



Life in a warmer world

Thomas Jung + many collaborators

Alfred Wegener Institute Helmholtz Center for Polar and Marine Research

Climate change: A brief overview



Late 19th century: CO₂ can impact climate

THE
LONDON, EDINBURGH, AND DUBLIN
PHILOSOPHICAL MAGAZINE
AND
JOURNAL OF SCIENCE.

[FIFTH SERIES.]

APRIL 1896.

XXXI. *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground.* By Prof. SVANTE ARRHENIUS *.

→ Doubling of CO₂ leads to a global mean warming of 5–6°C (IPCC = 2.5–4.5°C)

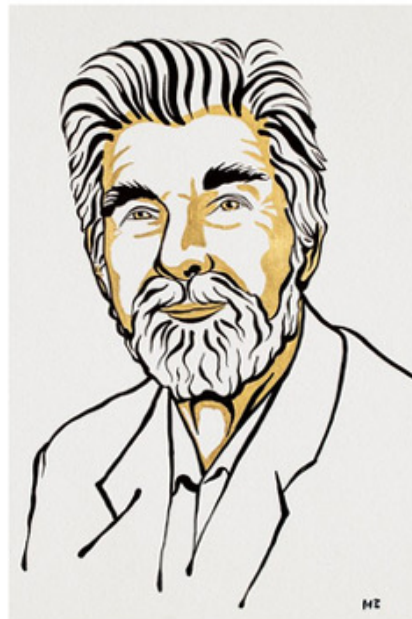


Climate change: A brief overview



1990s: It probably has and we know the spatial pattern

The Nobel Prize in Physics 2021

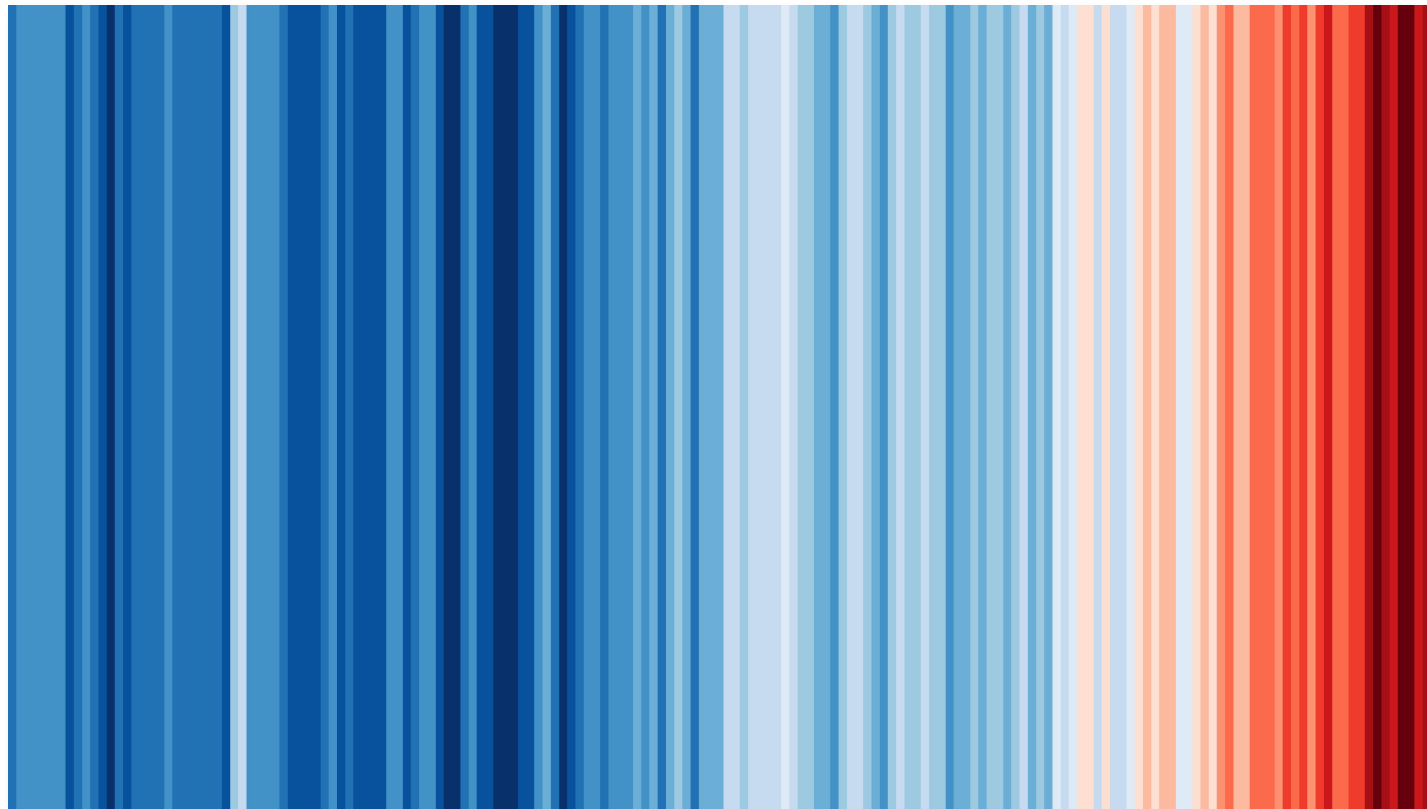


"for the physical modelling of Earth's climate, quantifying variability and reliably predicting global warming"

Climate change: A brief overview



Early 21st century: People recognize widely that it has, in a global mean sense



Climate change: A brief overview

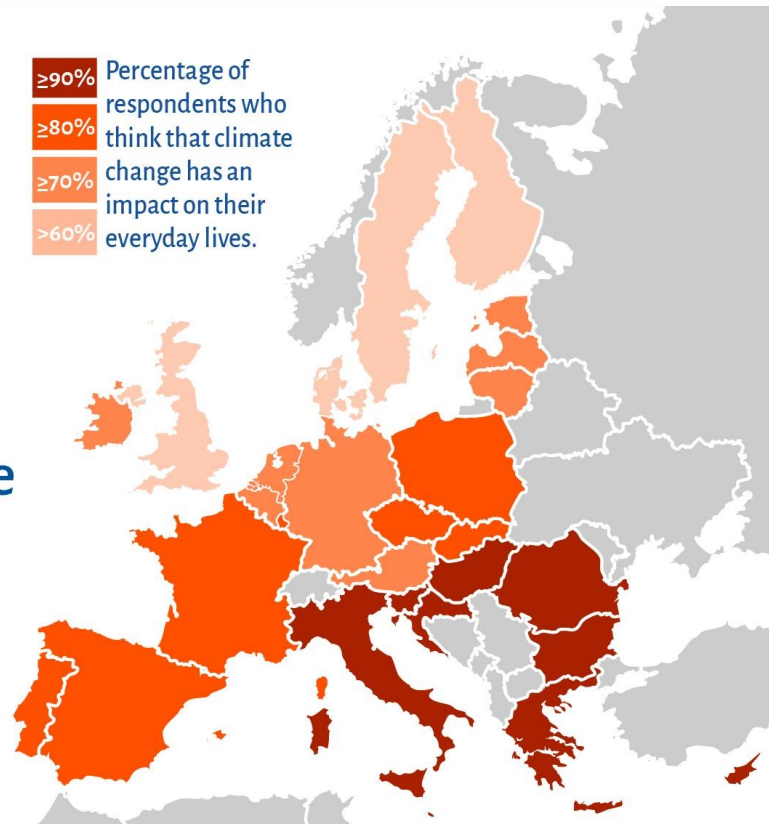


Today: It matters to all of us, everywhere

EIB Climate Survey

In **Eastern and Southern Europe**, more people feel the impact of climate change on their everyday lives.

