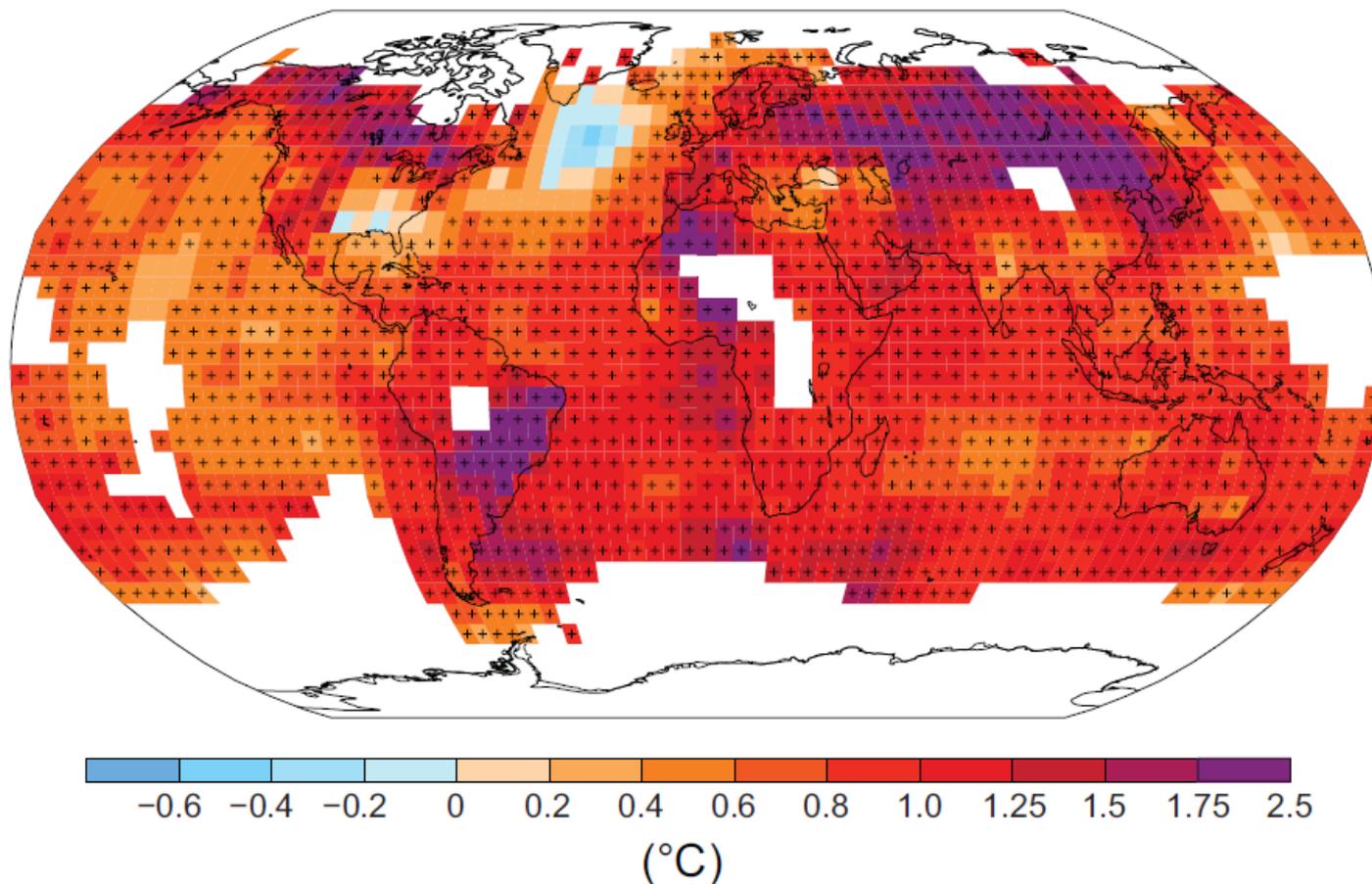
Summers in Switzerland



Example climate anomaly

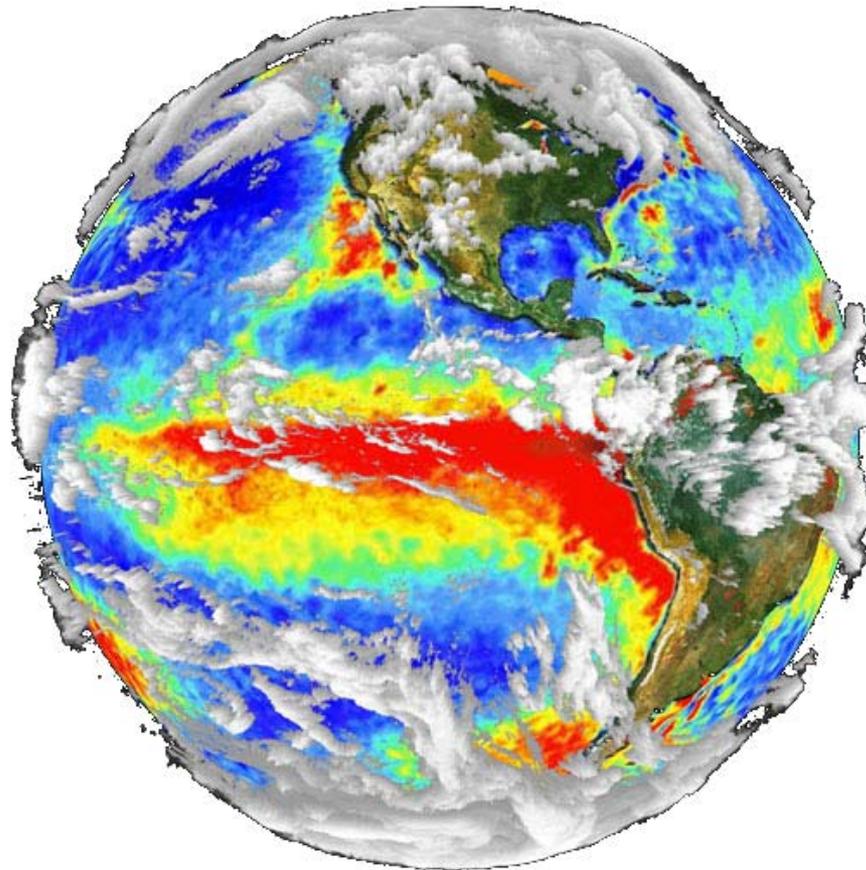
« Global warming of the climate since pre-industrial

Observed change in surface temperature 1901–2012



Example climate anomaly

« El Niño Southern Oscillation (ENSO). Warming of the equatorial Pacific at inter-annual scales.



A climate anomaly?

Drought



Meso-scale systems



No. But related to a climate anomaly ?

Why are climate anomalies important?



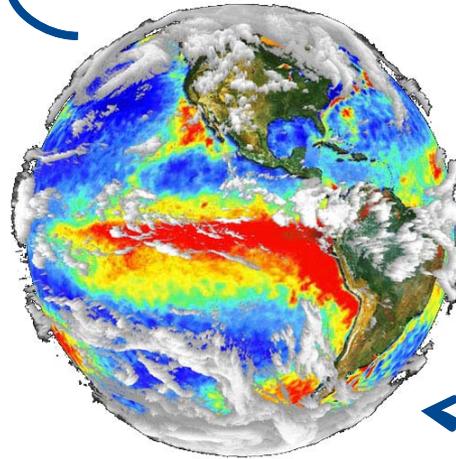
“We conclude that human influences on the climate system are implicated in the current Syrian conflict.”

*Kelly et al. (2015)
PNAS*

Why are climate anomalies important?



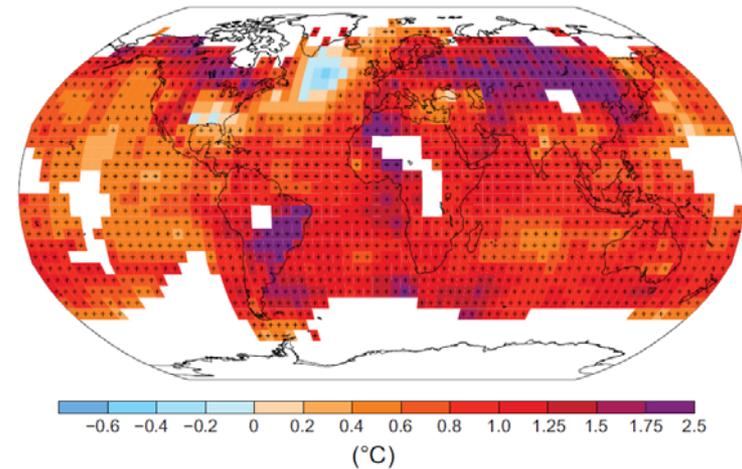
Impact eco-systems and socio-economical sectors



Attribution the human influence

Predictions to support decision making

Observed change in surface temperature 1901–2012



Overview

1. Detection and attribution of climate trends
2. Seasonal-to-decadal forecasting
3. Attribution of extreme climate/weather events
4. Climate services: How can we use this information?

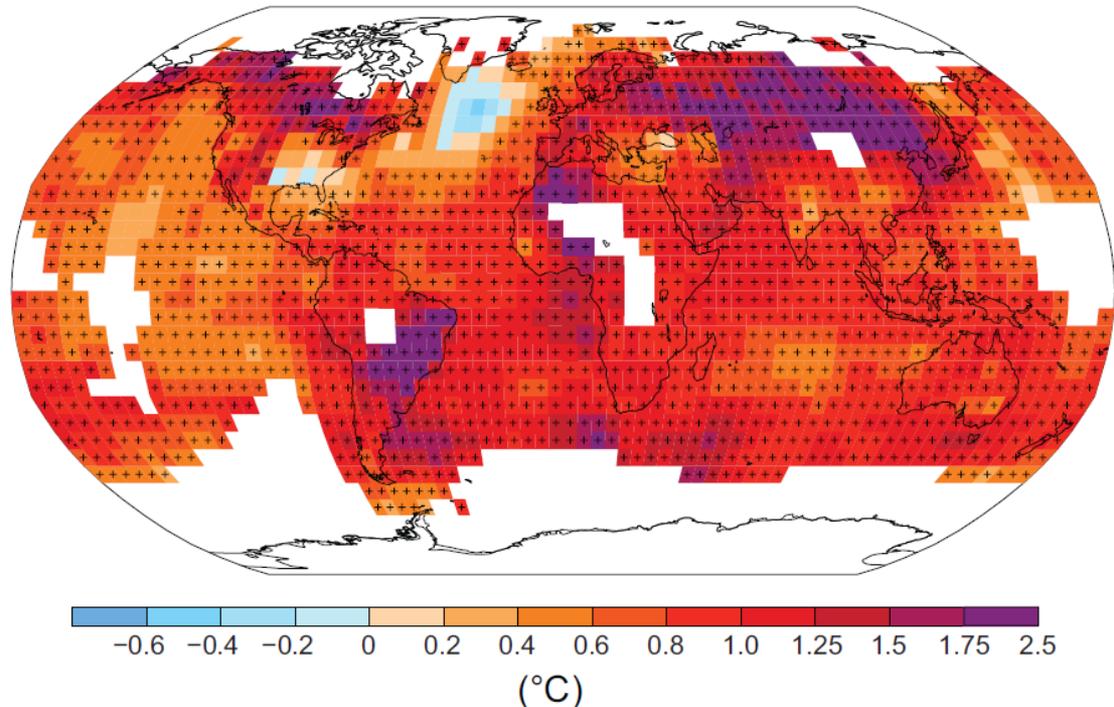
Overview

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An attribution statement

- “ Warming of the climate system is *unequivocal*, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased.”

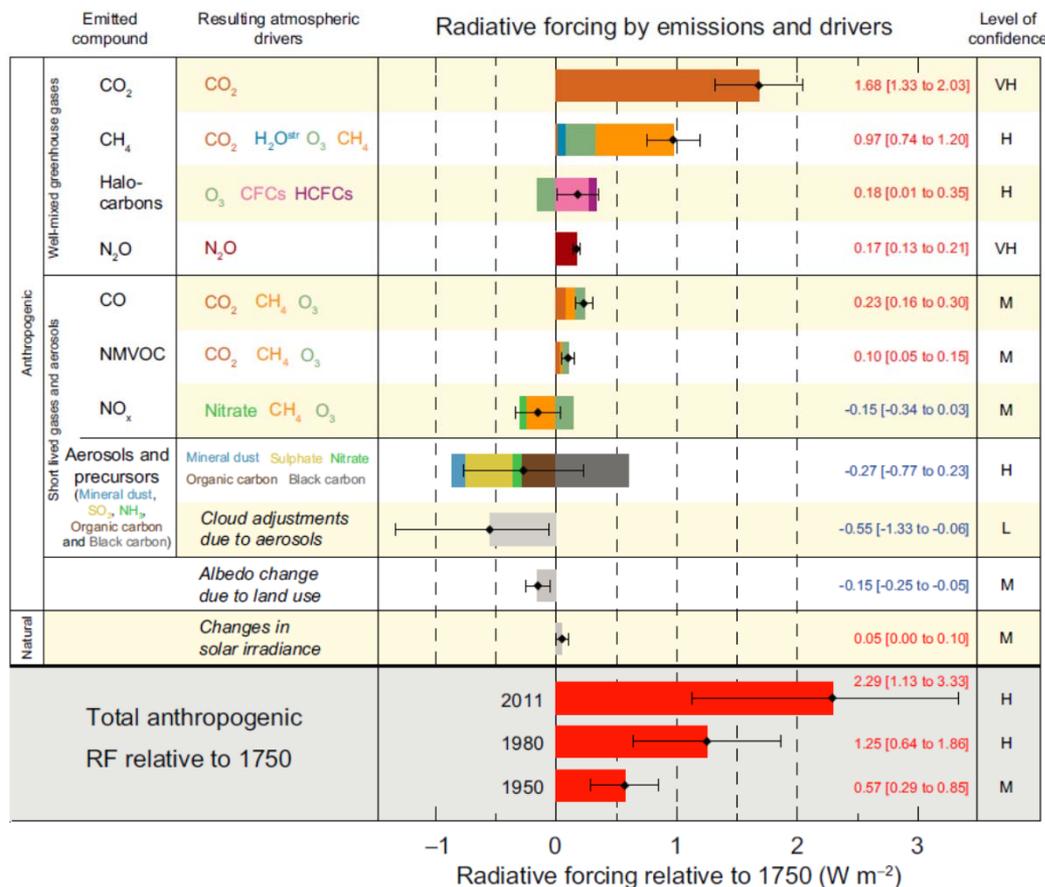
Observed change in surface temperature 1901–2012



Why can we say this?

Radiative imbalance

Anthropogenic emissions of green-house gases have caused a positive radiative forcing



Detection & Attribution (D&A)

“**But** knowing that the forcing is positive does not mean you have detected the cause of the observed warming ... “ F. Zwiers

Detection: Determine climate anomalies (*trends*) that can not be explained by natural variability only.

Attribution: Find causal factors that explain the climate anomaly and reject alternative explanations

Detection & Attribution (D&A)

“ Climate models show that observed changes are consistent with expected changes to forcing and inconsistent alternative explanations

<http://www.bloomberg.com/graphics/2015-whats-warming-the-world/>

Detection & Attribution (D&A)

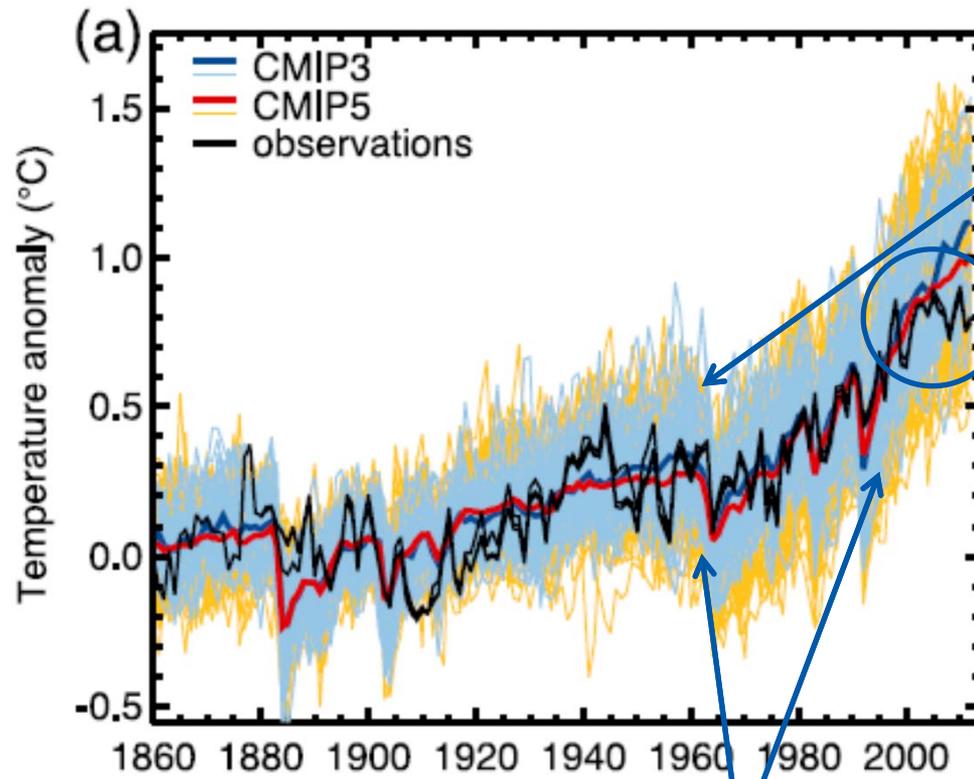
- ⌋ Carried out for many different spatial and temporal scales: e.g. attribution for each continent, tropospheric warming, stratospheric cooling (optimal fingerprinting), ice loss, hydrological cycle ...
- ⌋ Attribution carried out on long-term climate change trends, what about shorter time-scales?

