Klimawandel und Hochwasserrisiken

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Rosenheim, 10. Juli 2014

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Hochwasser in Deutschland 1

Hochwasser in Passau
www.sueddeutsche.de, 2. Juni 2013

Hochwasser in Kolbermoor
www.ovb-online.de, 4. Juni 2013

Hochwasser in Deutschland 2

Postkarte zum
Isar-Hochwasser im September 1899
Sammlung M. Deutsch, Erfurt/Göttingen

so genannte “Thüringer Sintflut”
am 29. Mai 1613
Deutsch et al., 2013

Fragen

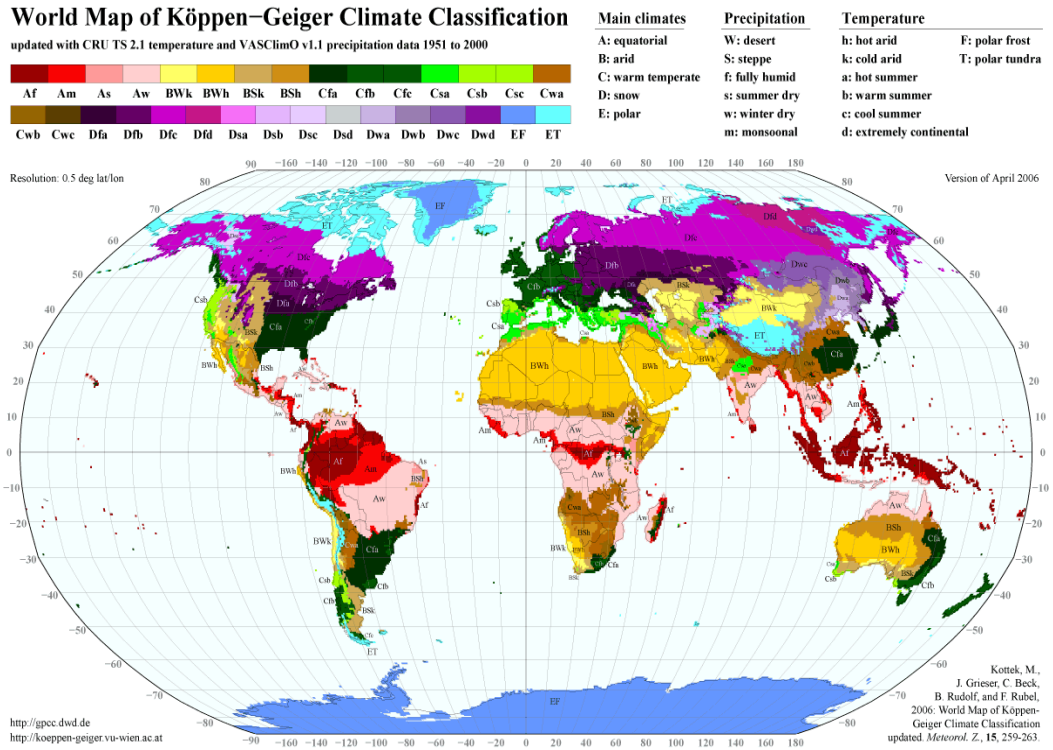
- Hat sich das Klima geändert?
- Welchen Einfluss hat der Mensch?
- Wie wird sich das Klima in Zukunft entwickeln?
- Was wissen wir über zukünftige Extremereignisse, speziell Hochwasser?

Bild Zeitung, 3 Februar 2007

Was ist „Klima“?

- Klima ist die *statistische Gesamtheit* der mittleren atmosphärischen Zustände und Prozesse in einem bestimmten Gebiet über einen längeren Zeitraum (30 Jahre).

- Meistens betrachtete Größen: Temperatur, Niederschlag und Wind am Erdboden.



Klimakarte der Erde

Kottek et al. (2006), Meterol. Z..

Beispiel für Klimaänderungen: Gletscher-Schwund in den Alpen

Aufnahme der Pasterzenzunge mit Großglockner (3798 m)

um 1900	2000

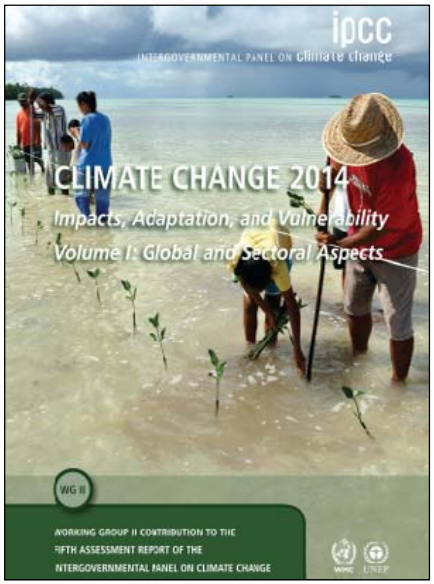
http://www.gletscherarchiv.de

Wichtige wissenschaftliche Grundlagen

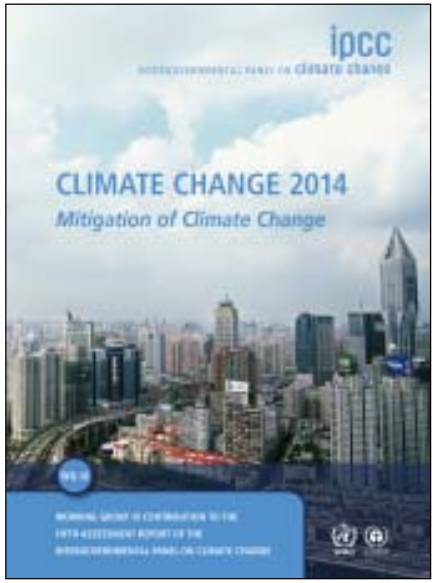
Assessment Reports of the Intergovernmental Panel on Climate Change (IPCC)