≥90% Percentage of respondents who think that climate change has an impact on their everyday lives.
≥80%
≥70%
>60%



Source: BVA for the European Investment Bank

Climate models: Our tools to look into the future

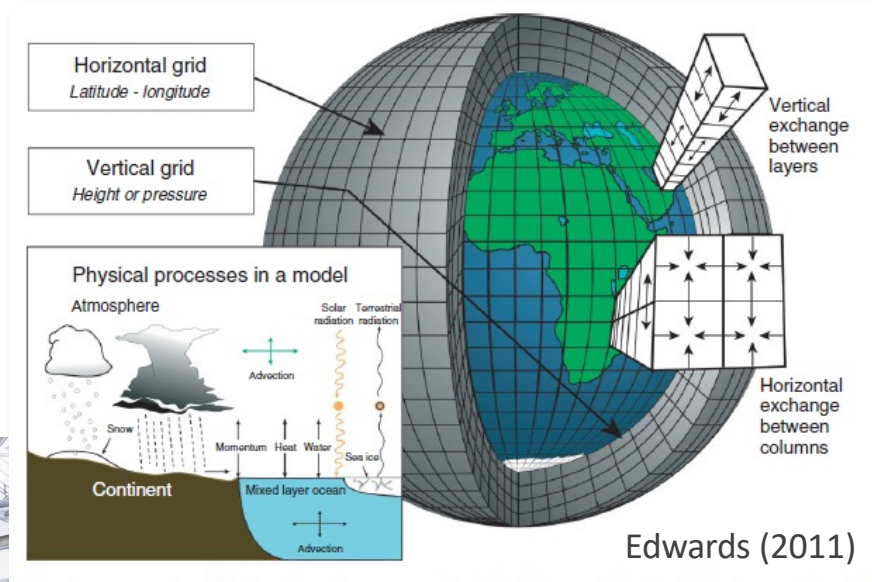


$$\frac{\partial \mathbf{v}}{\partial t} + \mathbf{v} \cdot \nabla \mathbf{v} = -2\boldsymbol{\Omega} \times \mathbf{v} - \frac{1}{\rho} \nabla p + \mathbf{g} + \mathbf{F}$$

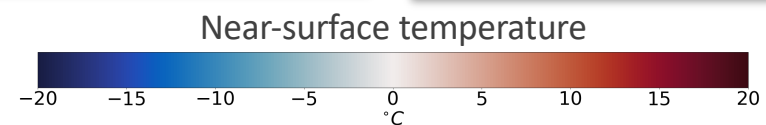
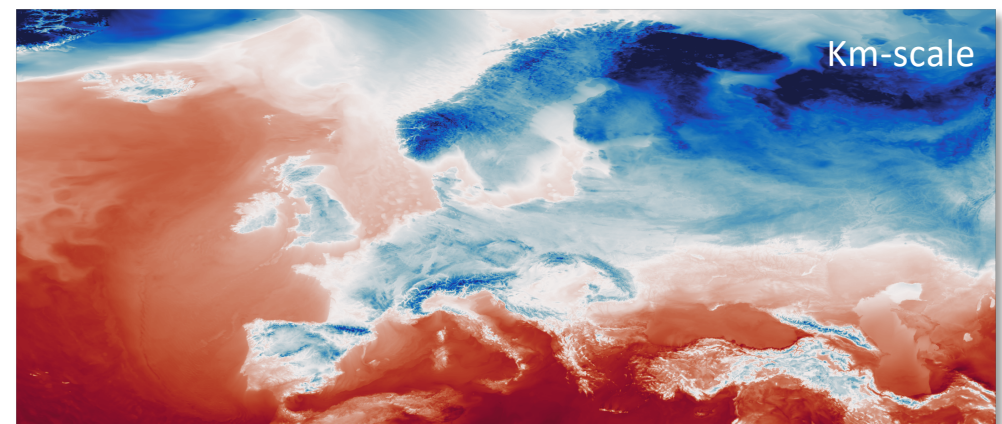
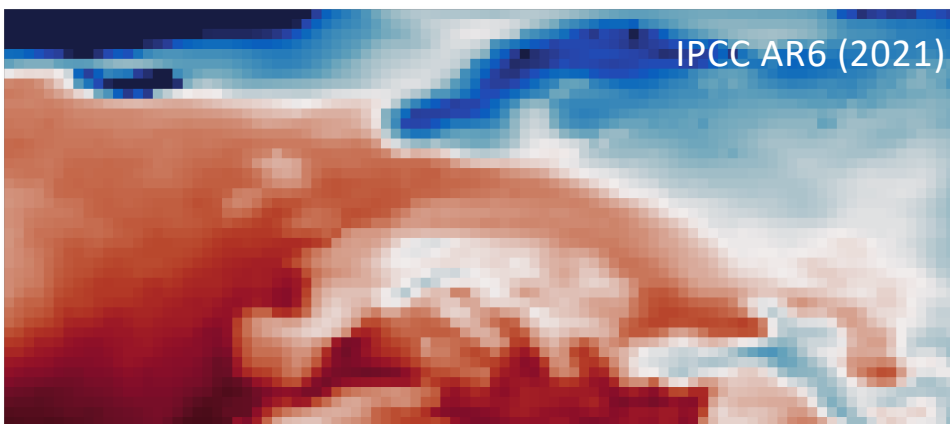
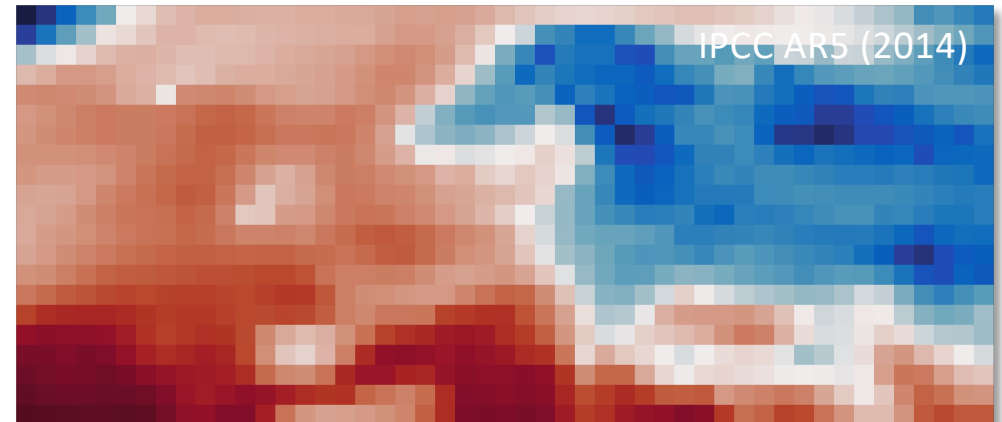
$$\frac{\partial \rho}{\partial t} + \nabla \cdot \rho \mathbf{v} = 0$$

$$\frac{\partial T}{\partial t} + \mathbf{v} \cdot \nabla T - \frac{p}{\rho^2} \frac{d\rho}{dt} = Q$$