Overview

1. Detection and attribution of climate trends
- 2. Seasonal-to-decadal forecasting**
3. Attribution of extreme climate/weather events
4. Climate services: How can we use this information?

Prediction of climate anomalies

CMIP5 Historical simulations



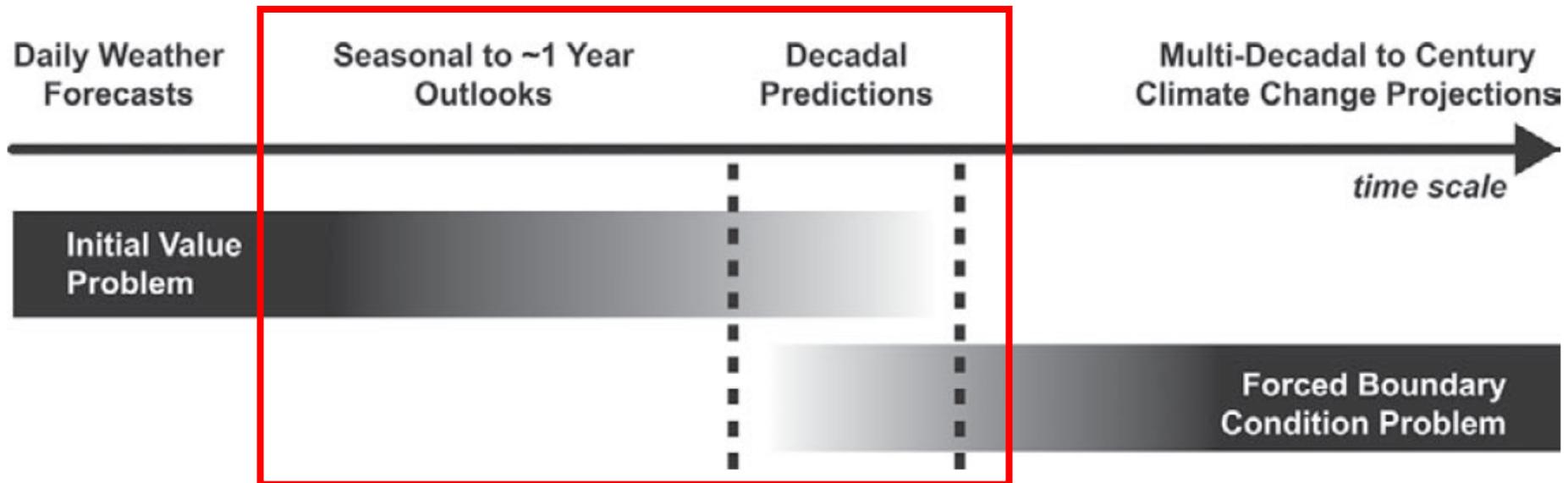
Historical simulations predict the climate trend attributable to human activity

Warming slow-down?
Seasonal-to-decadal forecasting

Historical simulations predict response to volcanic eruptions

Climate prediction

Focus on sub-seasonal, seasonal, interannual and decadal timescales



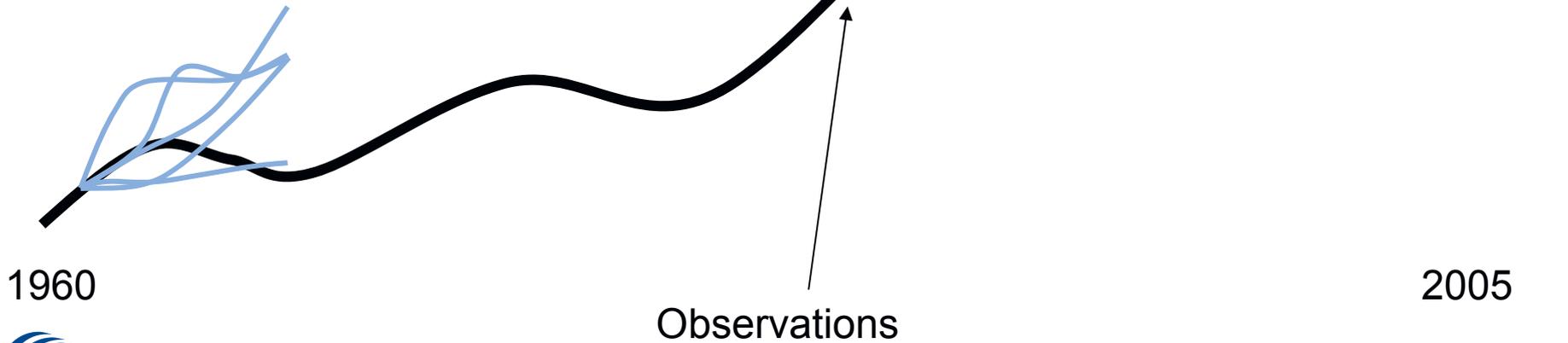
Climate system predictability

- ⌘ **External radiative forcings** (green-house gases, solar activity, aerosols)
- ⌘ Memory on interannual to centennial timescales in the **ocean**
- ⌘ Memory on seasonal to interannual timescales in the **sea ice** and **land surface**