Sachstandsberichte
des Zwischenstaatlichen Ausschusses für Klimaänderungen

The Physical Science Basis



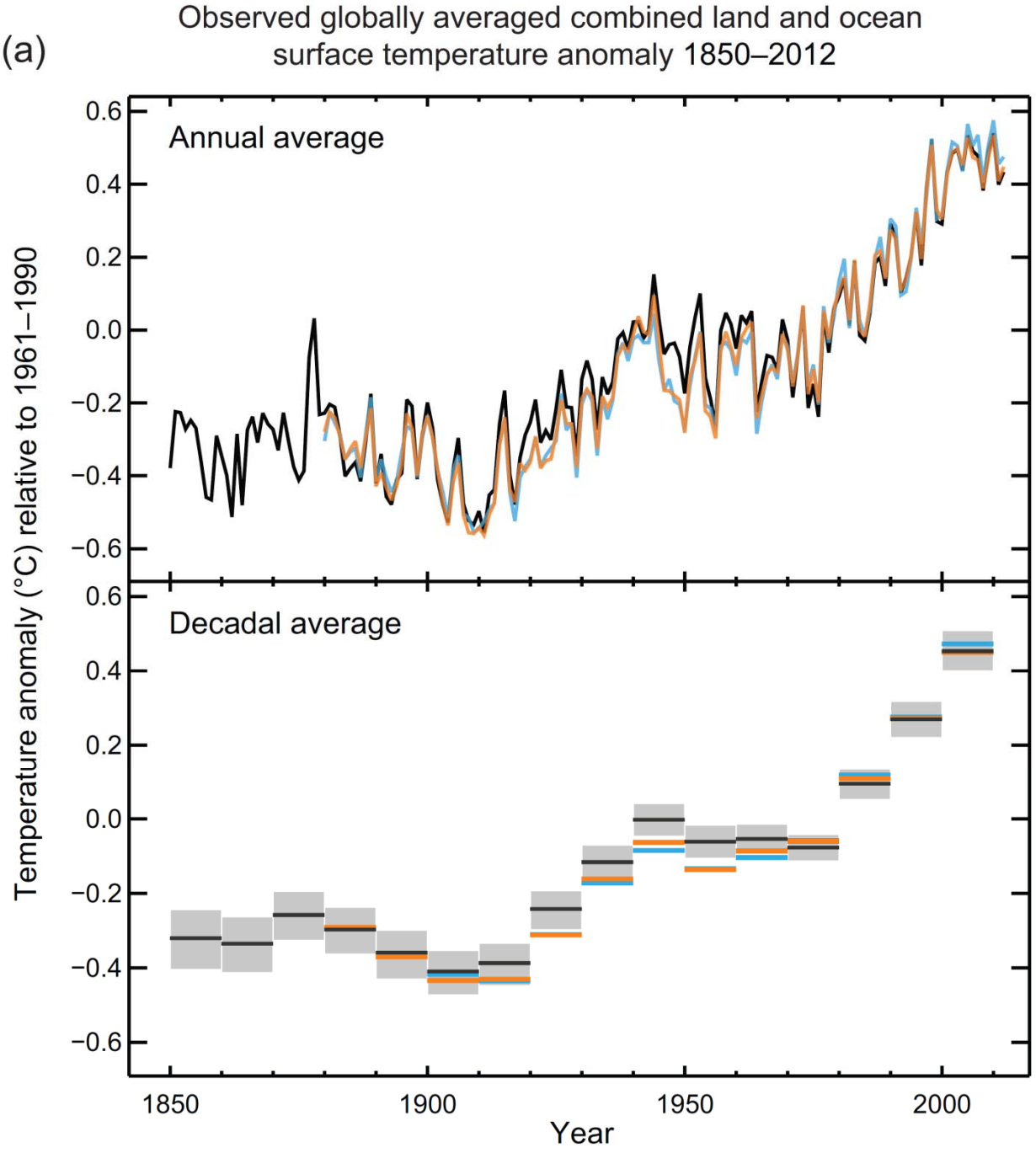
Impacts, Adaptation and Vulnerability



Mitigation of Climate Change

www.ipcc.ch
www.de-ipcc.de

DLR


(a)
Observed globally averaged combined land and ocean surface temperature anomaly 1850–2012
Annual average
Decadal average
Temperature anomaly (°C) relative to 1961–1990
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
1850
1900
1950
2000
Year