$$p = \rho RT$$



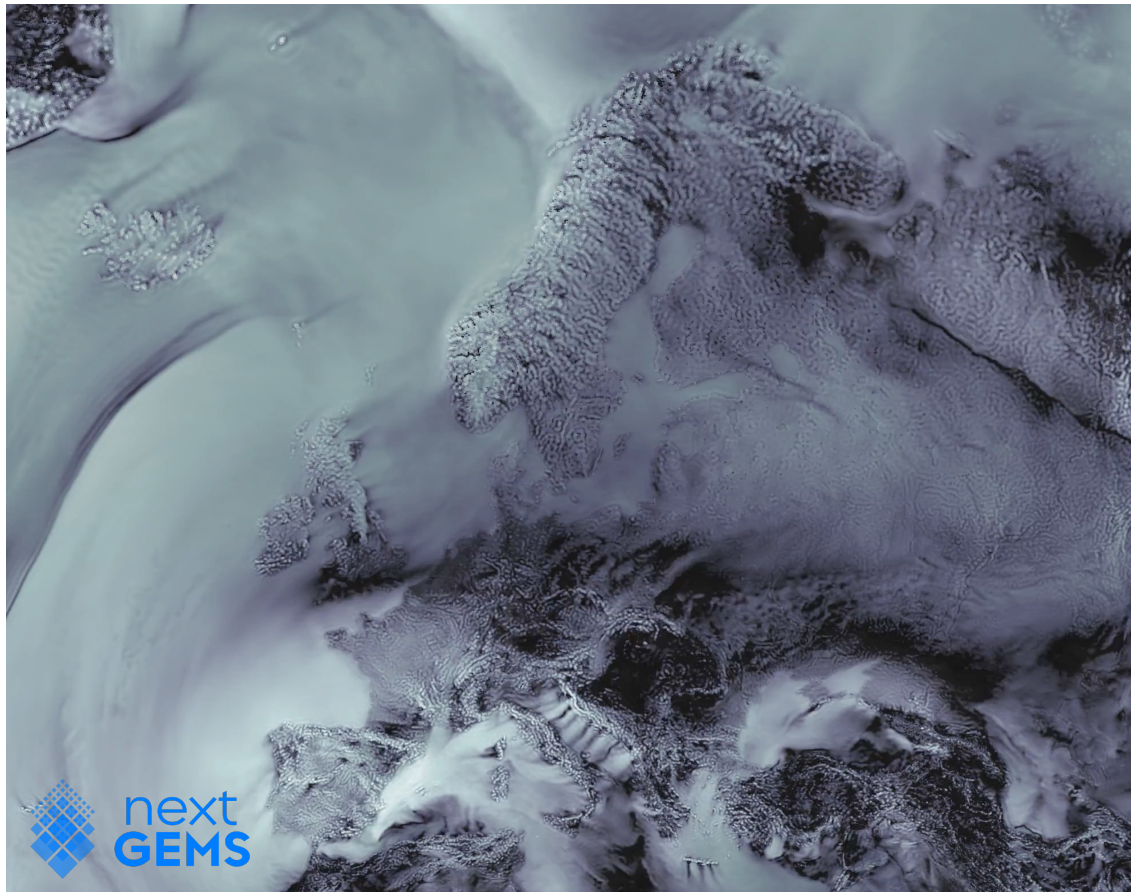
Climate models and resolution



A km-scale climate model in action

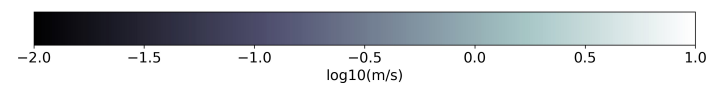
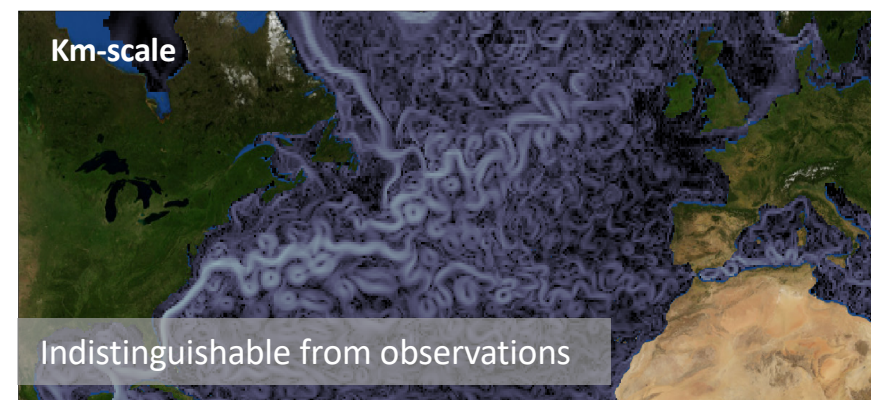
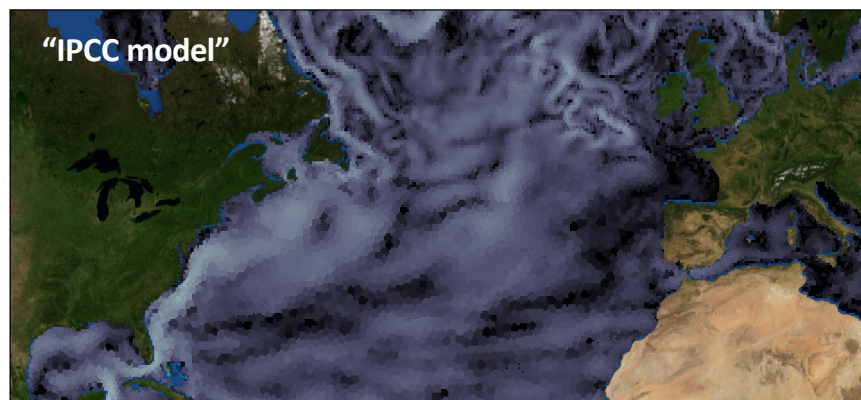
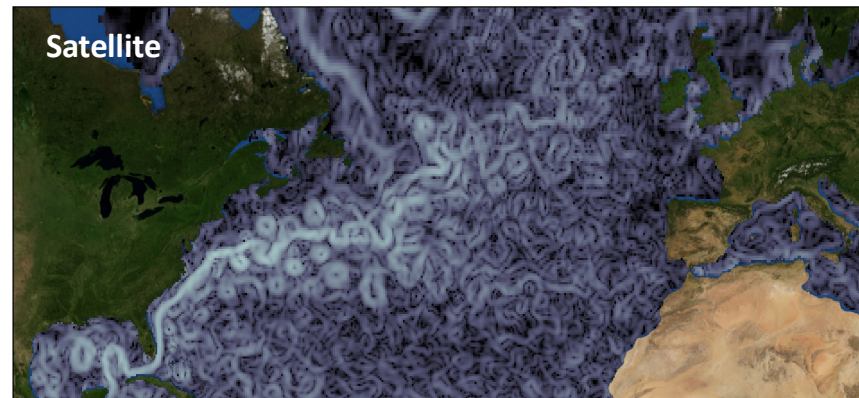