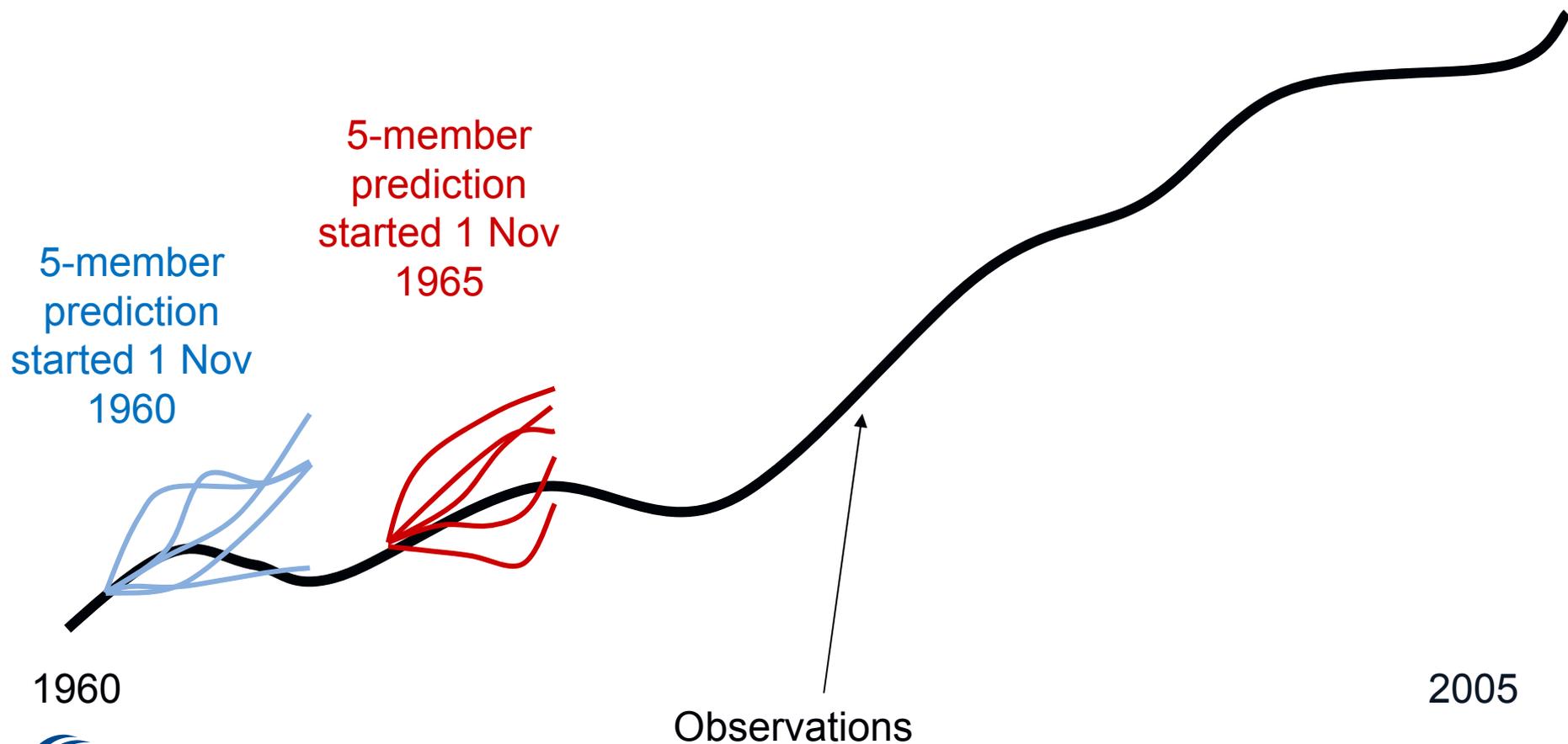
Example of a decadal prediction

until 2000

5-member
prediction
started 1 Nov
1960

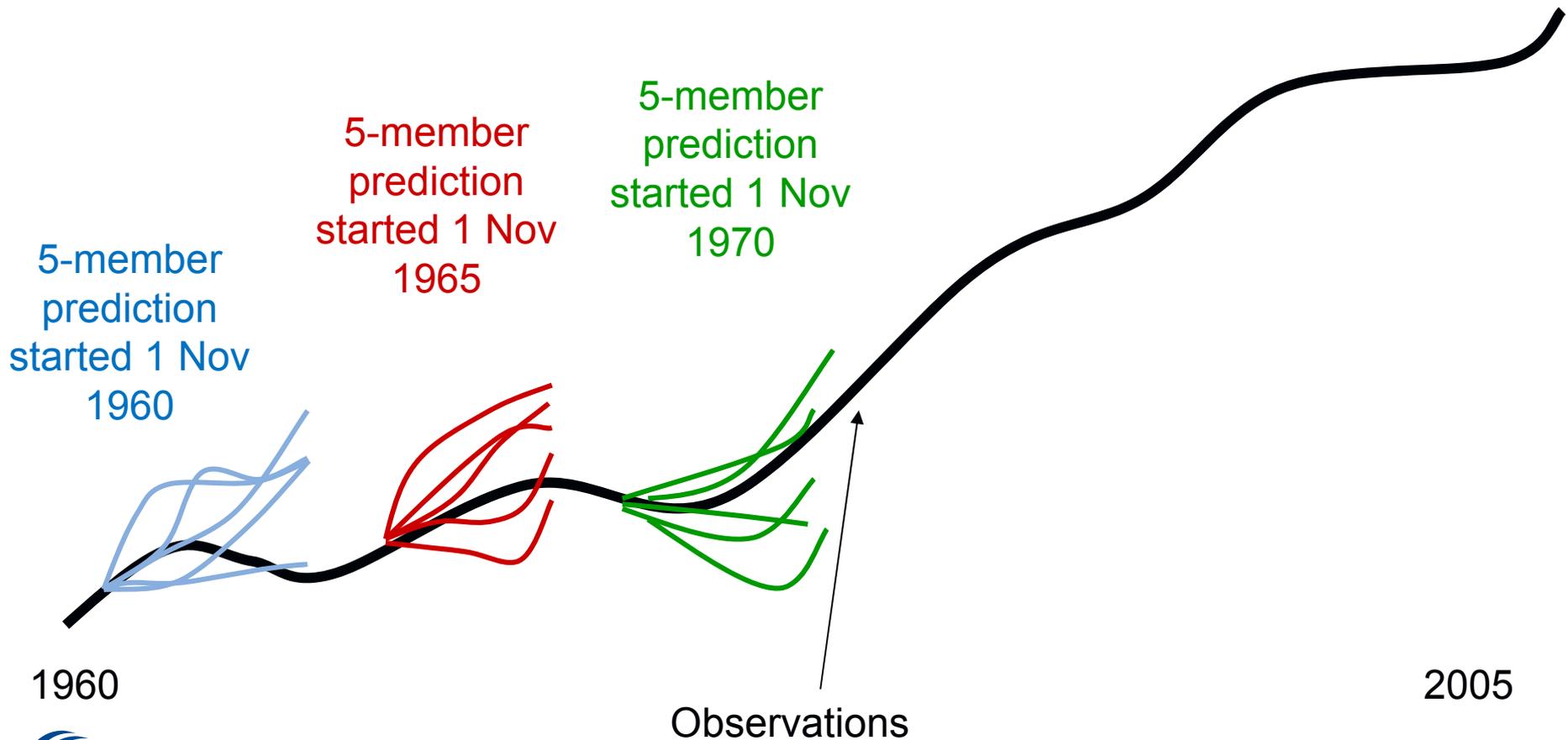


Example of a decadal prediction



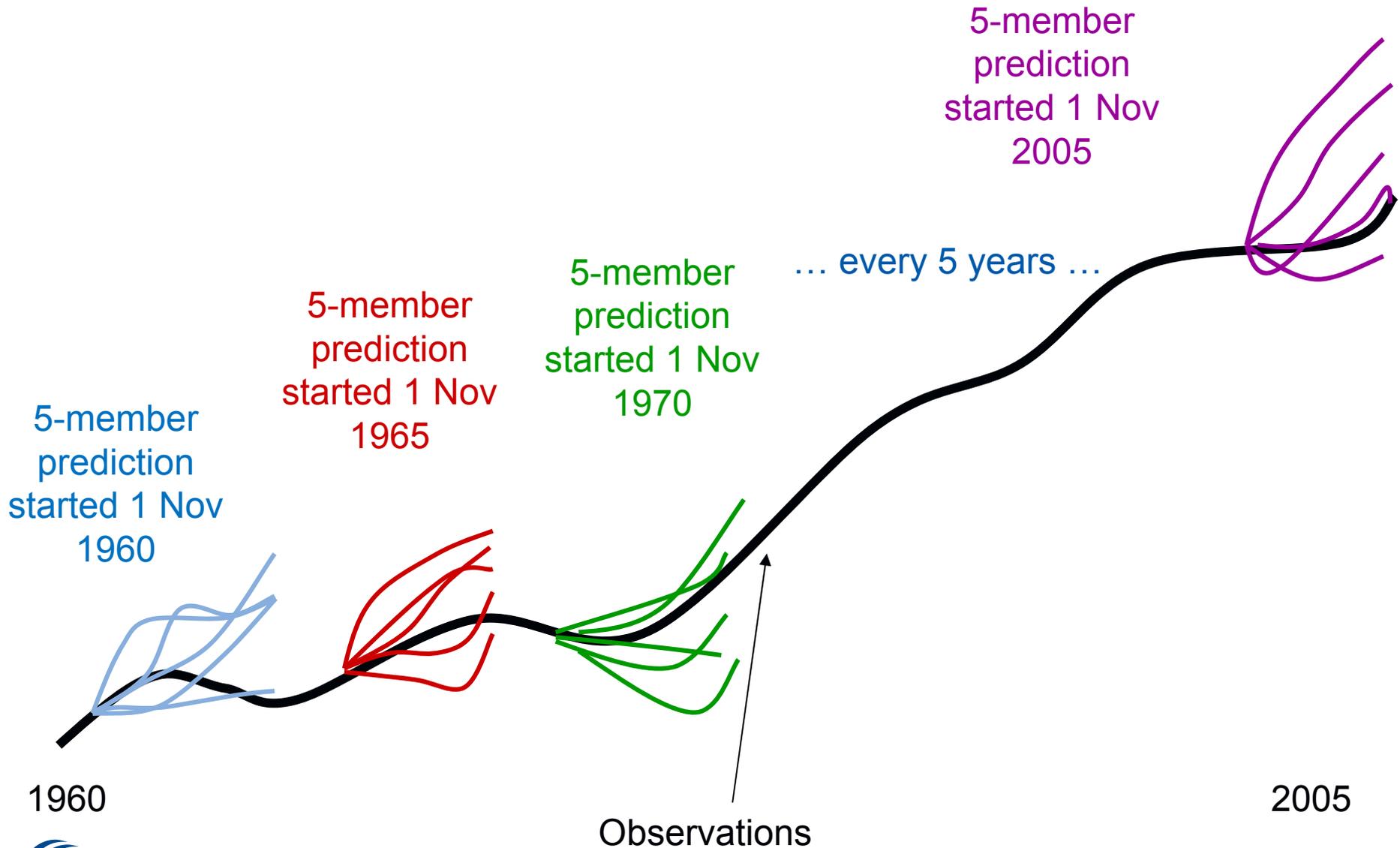
Example of a decadal prediction

until 2005



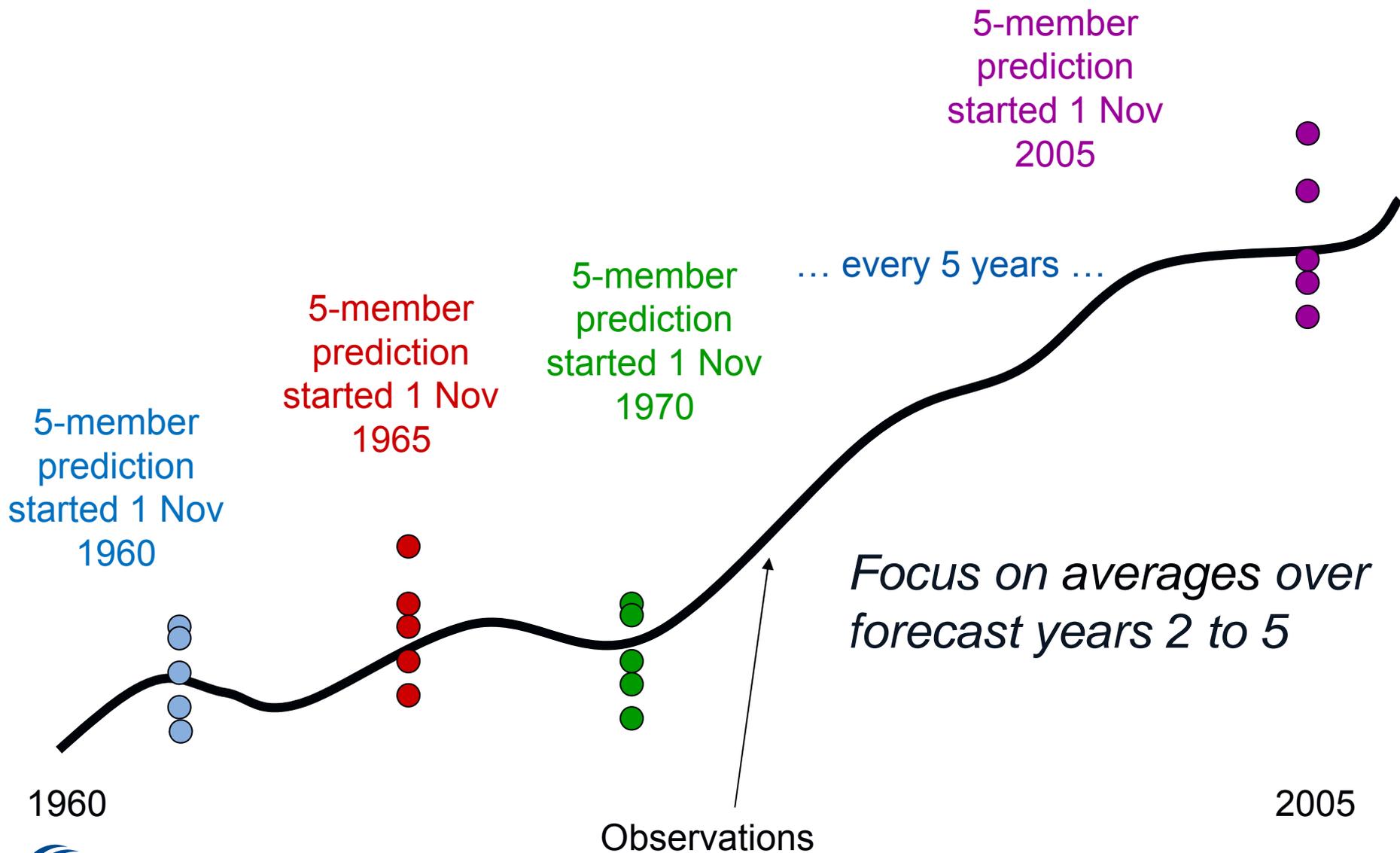
Example of a decadal prediction

until 2005



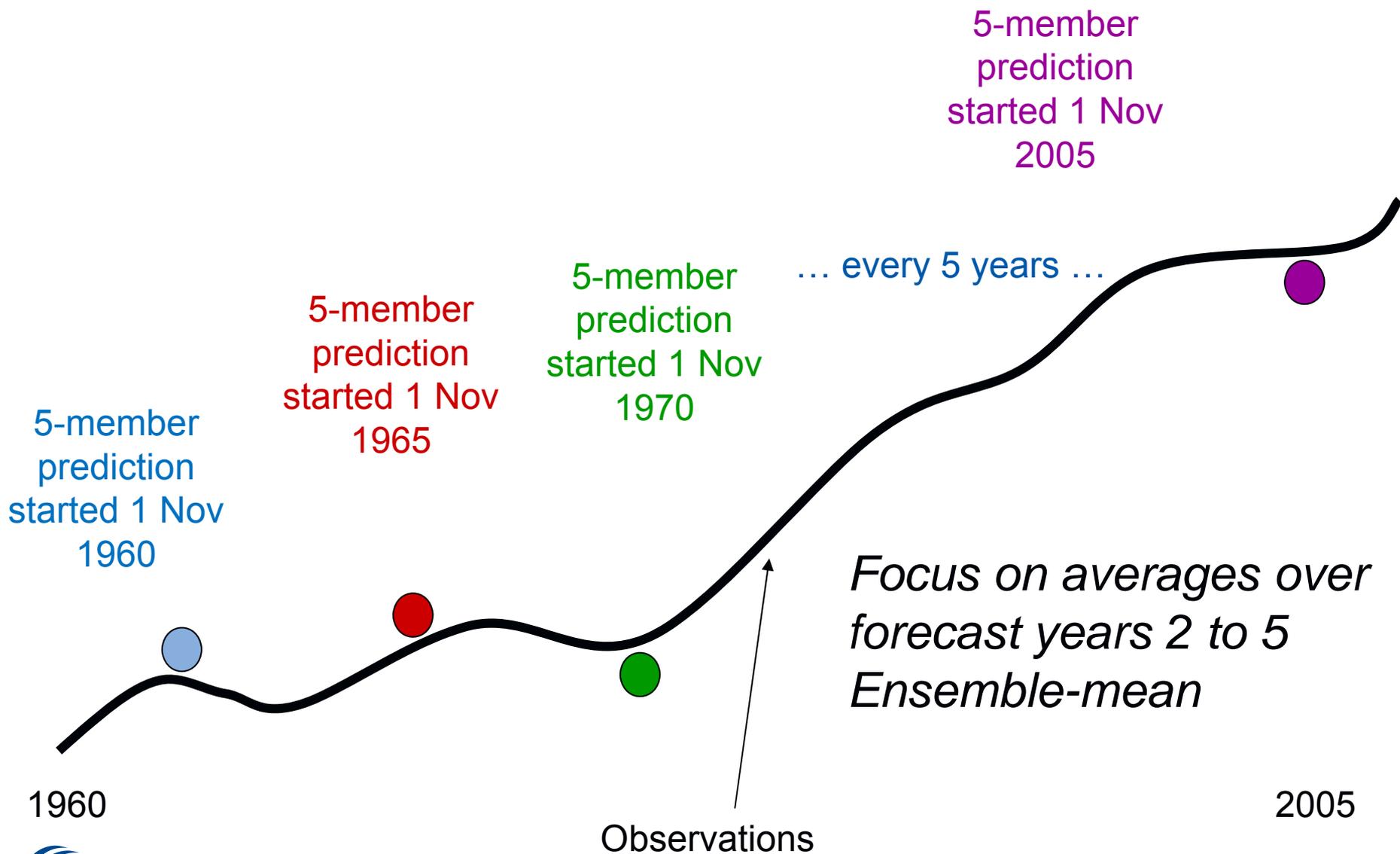
Example of a decadal prediction

until 2005



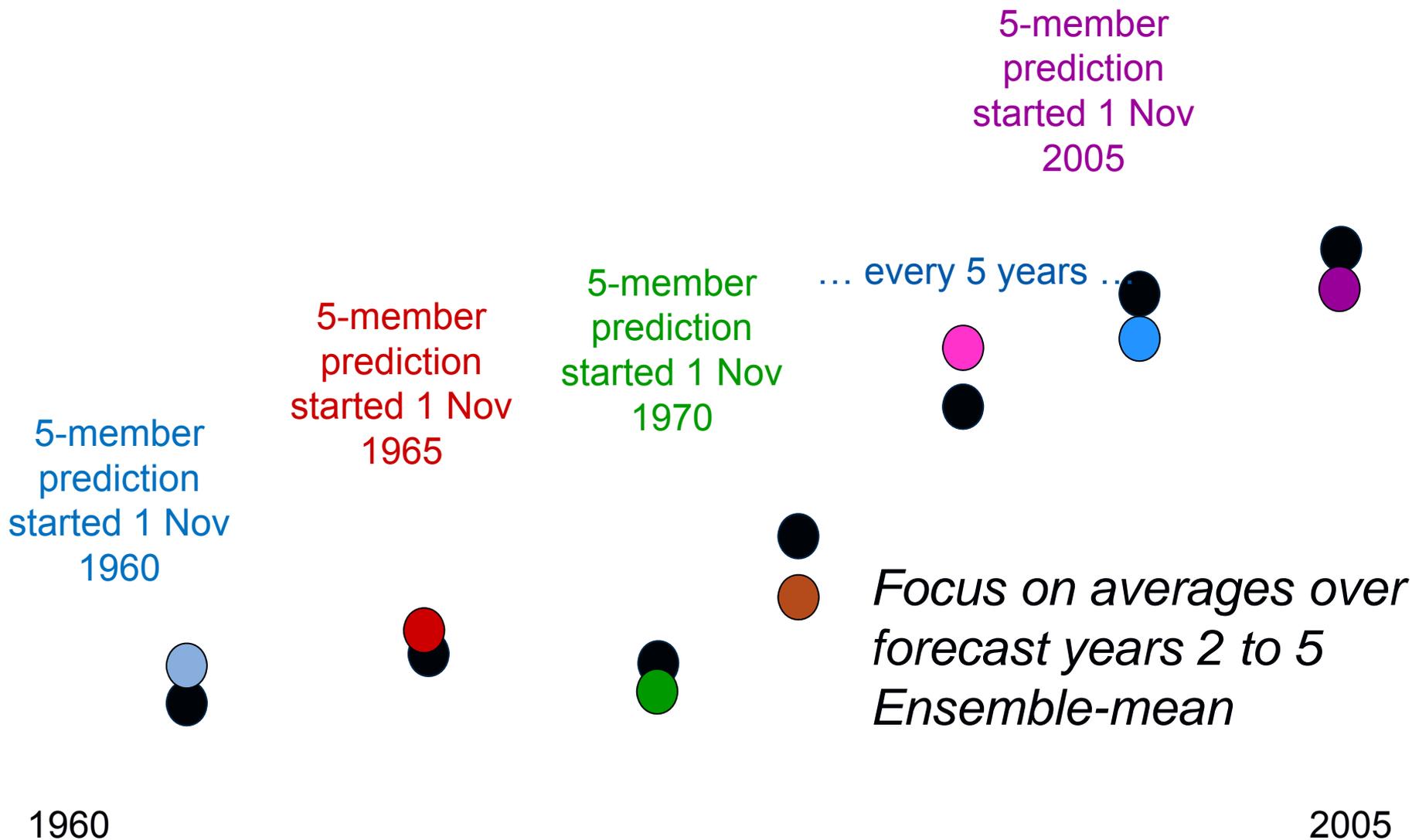
Example of a decadal prediction

until 2005



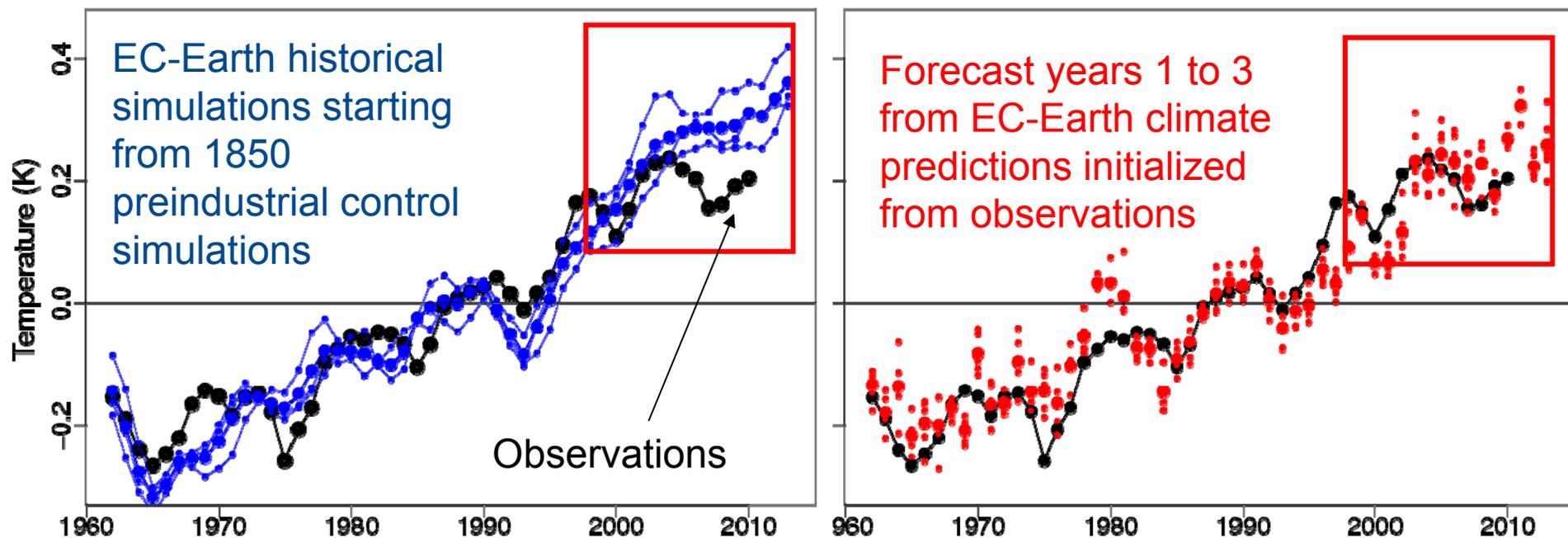
Example of a decadal prediction

until 2005



Predictions of the 21st century hiatus

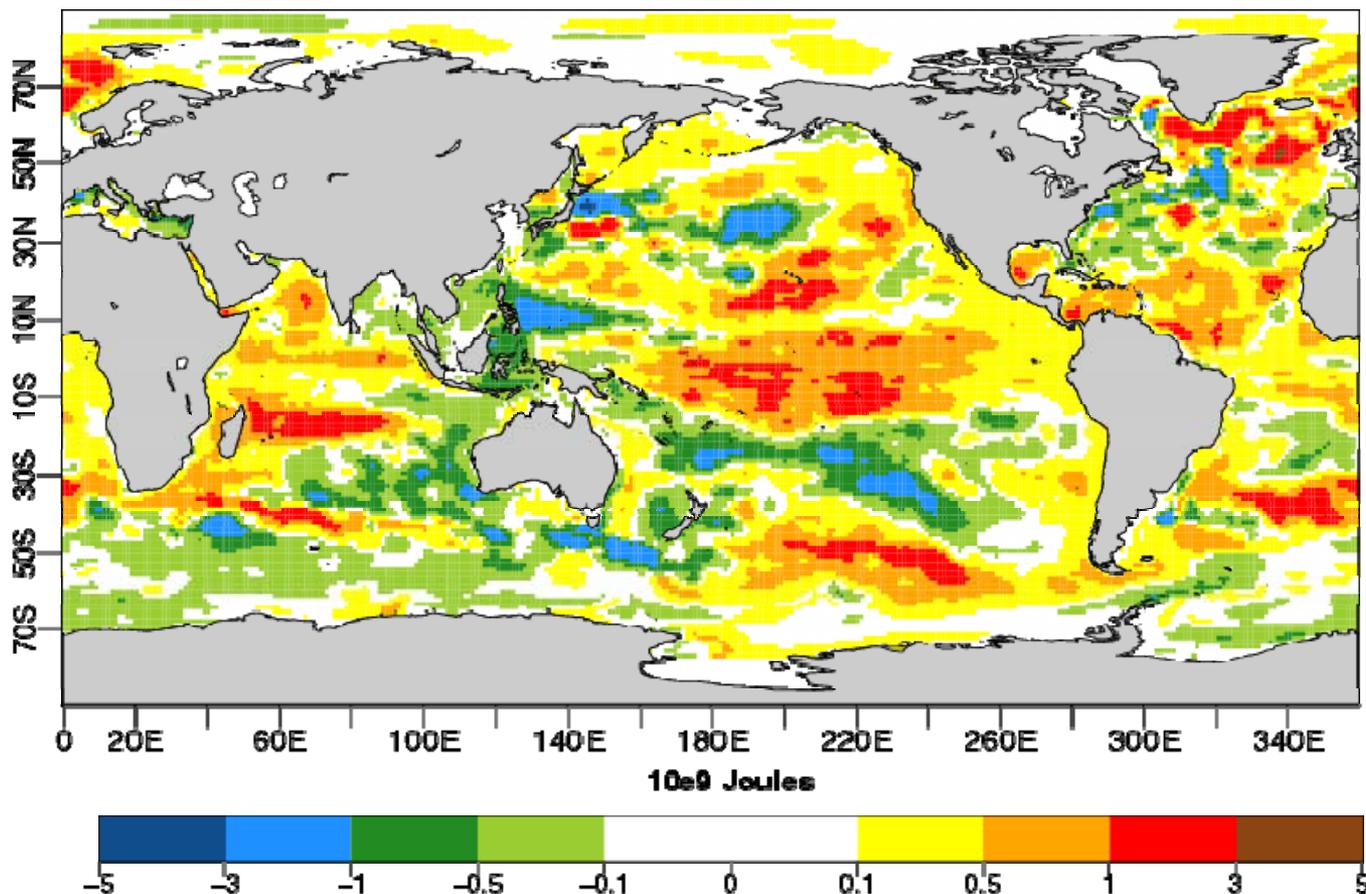
« Crucial role of initialization from observations in capturing the plateau