IPCC, 2013

Beobachtete Änderungen der Bodentemperatur 1901 - 2012

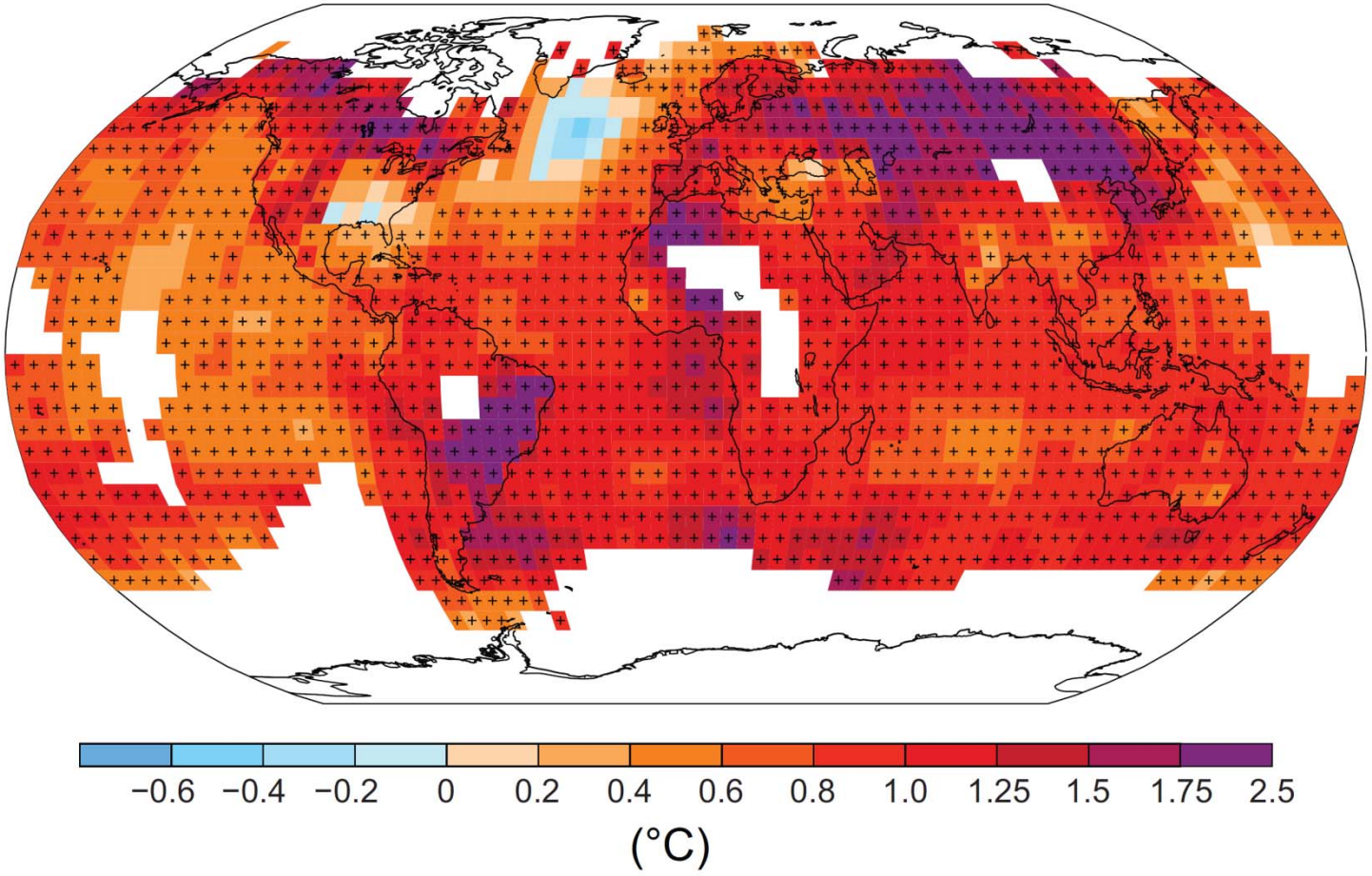
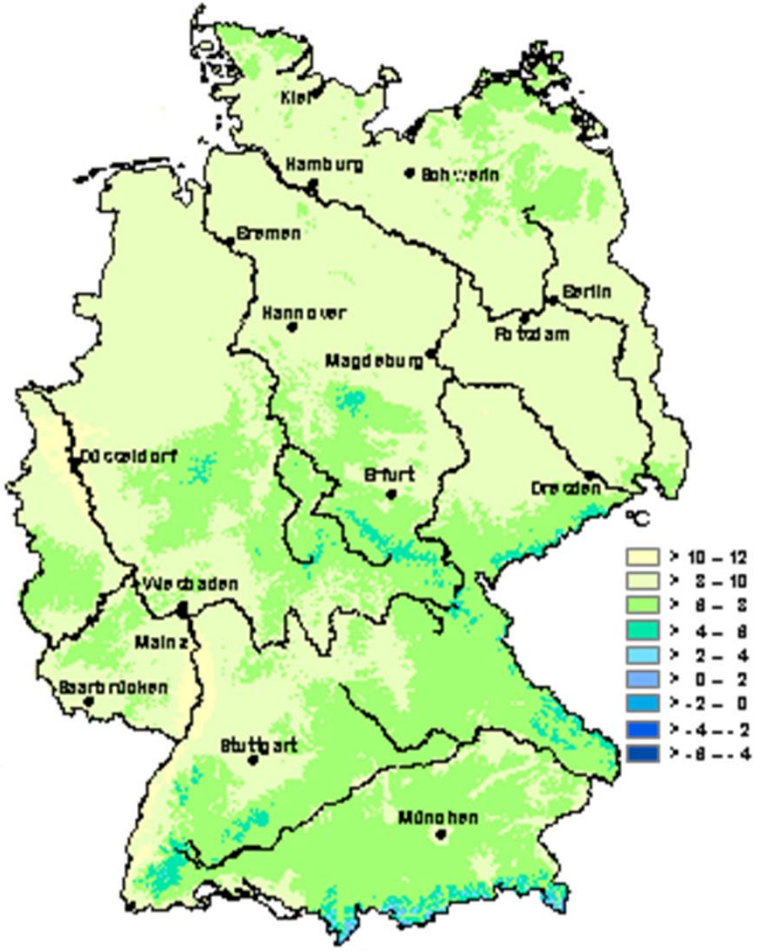


Figure SPM.1 | (a) Observed global mean combined land and ocean surface temperature anomalies, from 1850 to 2012 from three data sets. Top panel: annual mean values. Bottom panel: decadal mean values including the estimate of uncertainty for one dataset (black). Anomalies are relative to the mean of 1961–1990. (b) Map of the observed surface temperature change from 1901 to 2012 derived from temperature trends determined by linear regression from one dataset (orange line in panel a). Trends have been calculated where data availability permits a robust estimate (i.e., only for grid boxes with greater than 70% complete records and more than 20% data availability in the first and last 10% of the time period). Other areas are white. Grid boxes where the trend is significant at the 10% level are indicated by a + sign. For a listing of the datasets and further technical details see the Technical Summary Supplementary Material. {Figures 2.19–2.21; Figure TS.2}