Europe in winds



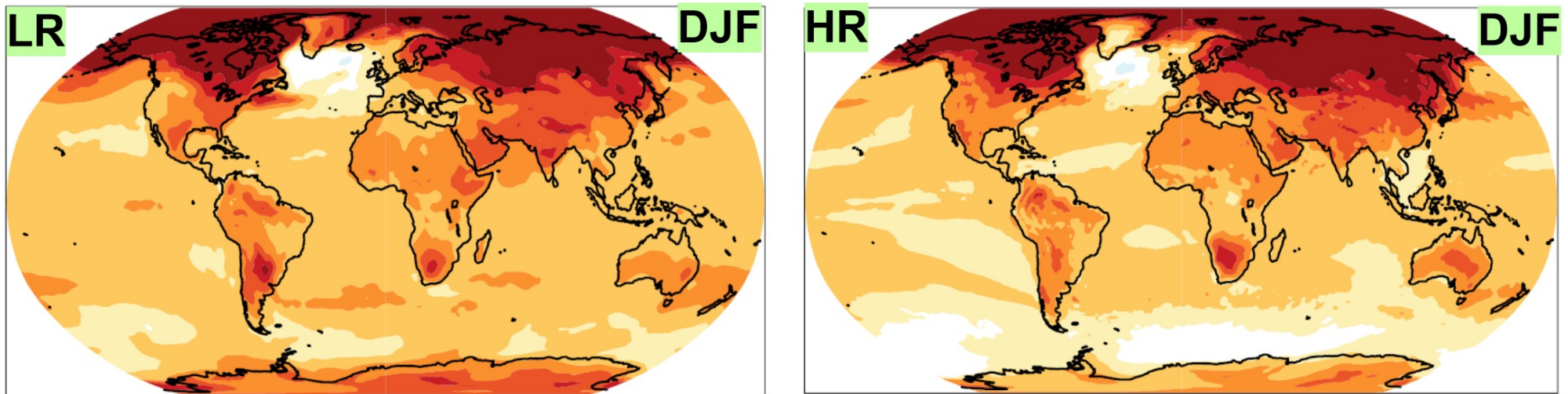
Rackow et al. (2024)

How realistic are these models?

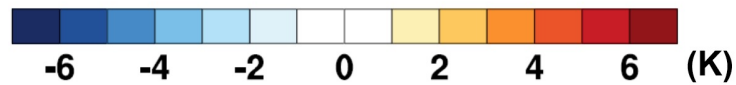


Does it matter: Upscaling?

2070–2099 minus 1976–2005



AWI-CM
AWI Climate Model

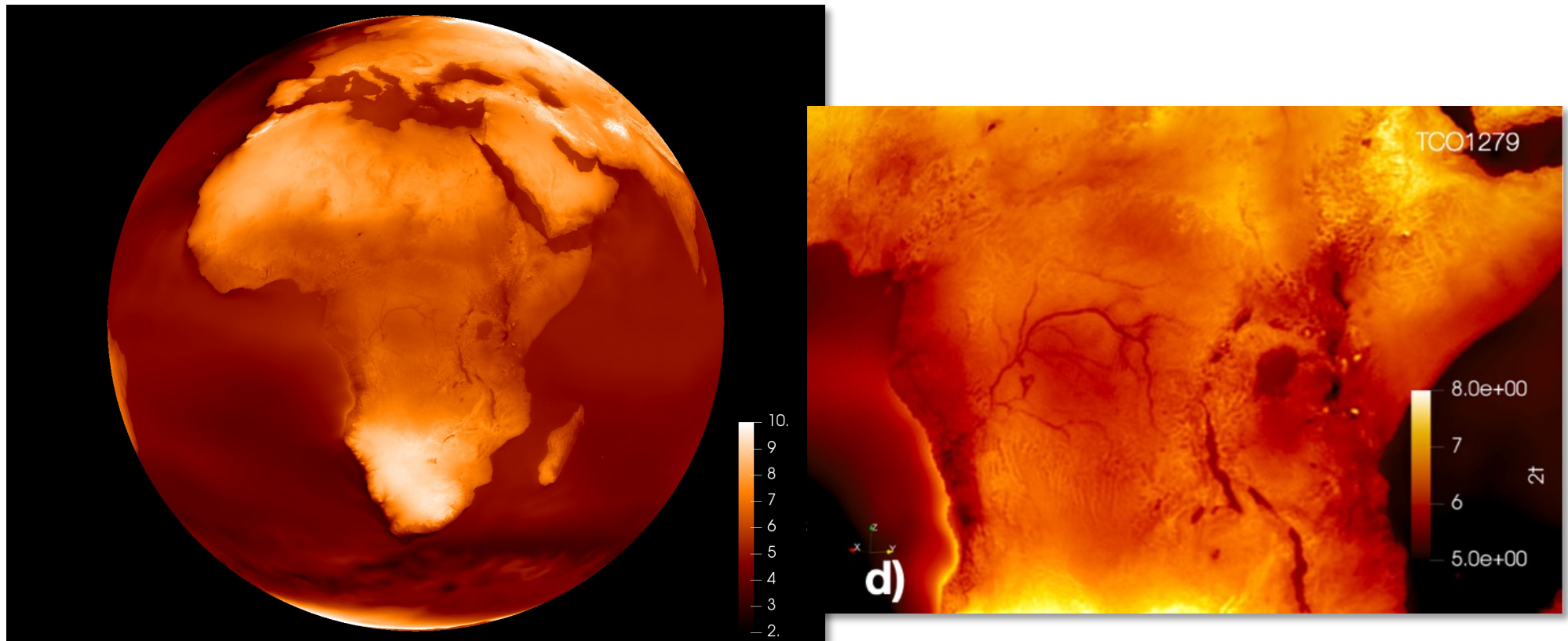


Rackow et al., Nature Comm. (2022)

Does it matter: Global downscaling?



Climate change at 9 km – climate change information with local granularity, globally



AWI-ICCP collaboration

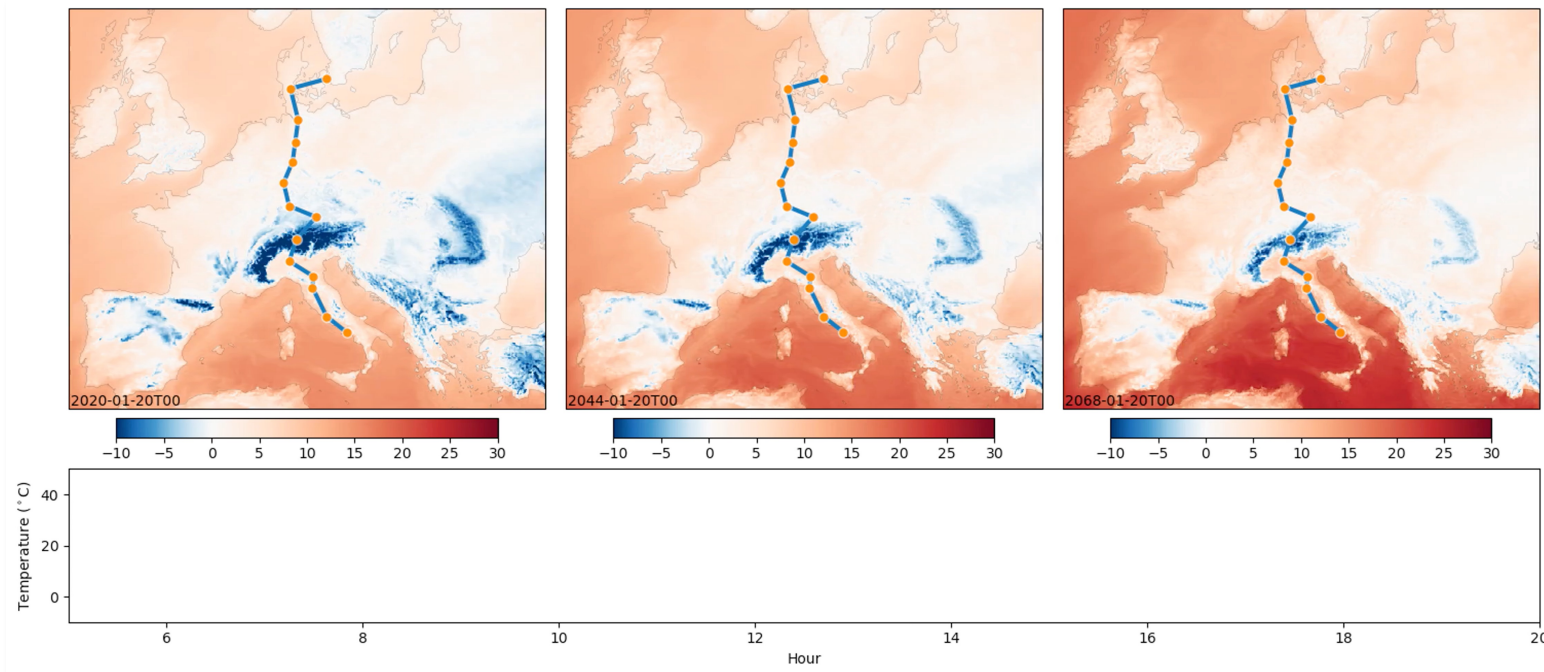
Climate information with local granularity – globally