Predictions of the 21st century hiatus

Plateau explained by increased ocean heat uptake

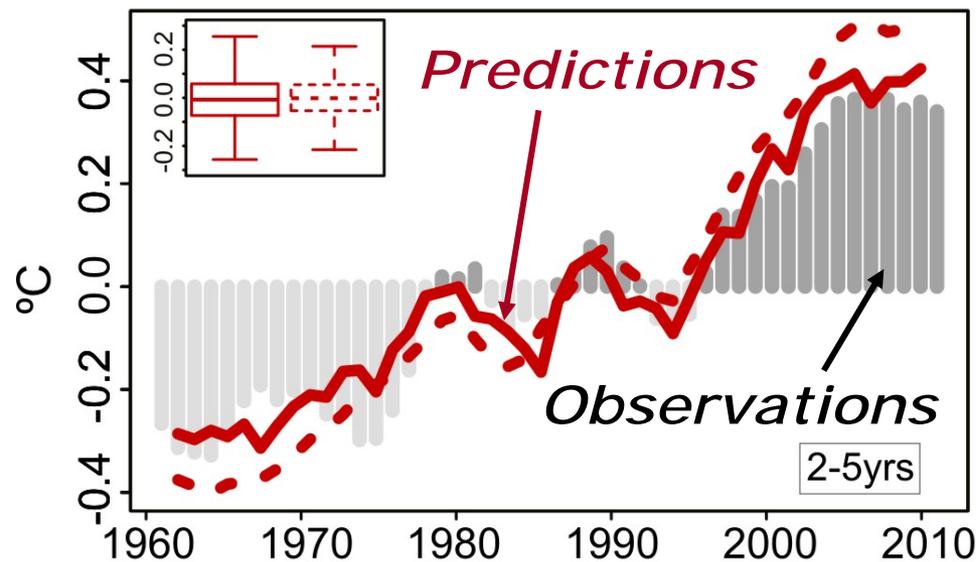
Ocean heat uptake (0-800m excluding the mixed layer) at the onset of the plateau



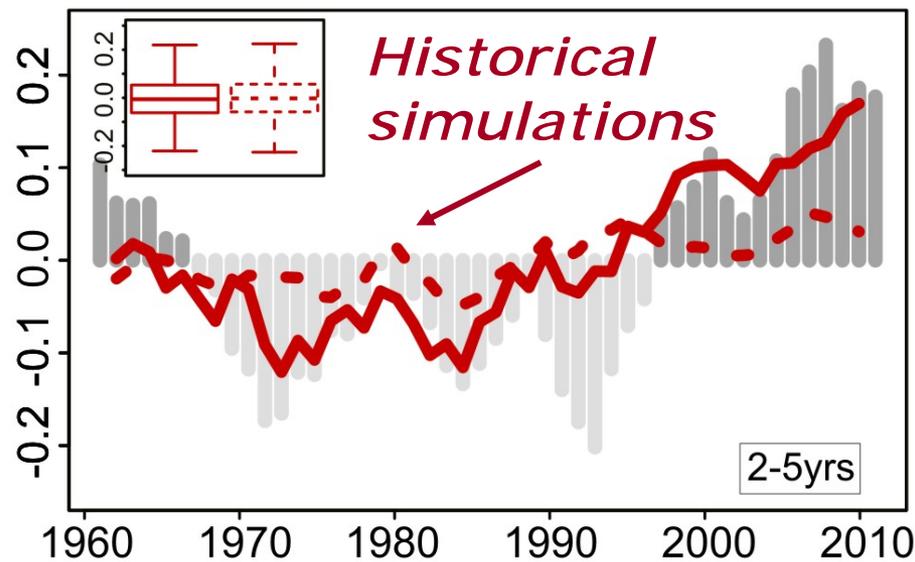
CMIP5 decadal predictions

Decadal prediction better reproduce temperature evolution and importantly decadal variability

Global mean surface atmospheric temperature

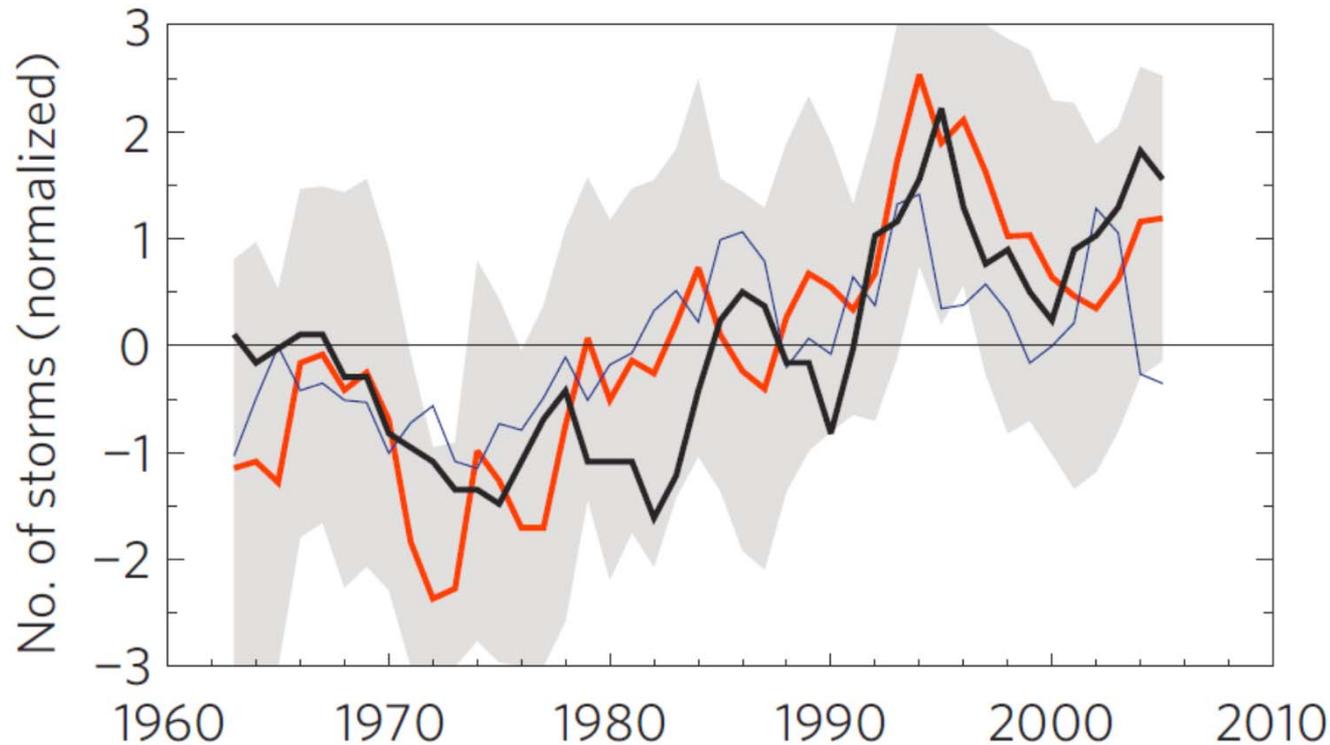


Atlantic multidecadal variability (AMV)



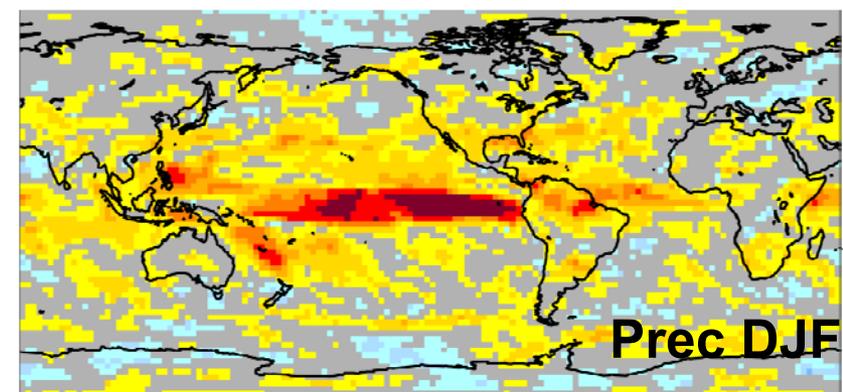
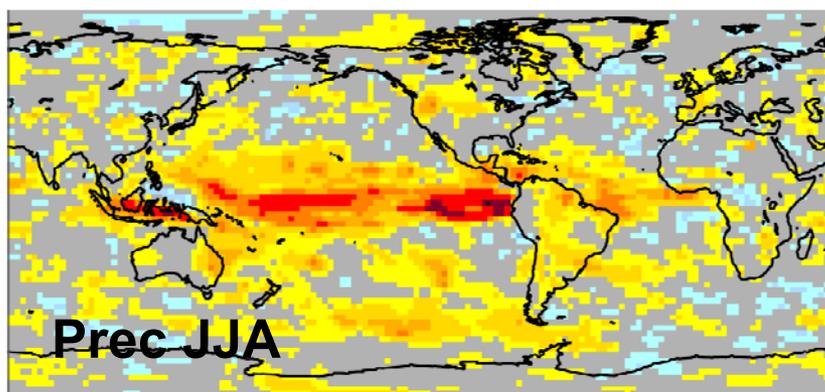
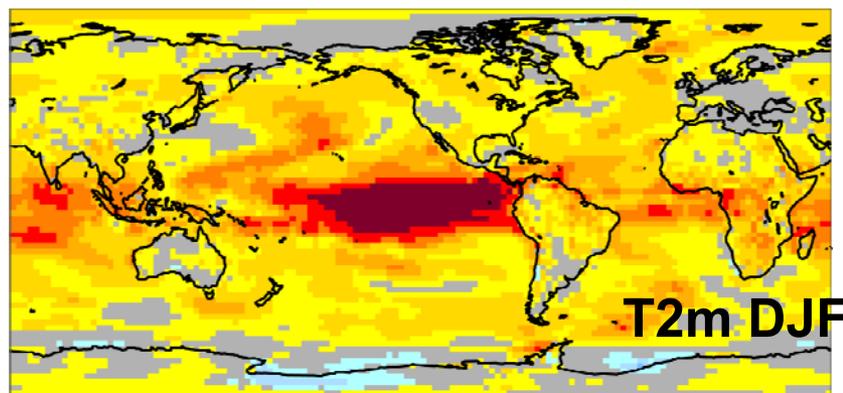
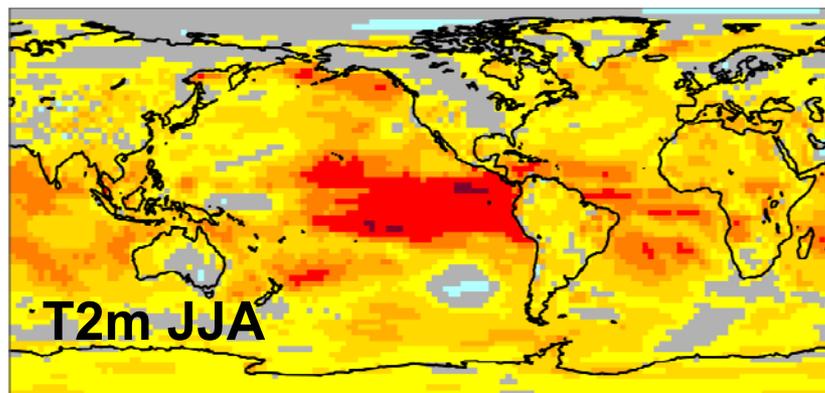
Predicting tropical cyclones

- AMV important for tropical cyclone activity in the Atlantic. Decadal systems are reliable for 5 years.



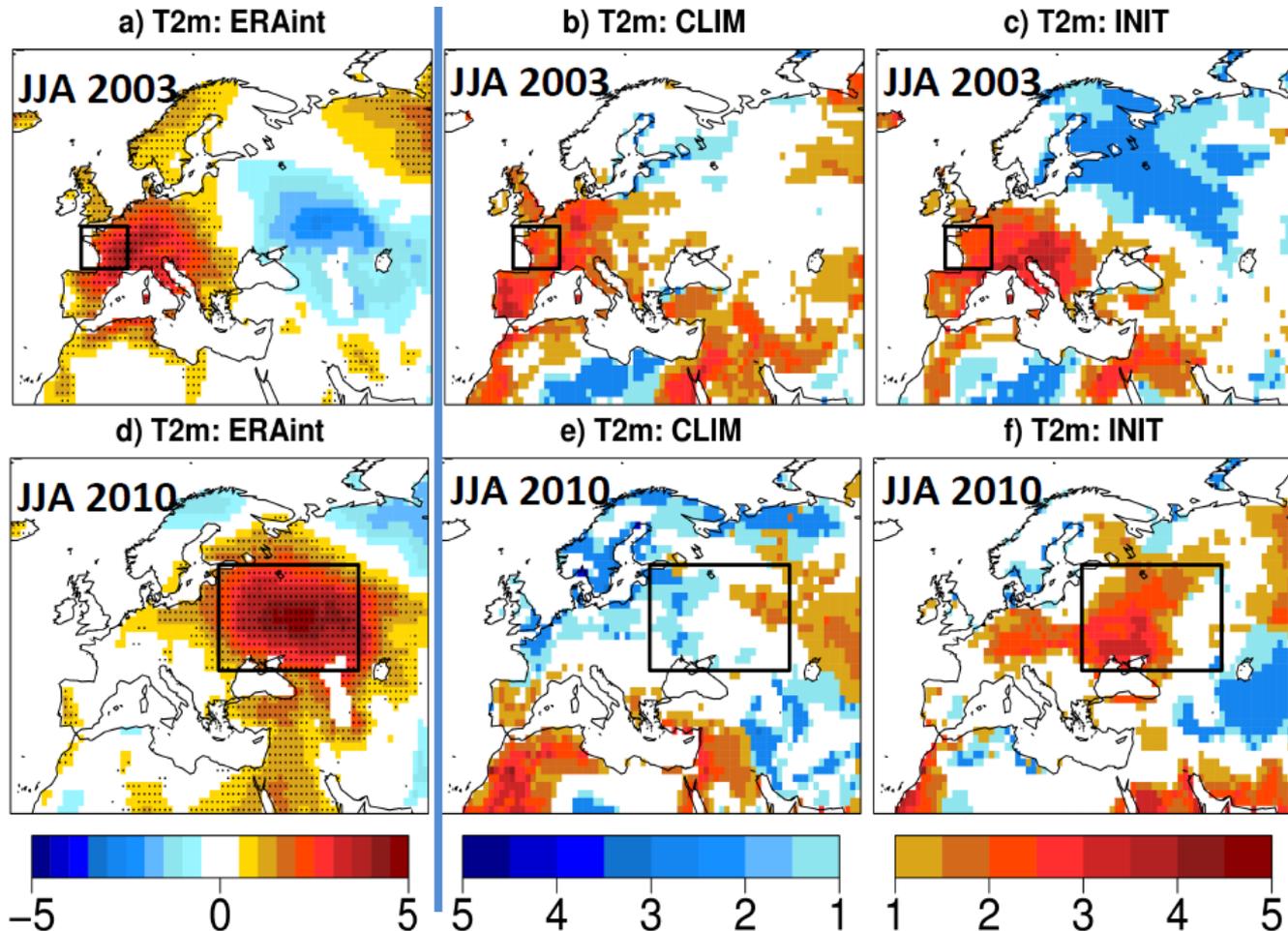
Seasonal predictions

Seasonal predictions have skill over large areas and ENSO provides most important source of skill.