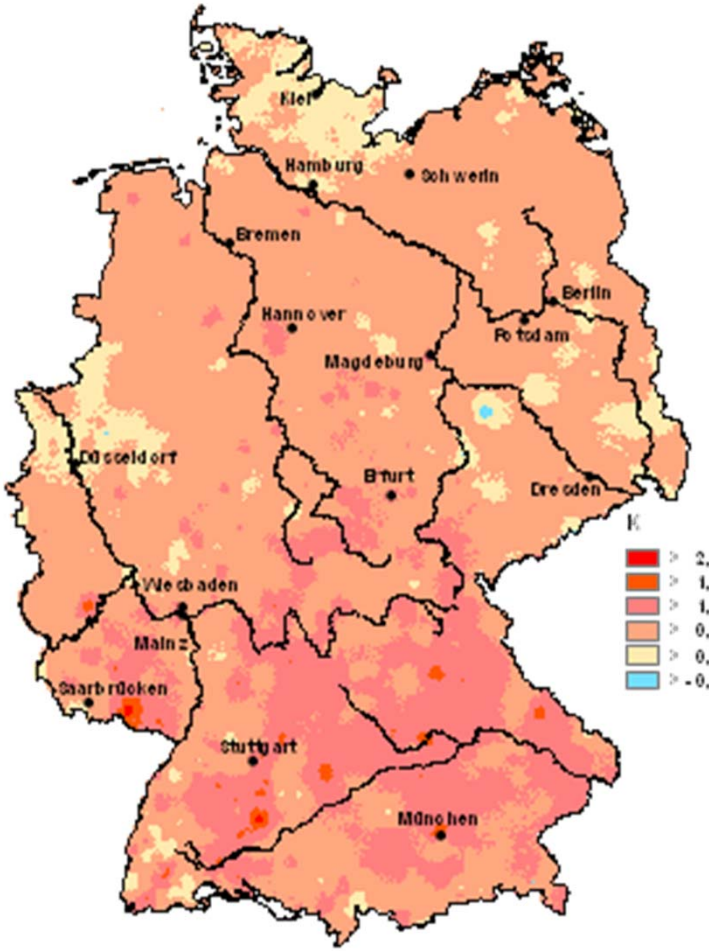
IPCC, 2013

Wie war die Temperaturänderung in den letzten Jahren in Deutschland?

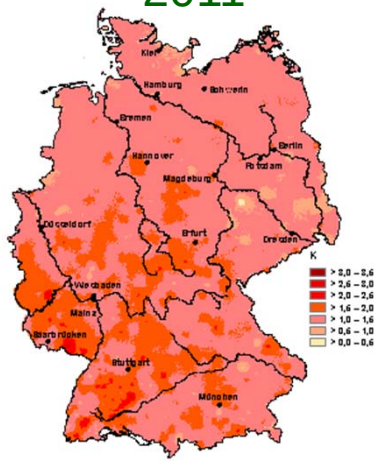
Mittelwerte (1961 - 1990)