Current conditions

+1°C world

+2°C world



Imagine a high-speed train that departs from Copenhagen at 6:00 and arrives in Naples at 19:00. This train could operate within the future climate, allowing you to estimate the conditions your equipment will experience. You could have thousands of different trains, routes, and schedules, and optimize your future transport system.

Storylines:
Making climate change more tangible

Extreme events in a warming world



Storylines: A heatwave example



Weather forecast for 25 July 2019

Deutscher Wetterdienst
Deutschland
Höchsttemperaturen

City	Temperature
Flensburg	27
Rostock	28
Hamburg	31
Berlin	35
Leipzig	36
Dresden	35
Münster	40
Köln	40
Stuttgart	39
München	35
Frankfurt	38
Hannover	38
Erfurt	36
Nürnberg	38
Regensburg	37
Salzburg	37
Wien	37
Zürich	37
Genève	37
Paris	37
London	37
Brüssel	37
Amsterdam	37
Rotterdam	37
Antwerpen	37
Lüttich	37
Strasbourg	37
Nantes	37
Bordeaux	37
Montpellier	37
Nizza	37
Palermo	37
Napoli	37
Rom	37
Athens	37
Istanbul	37
Teheran	37
Delhi	37
Mumbai	37
Kolkata	37
Jaipur	37
Chennai	37
Bangalore	37
Hyderabad	37
Coimbatore	37
Madurai	37
Trichy	37
Chennai	37
Bangalore	37
Hyderabad	37
Coimbatore	37
Madurai	37
Trichy	37

How would this day have “looked like” in pre-industrial times?
How would this day “look like” in a +2K and +4K warmer world?

Thomas Jung
25. Jul 2019 · 8
Passing through Cologne on a record breaking day, with the railway system in meltdown...

Cologne
Partly Cloudy
41°

Thursday TODAY 41 23
Now 18 19 20 21 21:28
41° 41° 39° 38° 36° Sunset

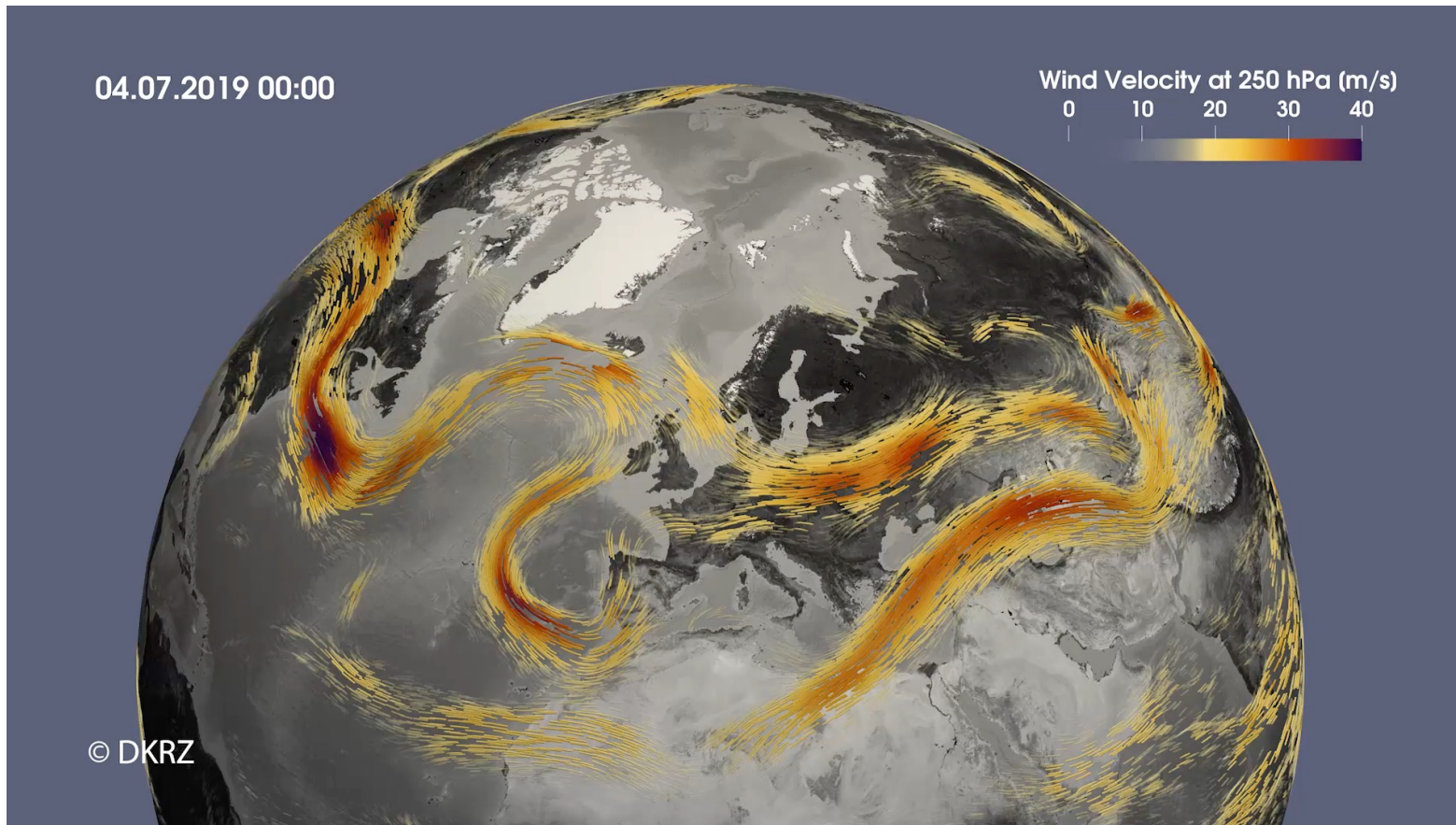
Friday 39 20
Saturday 28 18
Sunday 23 15
Monday 26 14
Tuesday 26 14
Wednesday 25 13
Thursday 25 14

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Politik Gesellschaft Wirtschaft Kultur Wissen Gesundheit Digital C

Hitzewelle
Deutscher Wetterdienst meldet neuen Hitzerekord
42,6 Grad – so heiß war es laut einer Messung in niedersächsischen Lingen. Der Rekordwert vor dem Krieg. Nie war es heißer in Deutschland.