Seasonal predictions of heat waves

Heat waves can be predicted and soil moisture helps



This summer heatwave

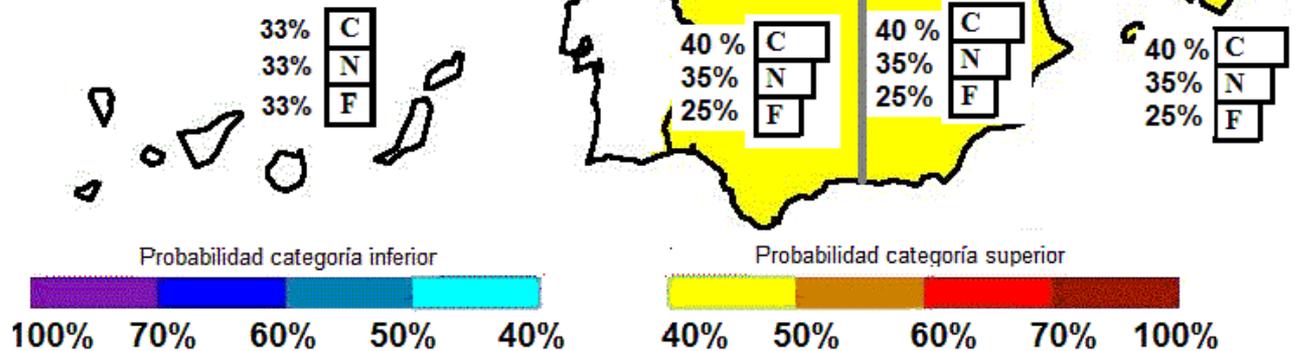
Alerta de Meteorología: se avecina un verano de calor extremo ? (May, 2015)

PROBABILIDAD DE LA CATEGORÍA MÁS PROBABLE DE TEMPERATURA JUNIO-JULIO-AGOSTO de 2015 (Con datos de Mayo de 2015)

Porcentaje de probabilidad:

| | |
|---|----------------------------------|
| C | Temperatura superior a lo normal |
| N | Temperatura cerca de lo normal |
| F | Temperatura inferior a lo normal |

Los colores muestran la probabilidad de la categoría más probable. El color blanco indica la climatología

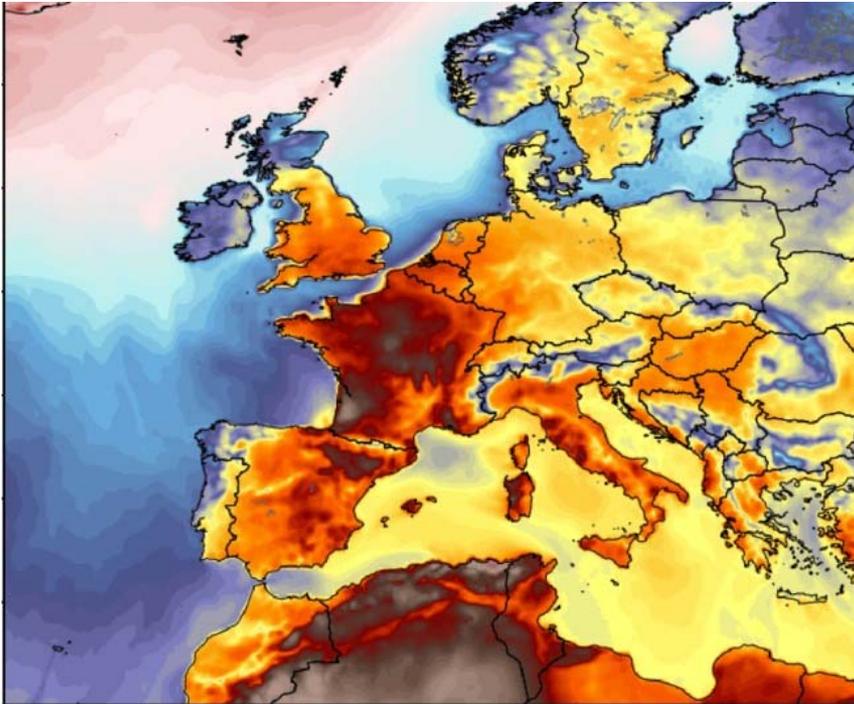


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Heat wave Europe 2015

« Predicted by seasonal forecasts, but not Indian heat wave for instance.

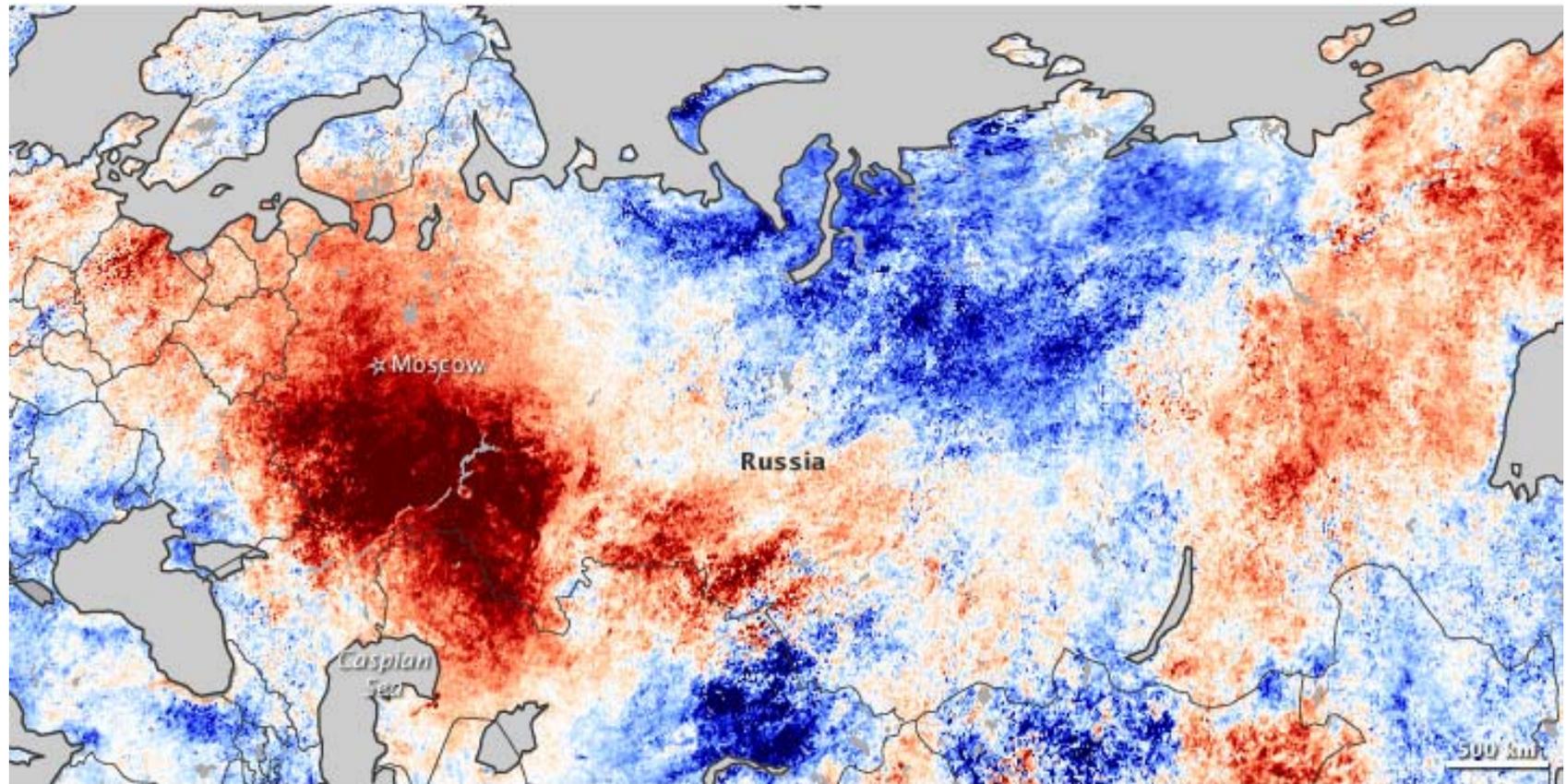


Overview

1. Detection and attribution I: Climate trends
2. Seasonal-to-decadal forecasting
- 3. Detection and attribution II: Extreme events**
4. Climate services: How can we use this information?

Russian (mega) heat wave 2010

⌘ Caused ~50'000 Deaths and 15\$bn losses

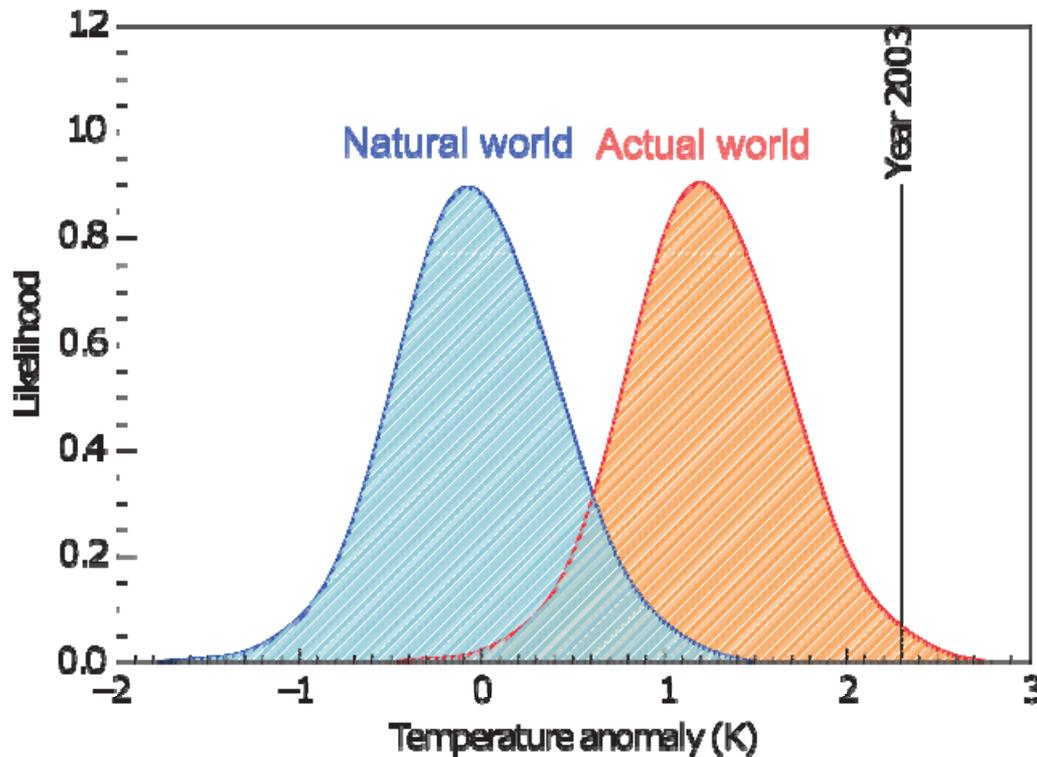


Was it due to climate change?

- ⌘ No. Science has insisted on the inability of single weather event attribution.
- ⌘ *“we estimate ... an approximate 80% probability that the 2010 July heat record would not have occurred without climate warming”.* Rahmsdorf and Comou (2011)
- ⌘ *“...the intense 2010 Russian heat wave was mainly due to natural internal atmospheric variability.”* Dole et al. (2011)

Event attribution: What can we say

How has the likelihood changed that a specific event occurred due to climate change?



Currently used framework:
Fraction of attributable risk

$$FAR = 1 - P_{CC} / P_{NoCC}$$

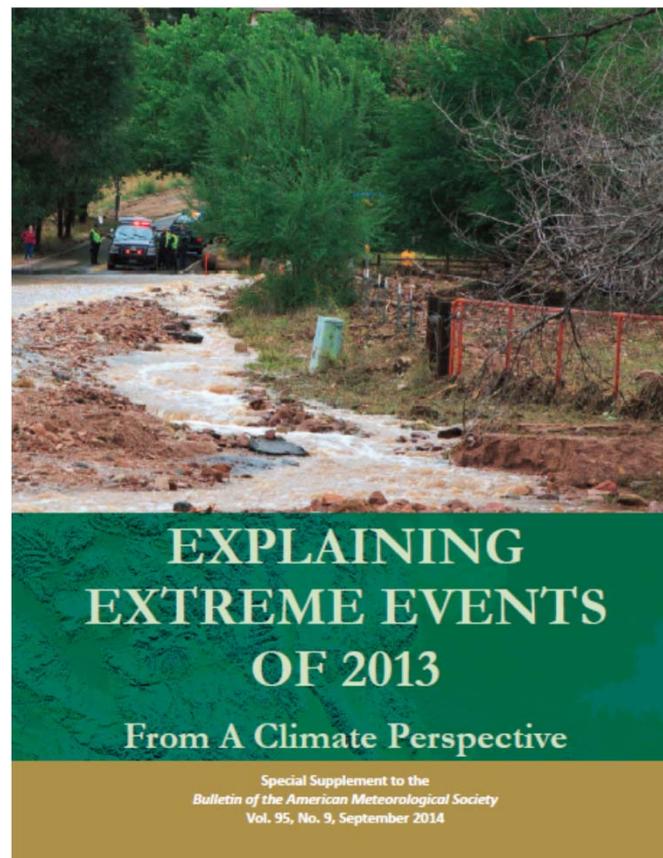
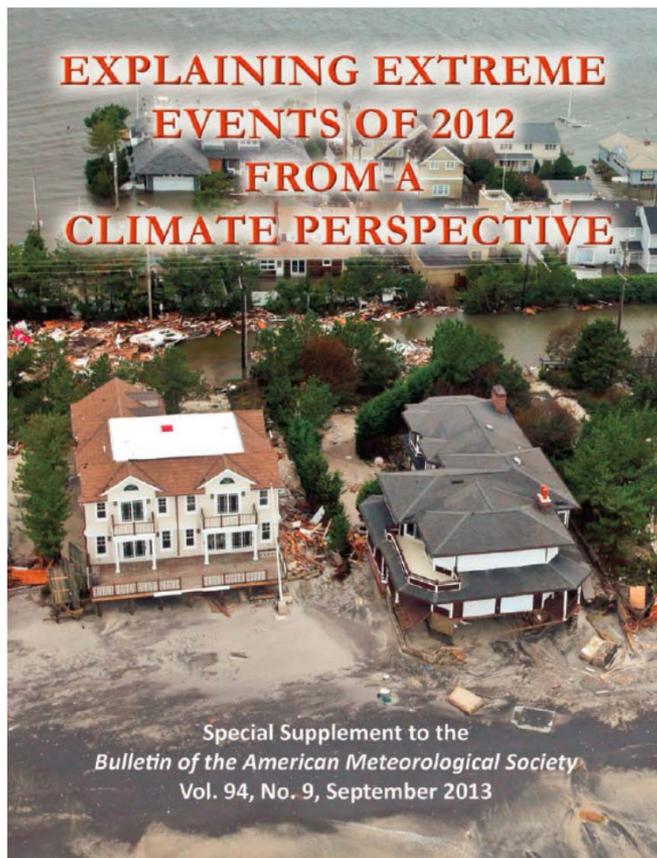
Analogy: By how much has smoking increased the risk of a lung cancer of patient?