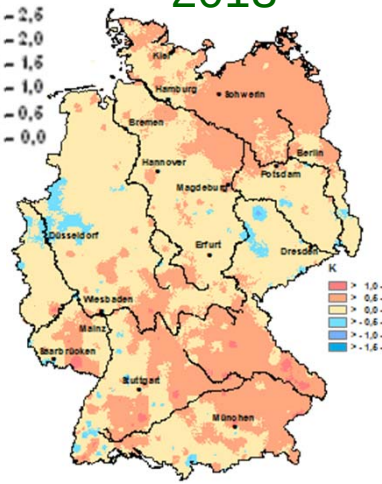
2012: Abweichung vom Mittelwert



2011



2013



Datenquelle: *DWD: Deutscher Klimaatlas*
http://www.dwd.de

Beobachtete Änderungen des Niederschlags über Land

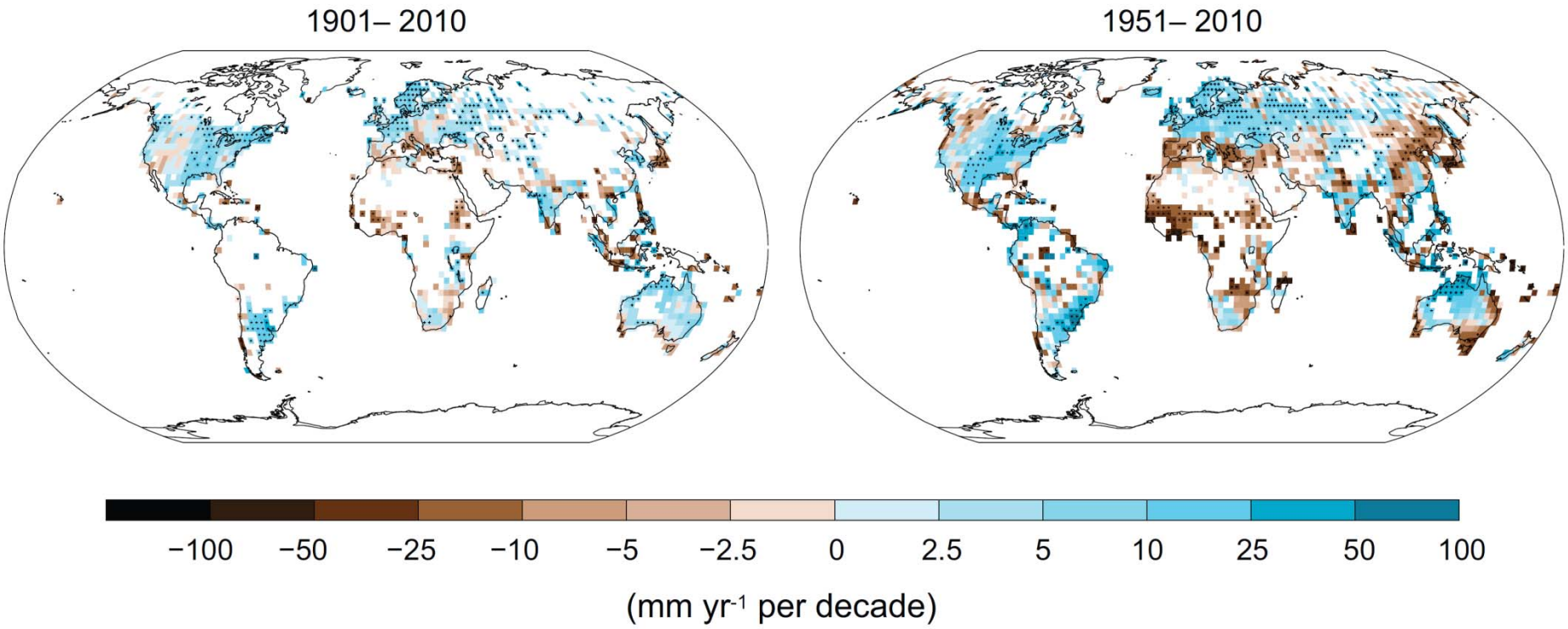


Figure SPM.2 | Maps of observed precipitation change from 1901 to 2010 and from 1951 to 2010 (trends in annual accumulation calculated using the same criteria as in Figure SPM.1) from one data set. For further technical details see the Technical Summary Supplementary Material. {TS TFE.1, Figure 2; Figure 2.29}

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Extreme Wetter- und Klima-Ereignisse

Table SPM.1 | Extreme weather and climate events: Global-scale assessment of recent observed changes, human contribution to the changes, and projected further changes for the early (2016–2035) and late (2081–2100) 21st century. Bold indicates where the AR5 (black) provides a revised* global-scale assessment from the SREX (blue) or AR4 (red). Projections for early 21st century were not provided in previous assessment reports. Projections in the AR5 are relative to the reference period of 1986–2005, and use the new Representative Concentration Pathway (RCP) scenarios (see Box SPM.1) unless otherwise specified. See the Glossary for definitions of extreme weather and climate events.

Phenomenon and direction of trend	Assessment that changes occurred (typically since 1950 unless otherwise indicated)	Assessment of a human contribution to observed changes	Likelihood of further changes	
			Early 21st century	Late 21st century
Warmer and/or fewer cold days and nights over most land areas	*Very likely* {2.6} *Very likely* *Very likely*	***Very likely*** {10.6} *Likely* *Likely*	*Likely* {11.3}	*Virtually certain* {12.4} *Virtually certain* *Virtually certain*
Warmer and/or more frequent hot days and nights over most land areas	*Very likely* {2.6} *Very likely* *Very likely*	***Very likely*** {10.6} *Likely* *Likely* (nights only)	*Likely* {11.3}	*Virtually certain* {12.4} *Virtually certain* *Virtually certain*
Warm spells/heat waves. Frequency and/or duration increases over most land areas	***Medium confidence*** on a global scale *Likely* in large parts of Europe, Asia and Australia {2.6} *Medium confidence* in many (but not all) regions *Likely*	***Likely***[a] {10.6} Not formally assessed *More likely than not*	Not formally assessed[b] {11.3}	*Very likely* {12.4} *Very likely* *Very likely*
Heavy precipitation events. Increase in the frequency, intensity, and/or amount of heavy precipitation	*Likely* more land areas with increases than decreases[c] {2.6} *Likely* more land areas with increases than decreases *Likely* over most land areas	***Medium confidence*** {7.6, 10.6} *Medium confidence* *More likely than not*	*Likely* over many land areas {11.3}	***Very likely*** over most of the mid-latitude land masses and over wet tropical regions {12.4} *Likely* over many areas *Very likely* over most land areas
Increases in intensity and/or duration of drought	***Low confidence*** on a global scale *Likely* changes in some regions[d] {2.6} *Medium confidence* in some regions *Likely* in many regions, since 1970[e]	***Low confidence*** {10.6} *Medium confidence*[f] *More likely than not*	*Low confidence*[g] {11.3}	***Likely*** *(medium confidence)* on a regional to global scale[h] {12.4} *Medium confidence* in some regions *Likely*[e]
Increases in intense tropical cyclone activity	***Low confidence*** in long term (centennial) changes *Virtually certain* in North Atlantic since 1970 {2.6} *Low confidence* *Likely* in some regions, since 1970	***Low confidence***[i] {10.6} *Low confidence* *More likely than not*	*Low confidence* {11.3}	***More likely than not*** in the Western North Pacific and North Atlantic[i] {14.6} *More likely than not* in some basins *Likely*
Increased incidence and/or magnitude of extreme high sea level	*Likely* (since 1970) {3.7} *Likely* (late 20th century) *Likely*	***Likely***[k] {3.7} *Likely*[k] *More likely than not*[k]	*Likely*[l] {13.7}	***Very likely***[l] {13.7} *Very likely*[m] *Likely*

Term*	Likelihood of the outcome
Virtually certain	99–100% probability
Very likely	90–100% probability
Likely	66–100% probability
About as likely as not	33–66% probability
Unlikely	0–33% probability
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Phänomen und Richtung des Trends	**Wahrscheinlichkeit, dass die Änderung eintrat (seit 1950)**	**V**
Wärmere und/oder häufigere heiße Tage und Nächste	90 - 100 %	
Starkniederschlags-Ereignisse, Zu-nahme von Häufig-keit und/oder Menge	66 - 100 % für Europa und Nordamerika	
Zunahme von inten-siven tropischen Zyklonen	66 - 100 % (99-100 % für Nordatlantik seit 1970)	

magnitude of extreme **high sea level**	*Likely* (late 20th century) *Likely*	*Likely*[k] *More likely than not*[k]		*Very likely*[m] *Likely*