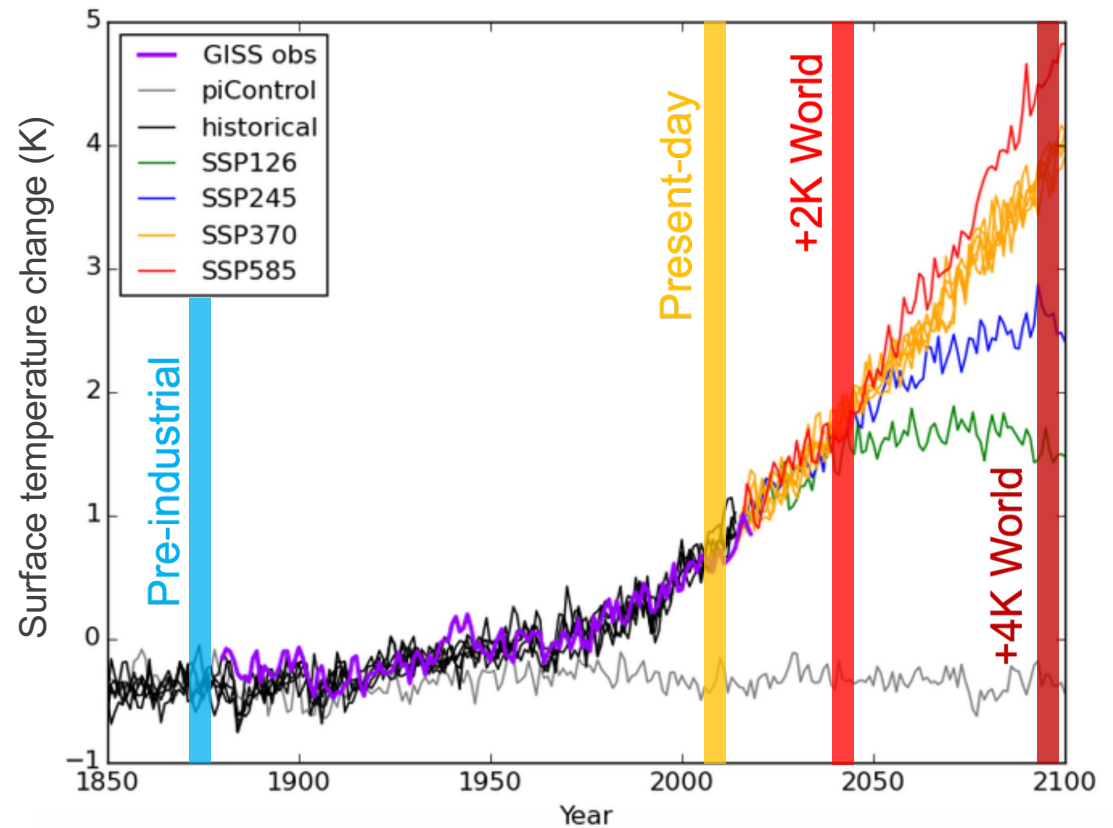
Frankfurt 150f 4
Paris Nord 4
Hamburg-Altona 2+
Rhein 3
Köln 4
Eindhoven 5+
Frankfurt 150f 4
Paris Nord 4
Hamburg-Altona 2+
Rhein 3
Köln 4
Eindhoven 5+

The jet stream



The approach

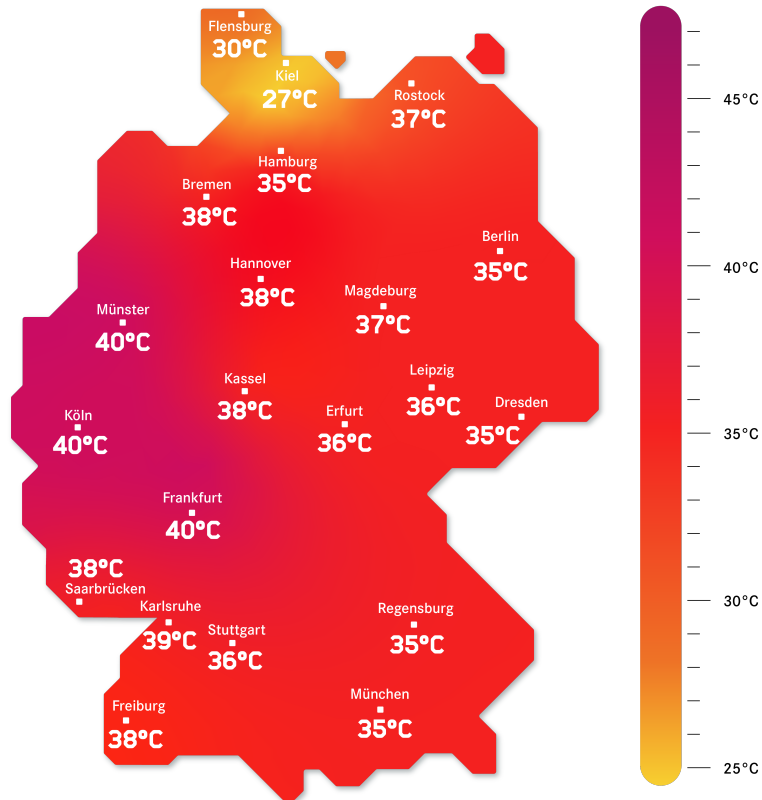
- Take a climate model that contributed simulations to IPCC AR6 (ssp370).
- Branch off simulations for present-day climate in which the observed evolution of the jet stream is imposed through spectral nudging (1 Jan 2017 to 31 Dec 2020), keeping everything else untouched.
- Repeat for +2K World (≈ 2042)
- Repeat for +4K World (≈ 2093)
- Repeat for pre-industrial climate (≈ 1850)



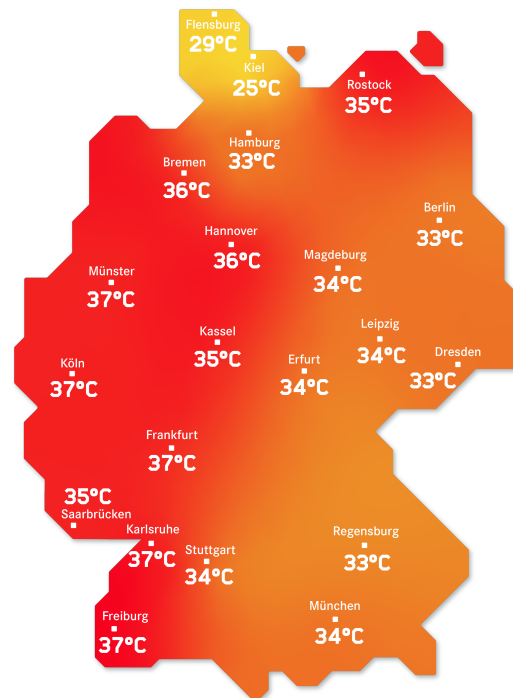
Temperatures for “25th July 2019” in different worlds