FAR = 0 No role of climate change

FAR = 1 Only due to climate change

Event attribution: continuous application

« Bulletin of the American Meteorological Society (BAMS) Annual special issue

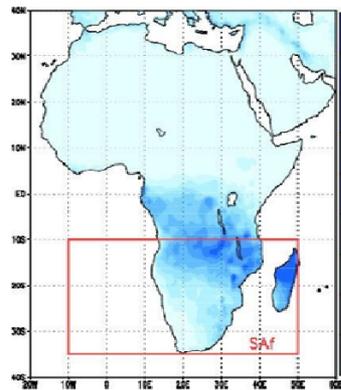


An example for Southern Africa

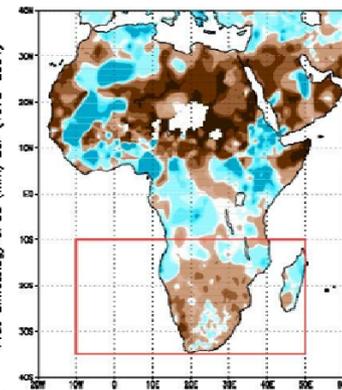
« The drought in 2002/03 and flood in 1999/00 can partly be attributed to human activity



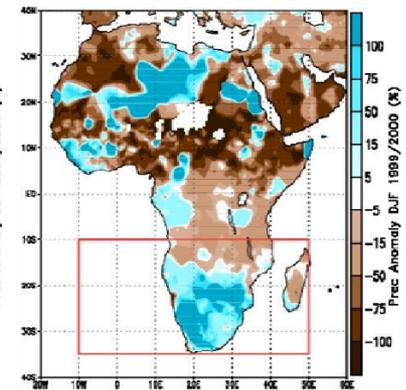
Climatology 1975-2004



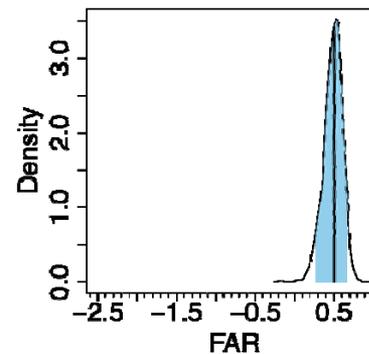
Drought 2002/03 | El Niño



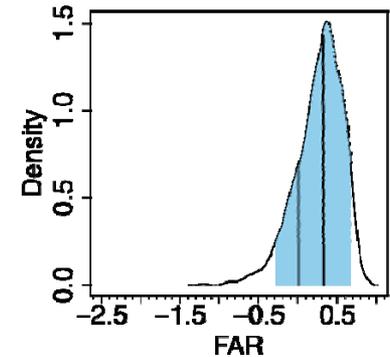
Flood 1999/00 | La Niña



Drought 2002/03



Flood 1999/00

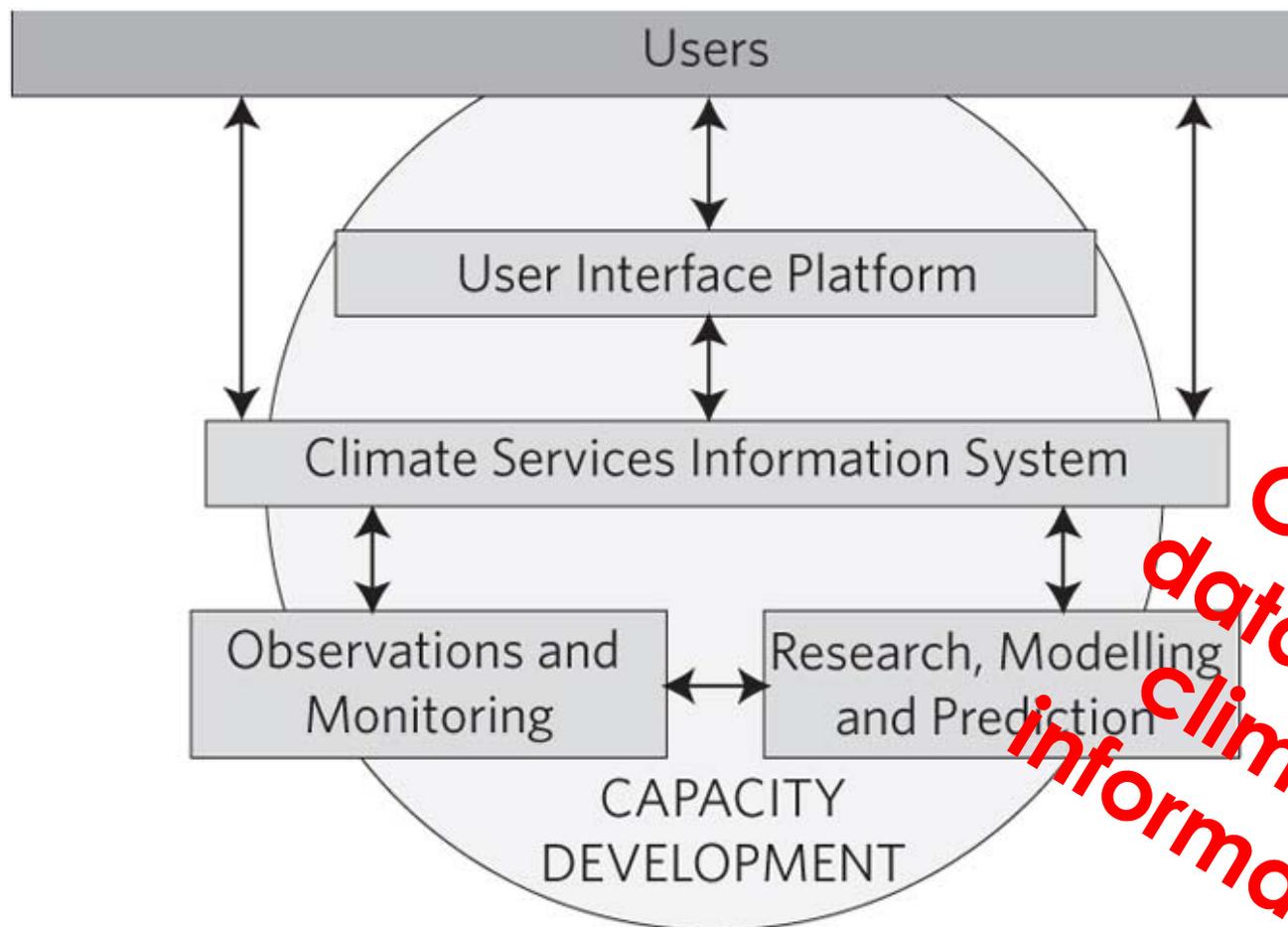


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4. **Climate services: How can we use this information?**

Climate services

WMO Climate Service Framework

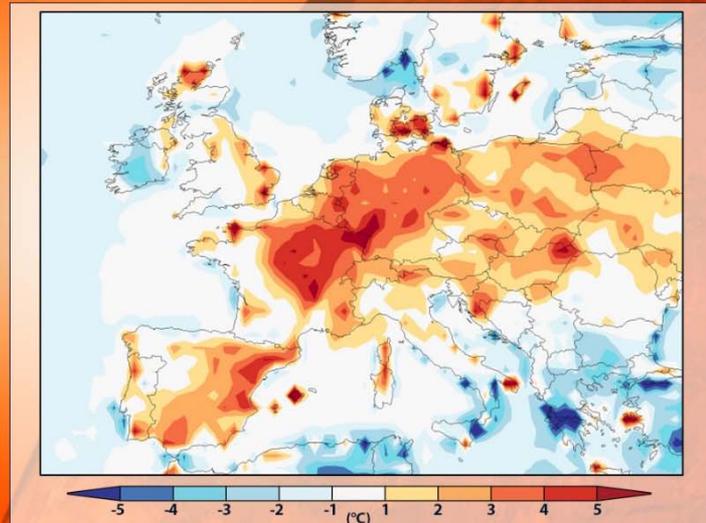


Climate data is not information

World attribution network

« The current heat wave has become twice as likely compared to pre-industrial times (monthly basis)

EUROPE HEAT WAVE SUMMER 2015



Observed/forecast 3-day maximum temperature of summer so far as departure from average JJA maximum (1981-2010)

Data: ECMWF/KNMI

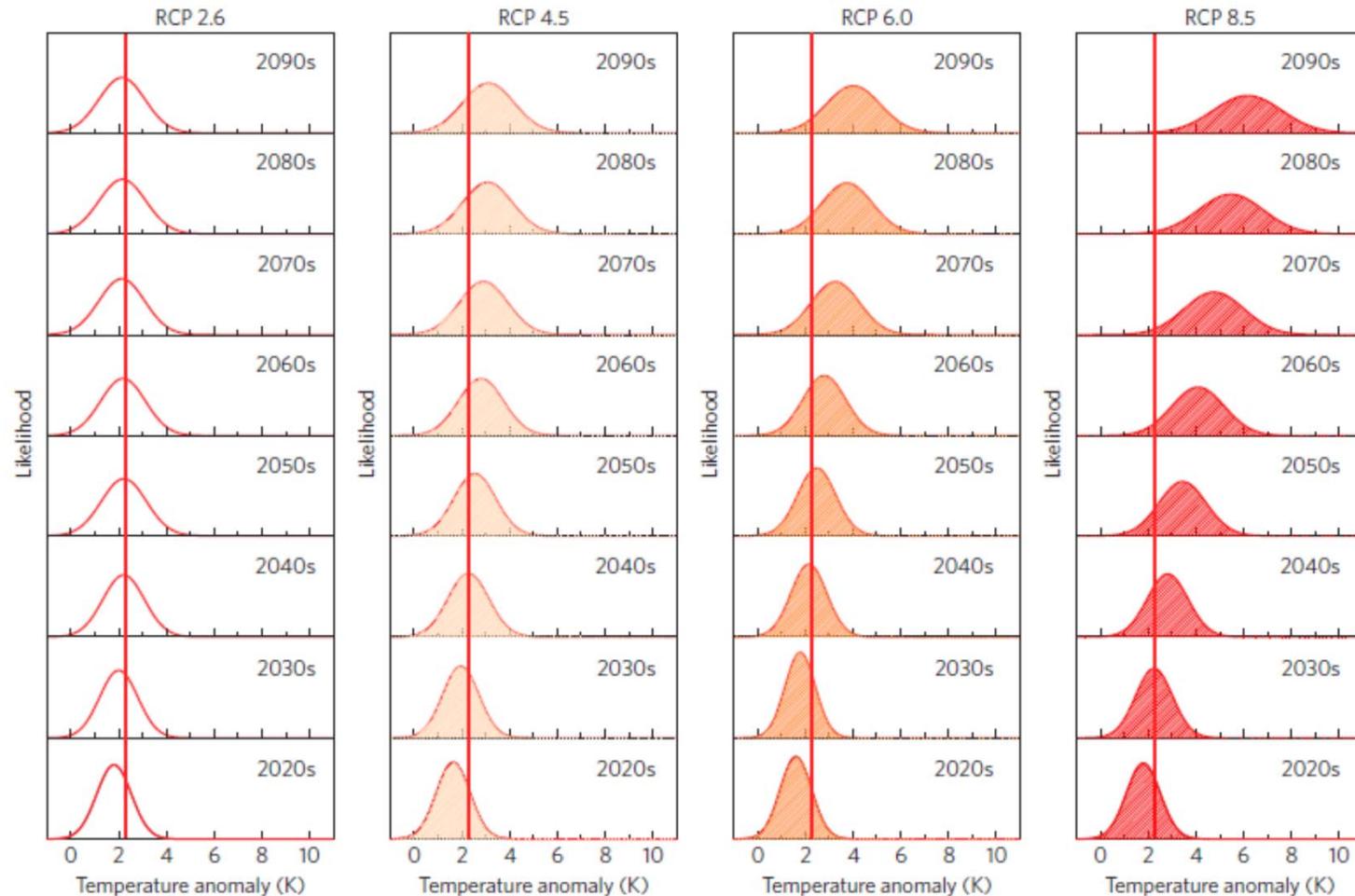
CLIMATE CENTRAL

CLIMATE
CENTRAL

RED CROSS/RED CRESCENT
CLIMATE CENTRE

We can also anticipate

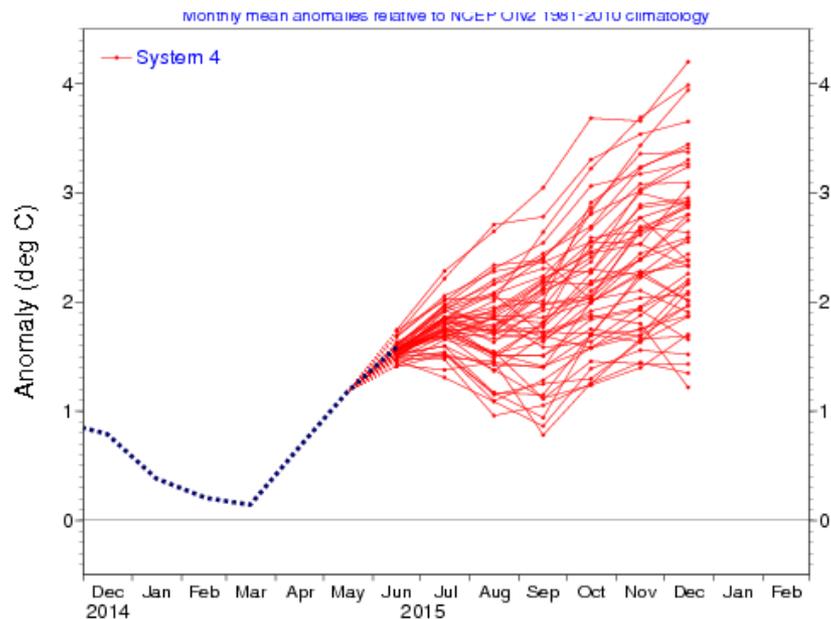
« Summer of 2003 will be soon a normal summer



Seasonal predictions

Seasonal prediction has become already an operational activity with wide range of applications

Strong El Niño predicted

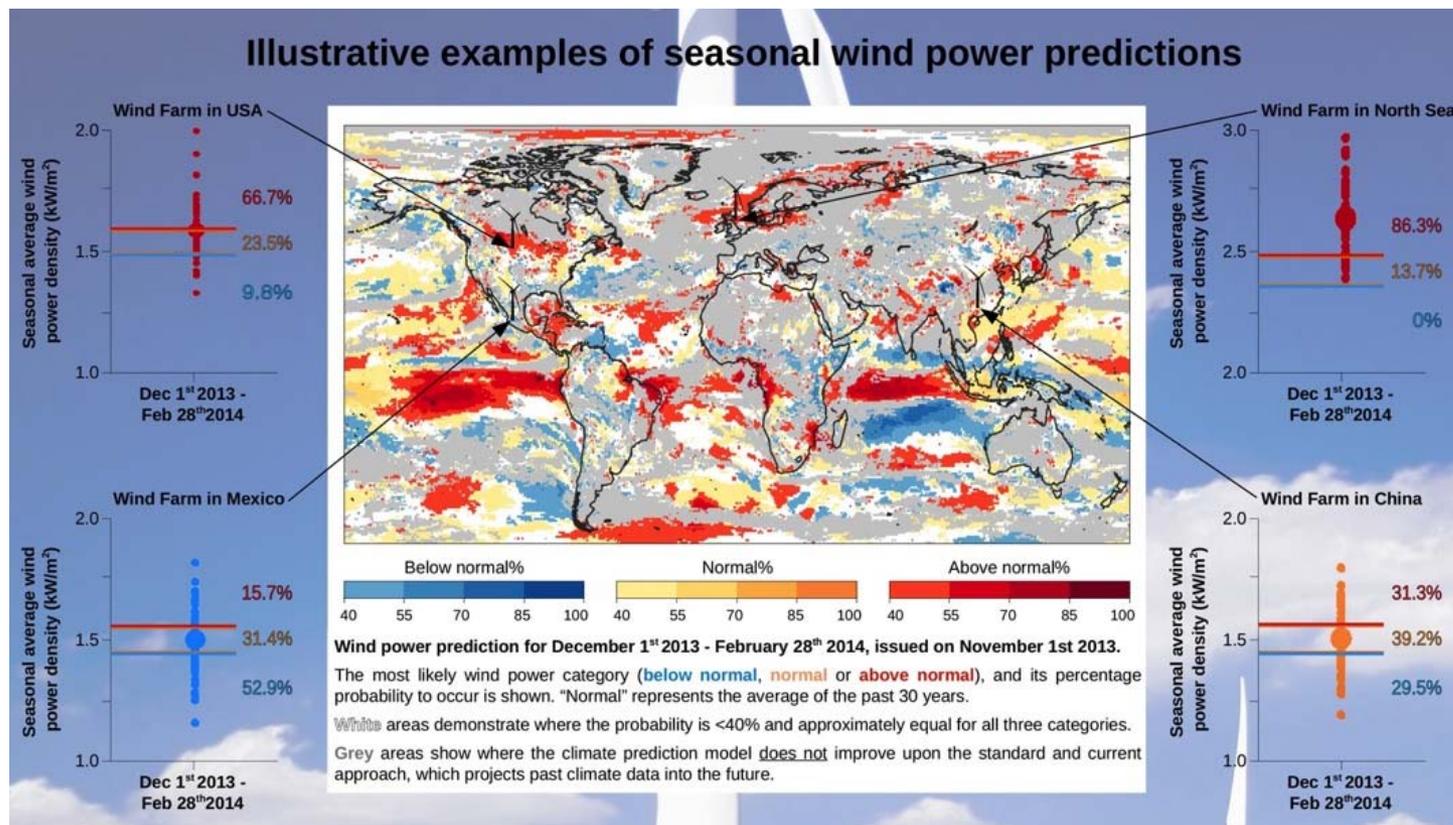


Increasing nickel prize



Wind energy predictions

Service example developed at IC3 on wind power predictions



Finding a location for vineyards

Bodegas Torres (a Spanish winery) is looking for new locations for its vineyards (and it's not the only one doing it).