Term*	**Likelihood of the outcome**
Virtually certain	99–100% probability
Very likely	90–100% probability
Likely	66–100% probability
About as likely as not	33–66% probability
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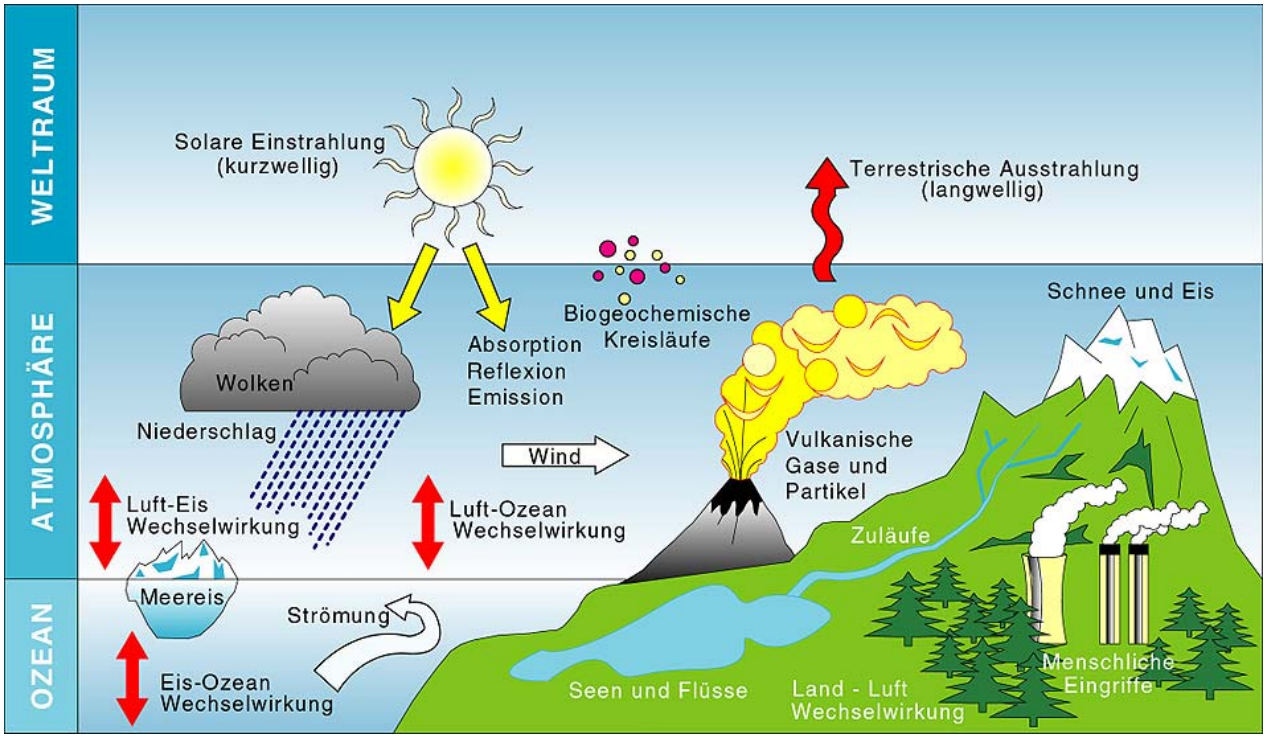
Fragen

- Hat sich das Klima geändert?
- Welchen Einfluss hat der Mensch?
- Wie wird sich das Klima in Zukunft entwickeln?
- Was wissen wir über zukünftige Extremereignisse, speziell Hochwasser?

Was bestimmt unser Klima?

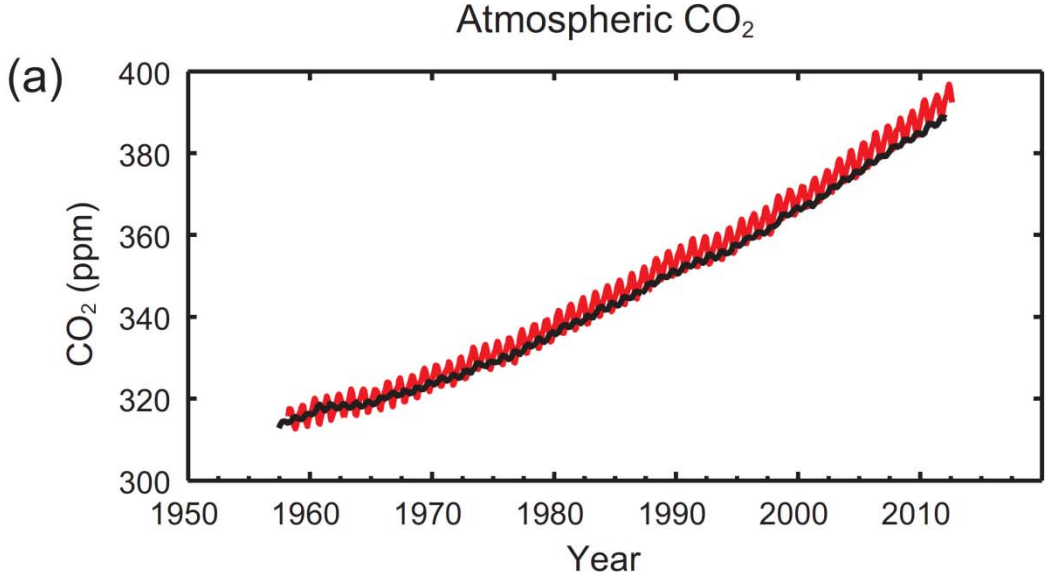
- Einstrahlung der Sonne
- Konzentrationen von Treibhausgasen (natürliche und anthropogene) und anderer strahlungsaktiver Substanzen
- Orographie, Land-See-Verteilung, Bodeneigenschaften
- . . .