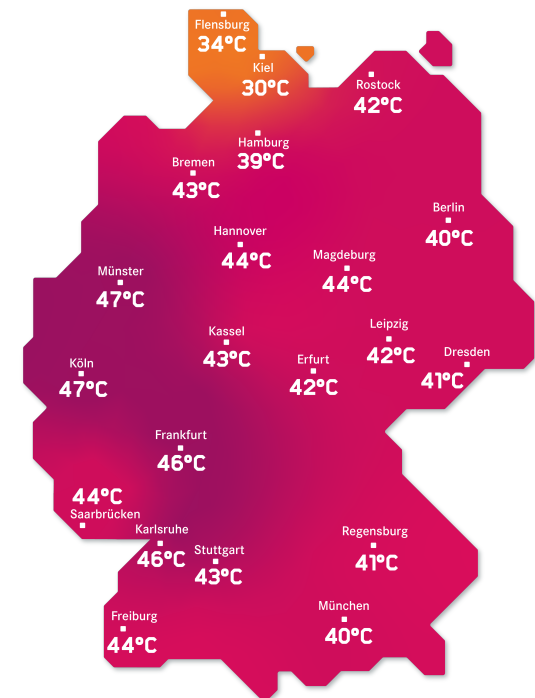
Present-day



Pre-industrial

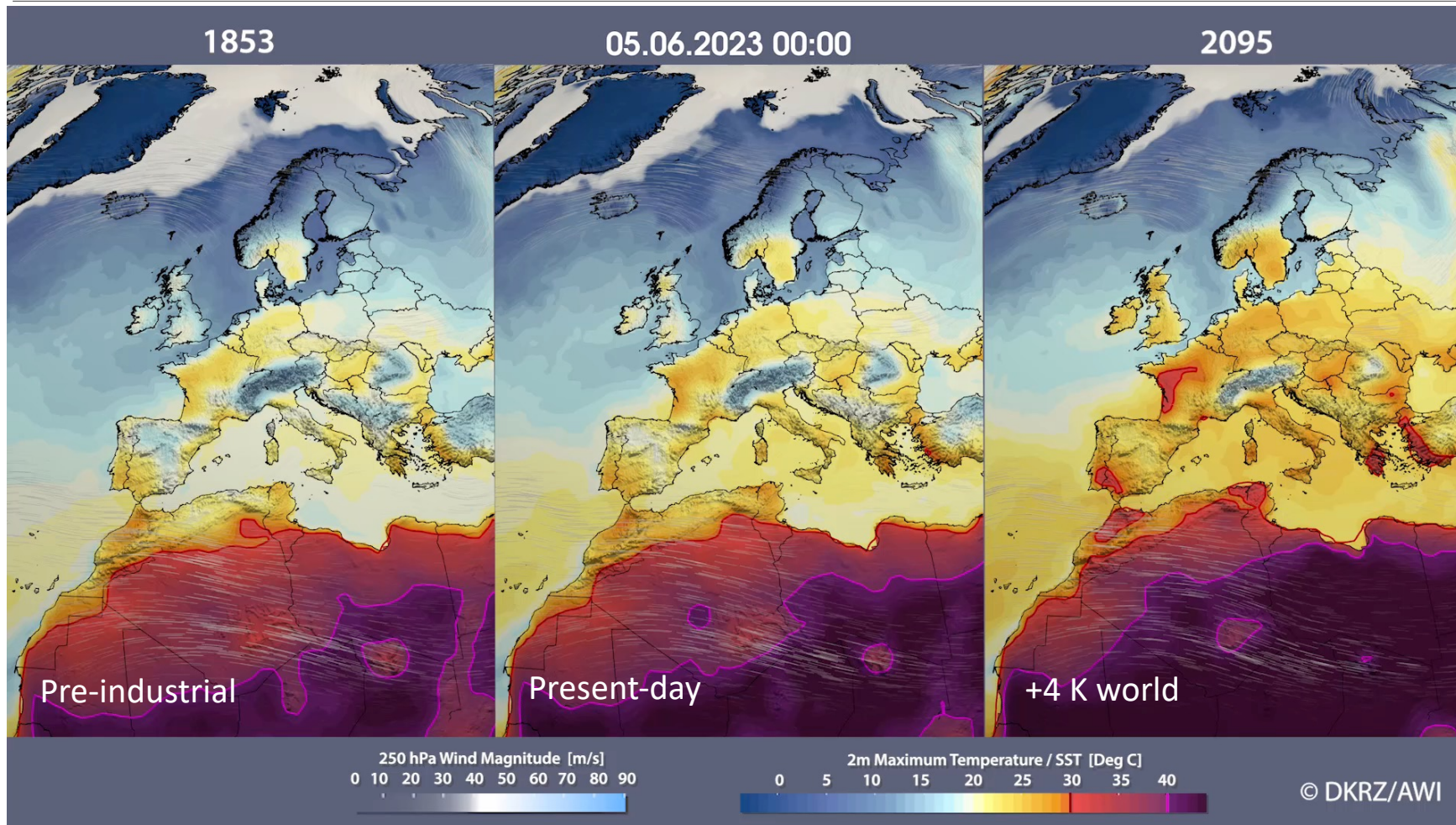


+4K warmer world



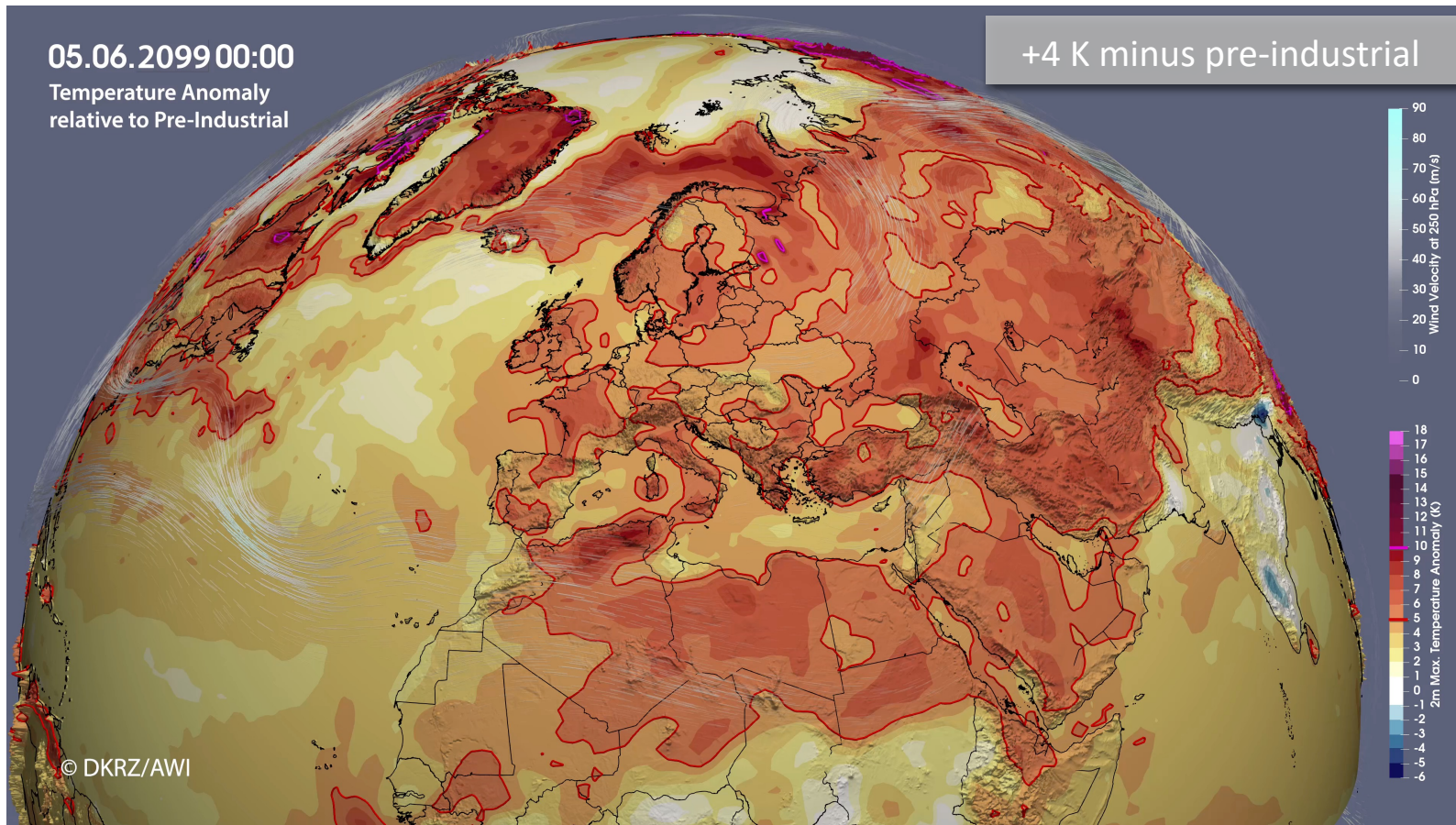
Sanchez-Benitez et al., J. Climate (2022)