Land is being purchased closer to the Pyrenees, at higher elevation. They are considering acquiring land in South America too, in areas where wine is currently not produced.

Bodegas Torres requests local climate information (including appropriate uncertainty assessments) for the vegetative cycle of the vine, which lasts 30-40 years.

The user needs to make the decision now.

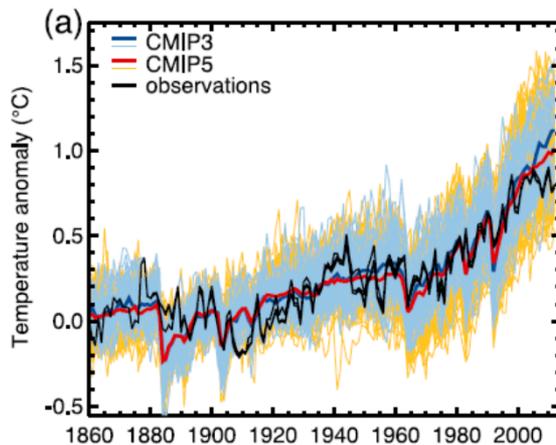


Conclusions and discussion

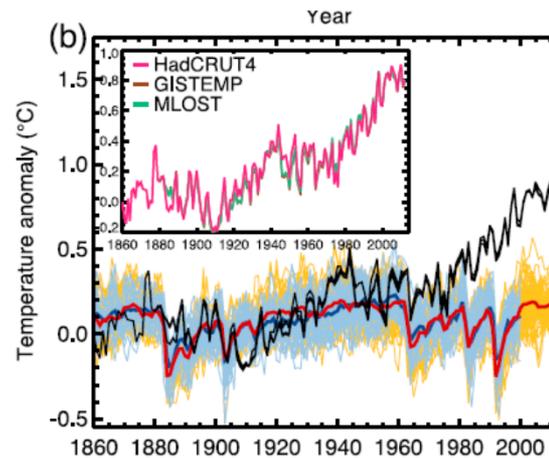
- ⌋ Using climate models we are able to predict climate anomalies and provide a service to society, an ongoing activity called “climate services”
- ⌋ Attribution shows that climate change is man made and extreme events are already more likely because of it. Event attribution helps us to inform the public.
- ⌋ *“Maybe we should no longer care about uncertainties of climate projections by the end of the century (2100) as we will adapt to it anyway, we have to take decisions now, climate change is already happening”*

Climate models show that observed changes are consistent with expected changes to forcing and inconsistent alternative explanations

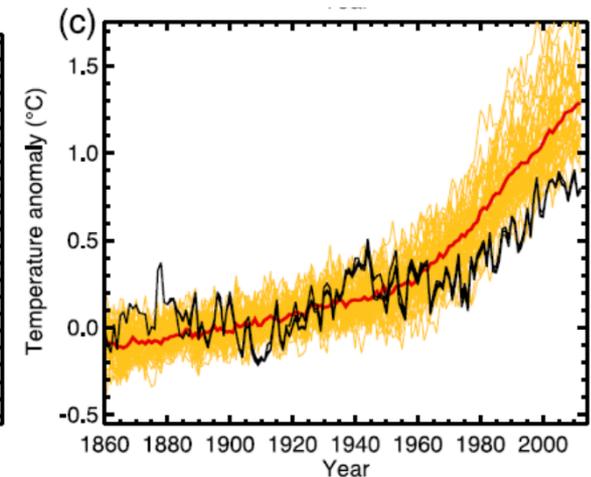
All forcings



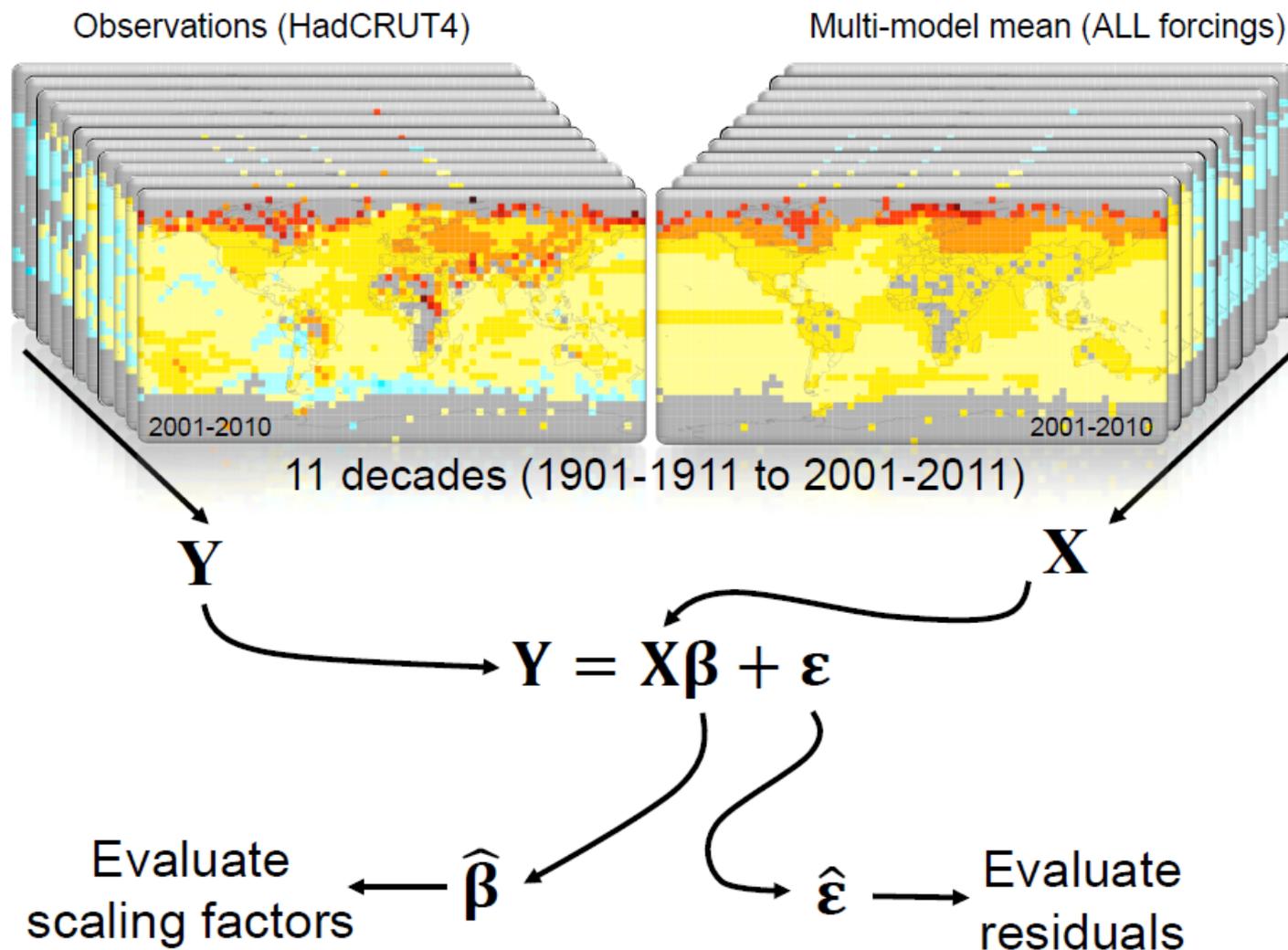
Solar + Volcanoes



GHGs

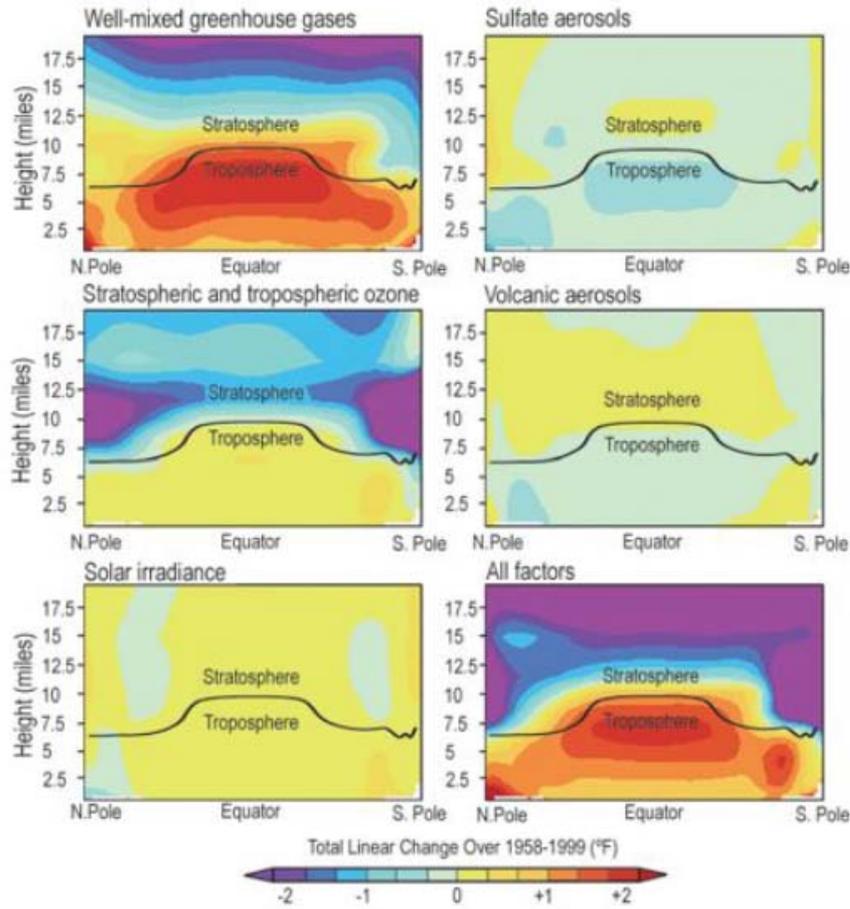


Detection & Attribution (D&A)

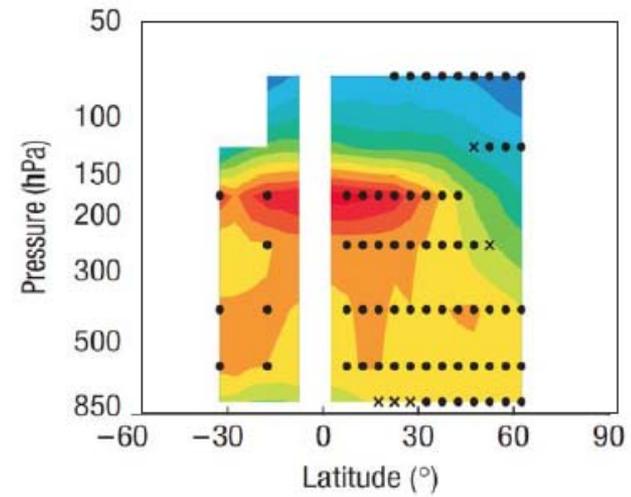


Detection and Attribution (D&A)

Model patterns (finger prints)