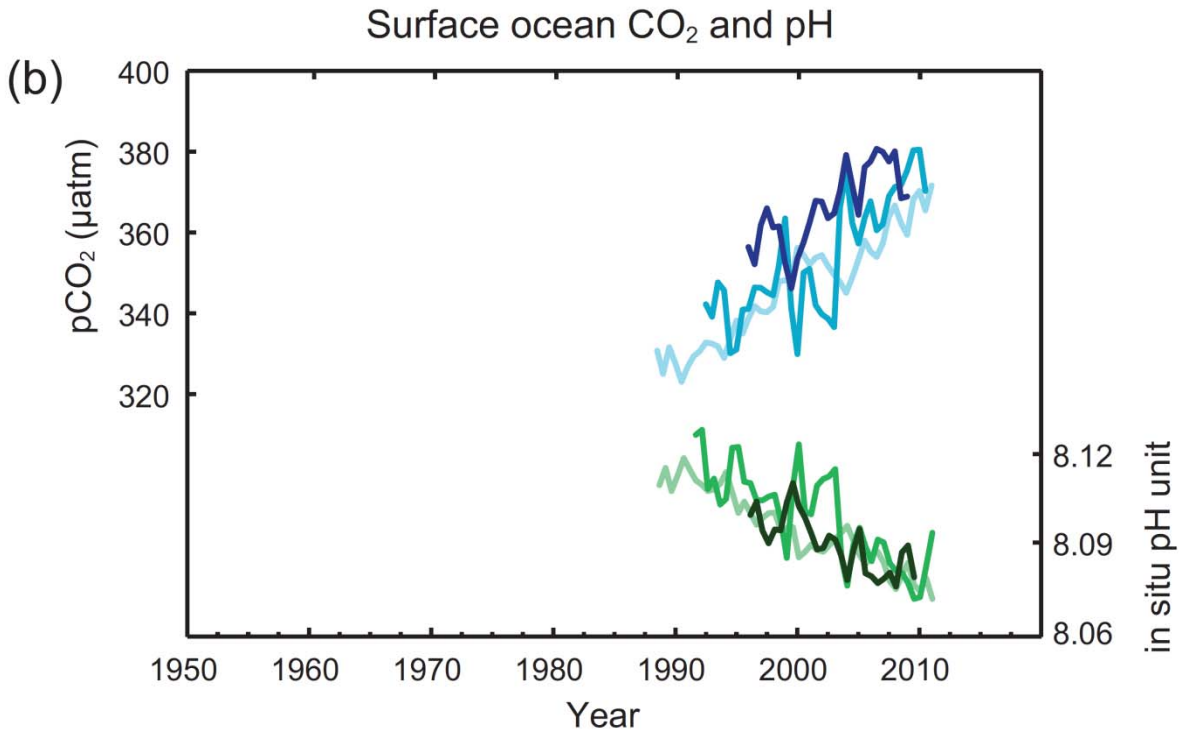


Der Treibhauseffekt

Erde ohne Atmosphäre: T_S = -15°C

Erde mit einfachem Glasdeckel: T_S = +15°C


Atmospheric CO_2
(a)
400
380
360
340
320
300
CO_2 (ppm)
1950
1960
1970
1980
1990
2000
2010
Year


Surface ocean CO_2 and pH
(b)
400
380
360
340
320
pCO_2 (µatm)
8.12
8.09
8.06
in situ pH unit
1950
1960
1970
1980
1990
2000
2010
Year