Storylines of the summer of 2023



Updated from Sanchez-Benitez et al., J. Climate (2022)

Climate change signal of the day



Other applications: Near-real-time storylines



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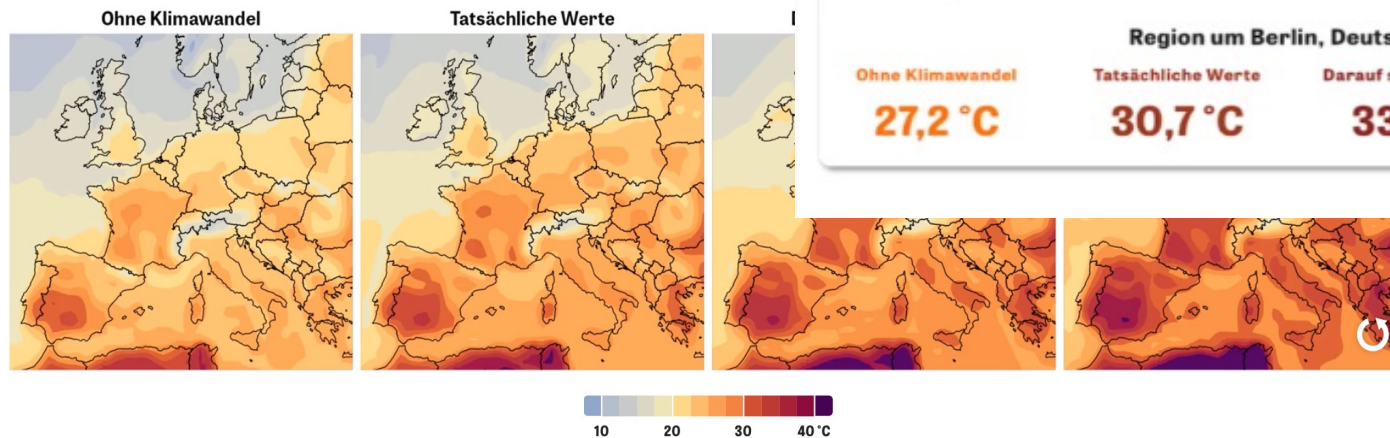
Hitzewelle

So viel heißer wäre die aktuelle Hitze in Zukunft

Der bislang heißeste Tag des Jahres war im Juli. Eine Sir die Klimakrise gewesen wäre – und wie extrem e

13. Juli 2023, 16:22 Uhr / 229 Komme

6. Juli 2023



Wie viel heißer macht der Klimawandel es bei Ihnen?

So warm wäre es am 9. Juli in Ihrer Region ohne den Klimawandel gewesen – und wenn Klimaszenarien der Zukunft schon heute eintreten würden.

Ort in Europa suchen ...

Region um Berlin, Deutschland

Ohne Klimawandel	Tatsächliche Werte	Darauf steuern wir zu	Worst-Case-Szenario
27,2 °C	30,7 °C	33,4 °C	36,1 °C

Quelle: Alfred-Wegener-Institut, eigene Berechnungen

How to answer the (many) questions people may have?



Towards local climate information, for all



communications earth & environment

COMMENT

<https://doi.org/10.1038/s43247-023-01199-1>

OPEN

Local climate services for all, courtesy of large language models

Nikolay Koldunov ¹✉ & Thomas Jung ^{1,2}

Large language models can summarize, aggregate, and convey localized climate-related data to people in a cost-effective and expeditious manner. We have built a simple, proof-of-concept prototype and argue that the approach holds the potential to truly democratize climate information.

Components of the prototype:

- + Large Language Model (OpenAI API)
- + Clear definition of the scope
- + *User question + location*
- + Climate data
- + Other spatial data (e.g., land use and height)
- + Text data (e.g., IPCC and policy documents)

Towards local climate information, for all



Box 1 | Summary of the potential risks and benefits arising from climate change for growing wheat in Saâda, Marrakech Prefecture, Morocco (31.6912N, 8.1098W), generated by ClimSight

Climate impact on wheat cultivation in Saâda, Morocco

Climate change could significantly impact your plans for wheat cultivation in Saâda, Morocco.

Temperature:

The current mean monthly temperature in your location varies from 8.58 °C to 34.645 °C. In the future, the monthly temperatures are expected to rise, with a range from 13.17 °C to 40.88 °C. This increase can affect the growth of wheat crops, as they are sensitive to temperature changes. Wheat prefers a cooler climate for its growth and development, with an optimal temperature for germination of around 12–25 °C. With the expected rise in temperature, there could be serious implications for wheat production such as decreased yield and increased susceptibility to pests and diseases.

Precipitation:

The current monthly precipitation flux ranges from 0.01941 mm/month to 4.794 mm/month. However, future predictions indicate a decrease in precipitation, with a range from 0.003157 mm/month to 2.608 mm/month. Wheat crops require around 450–650 mm of rainfall annually, preferably well-distributed throughout their growth period. A decrease in rainfall could lead to water stress, impacting wheat growth and yield.

Wind:

The future u and v wind components indicate an increase in wind speed. High wind speeds can cause physical damage to the wheat crops, disrupt pollination, and lead to moisture loss.

Policy and regulatory implications:

In Morocco, climate change adaptation policies are in place to support sustainable agriculture. The Green Morocco Plan (2008–2020) aims to modernize agriculture and make it more resilient to climate change. It is advisable to align your wheat cultivation plans with these policies to benefit from potential government support.

Recommendations:

Given the future climate predictions, it would be prudent to consider the following:

- **Irrigation:** Due to the predicted decrease in rainfall, consider implementing efficient irrigation systems to ensure adequate water supply.
- **Heat-resistant varieties:** Look into heat-resistant wheat varieties that can withstand higher temperatures.
- **Wind protection:** Implementing windbreaks in your field could provide some protection against the predicted increase in wind speed.
- **Policy alignment:** Ensure your practices align with local climate change adaptation policies to potentially benefit from financial and technical support.

(Please note, this analysis is based on the provided future climate predictions. It is advisable to continuously monitor local weather and climate trends for more accurate decision-making.)

Towards local climate information, for all



A screenshot of a web application interface. On the left is a map of Europe and North Africa with a zoom control (+/-) in the top-left corner. On the right is a form titled "Climate Foresight" with a globe icon. The form includes a text input field for "Describe the activity that you would like to evaluate for this location:", two input fields for "Latitude" (47,9736) and "Longitude" (11,2402), a checkbox labeled "Provide additional information" which is checked, and a "Generate" button. A "Deploy" button with a menu icon is in the top-right corner of the interface.

Koldunov and Jung (2024)

Positive narratives



How a net-zero world in which humans have adapted to the inevitable climate change could look like.