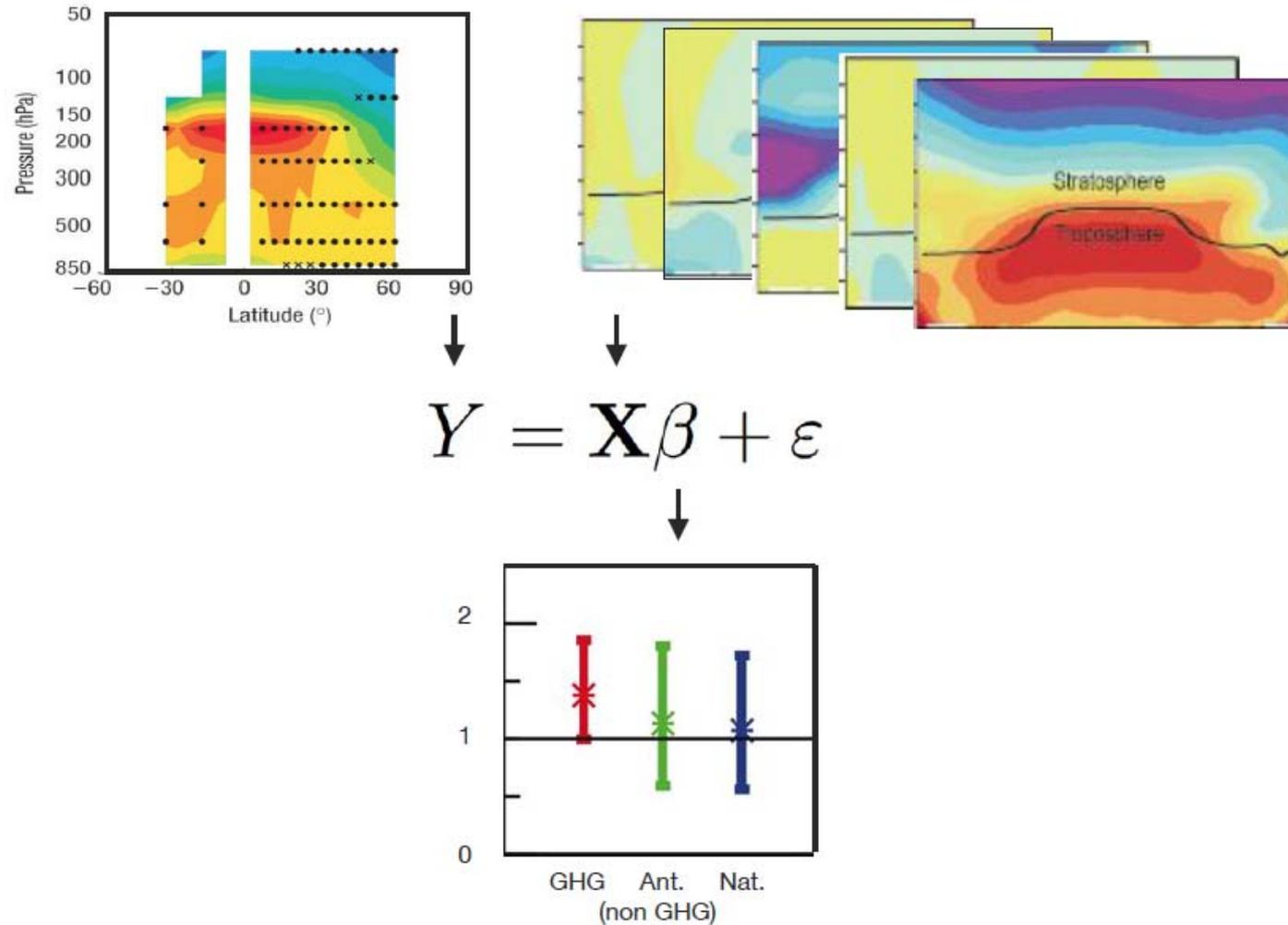


Observations



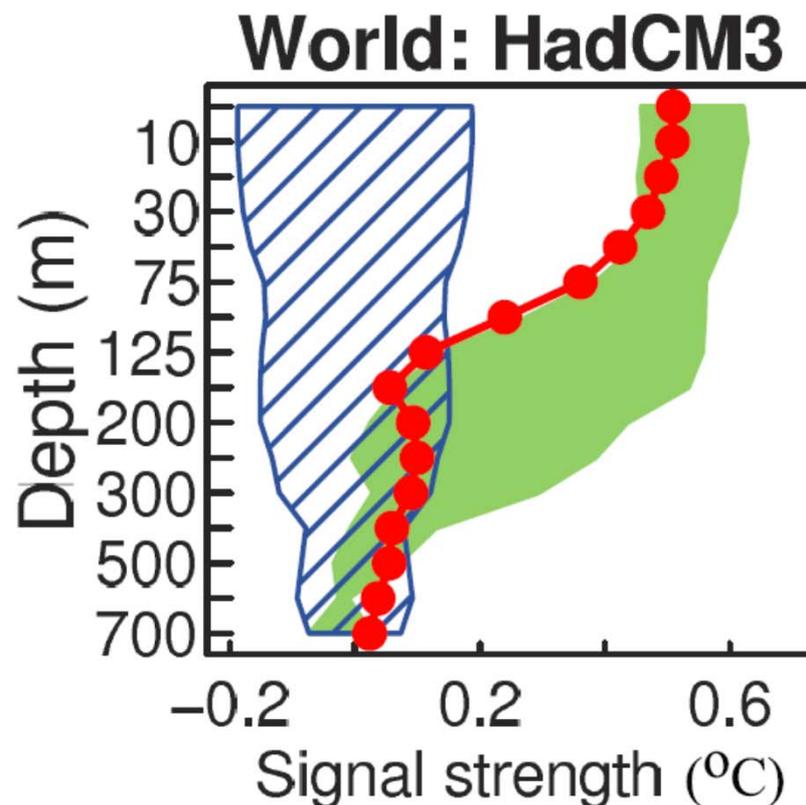
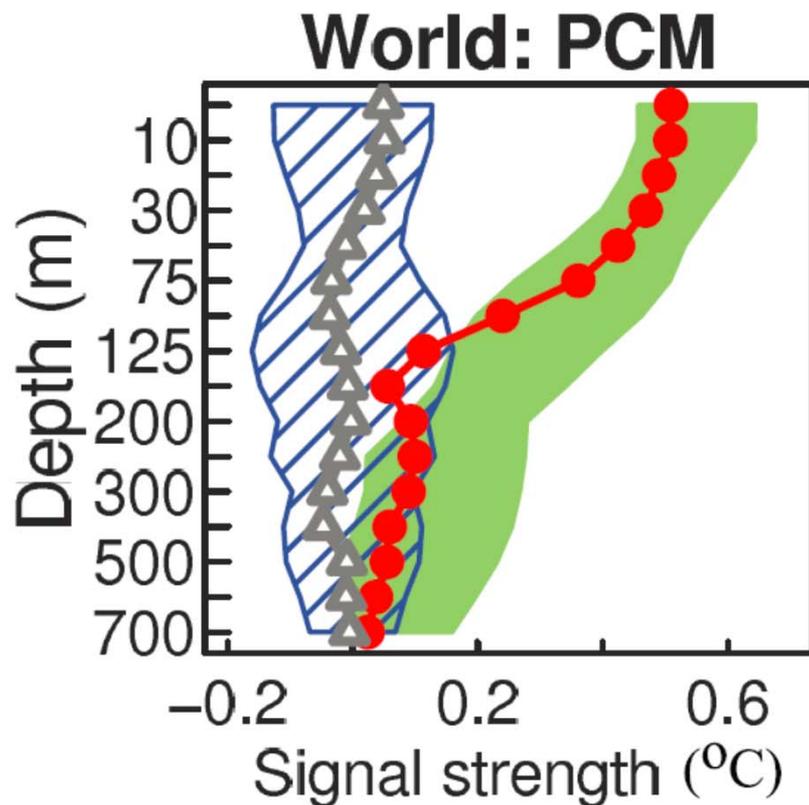
Atmospheric warming over the period 1958-1999

Optimal fingerprinting



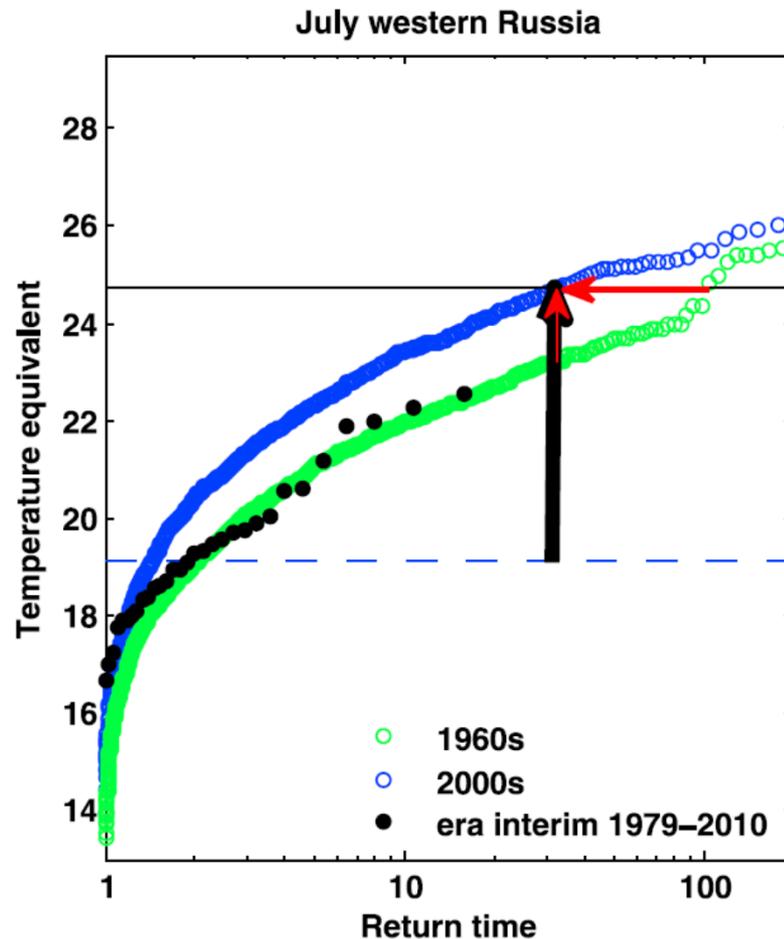
Detecting the human fingerprint

« Detection and attribution is done at spatial and temporal scales



Event attribution Russia 2010

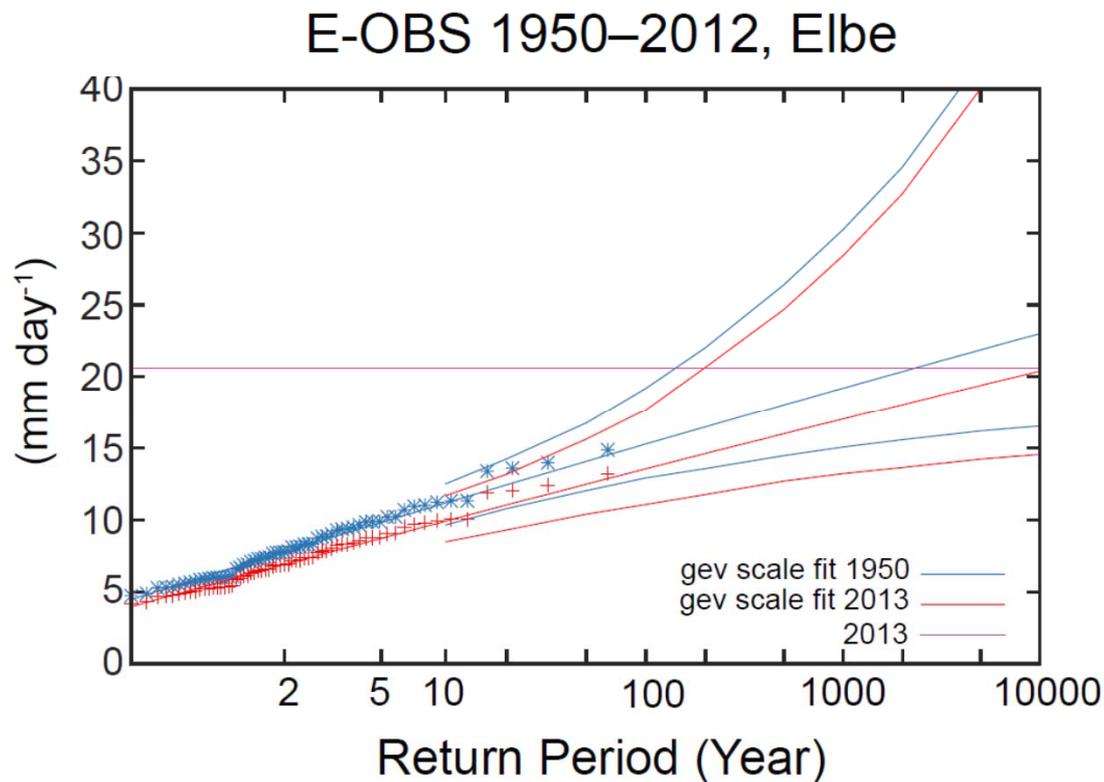
- ⌘ Magnitude mostly natural variability, however frequency strongly increased due to climate change



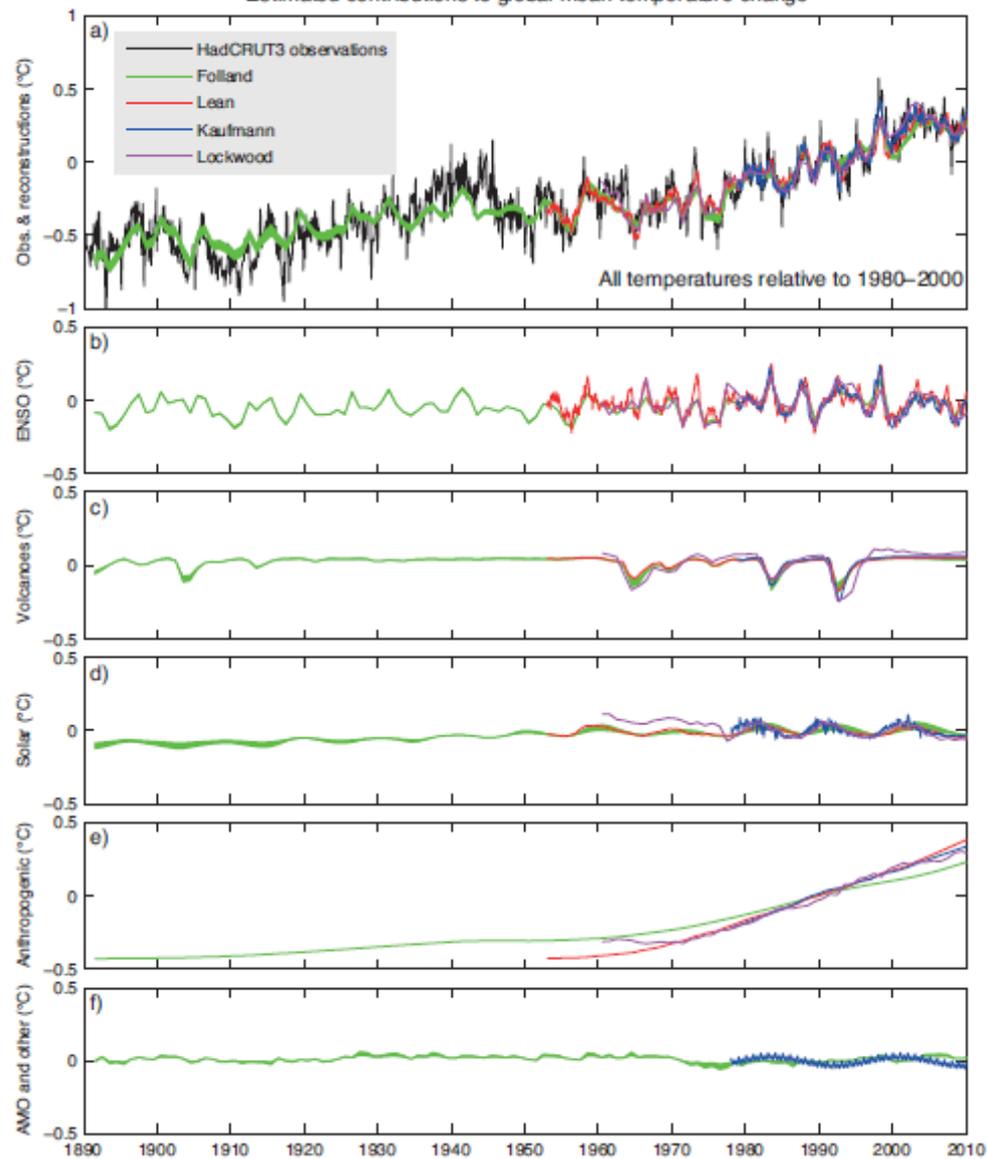
*Eucleia*α

Do-it-yourself attribution

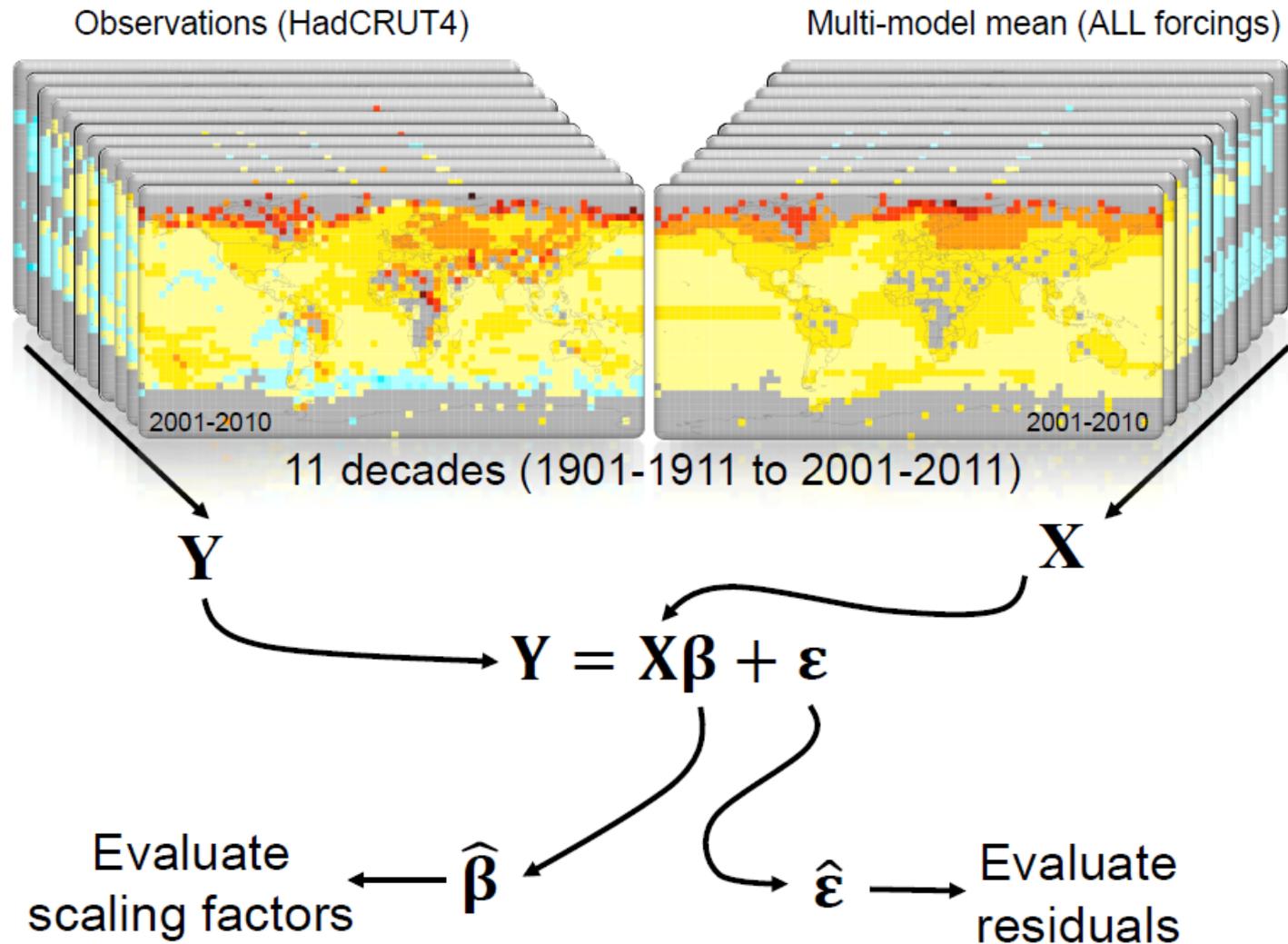
Fast-track attribution can be done on the KNMI climate explorer <http://climexp.knmi.nl>



Estimated contributions to global mean temperature change



Detecting the human fingerprint



The glacial inter-glacial oscillations

« The well-known climate anomalies