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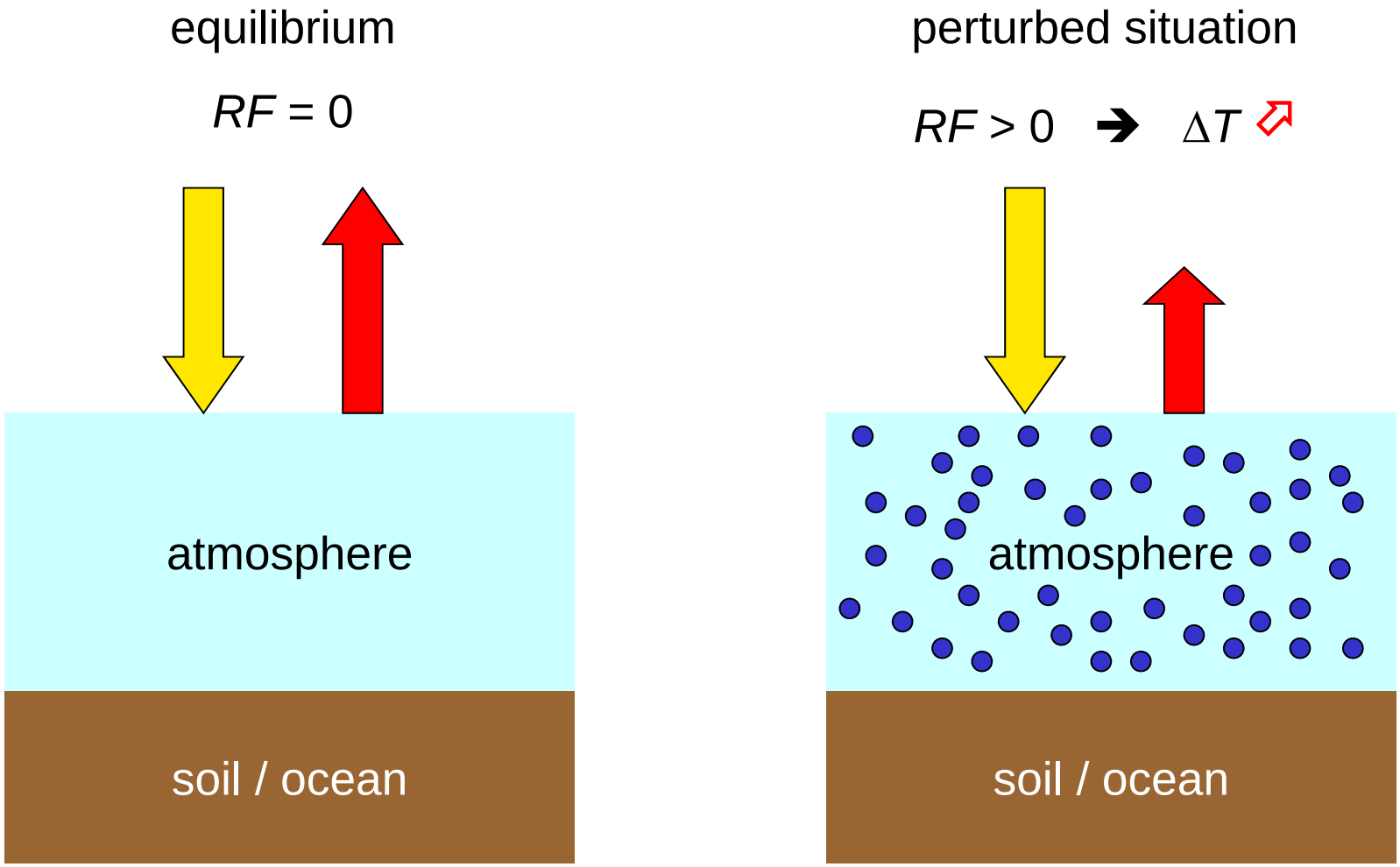
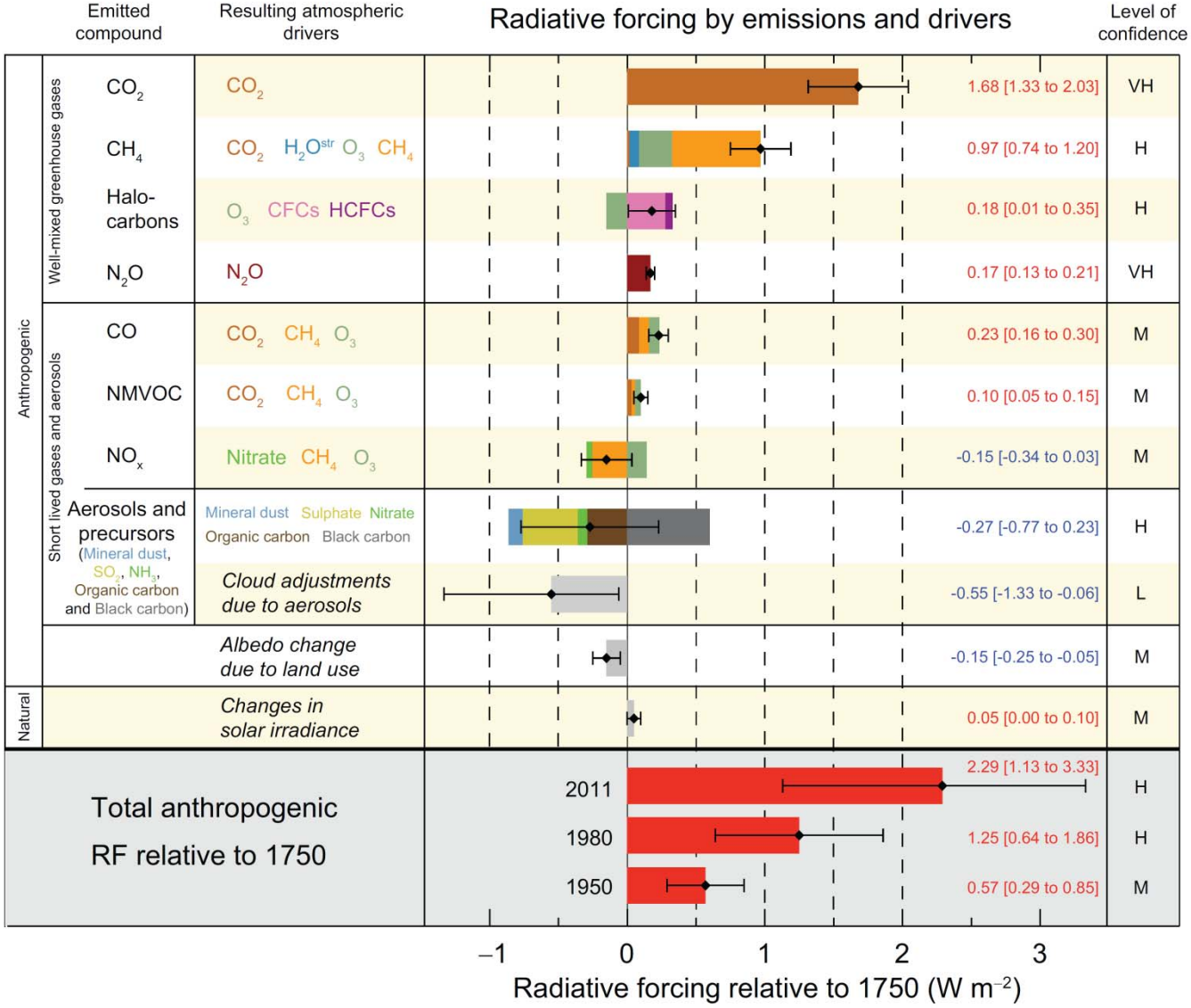
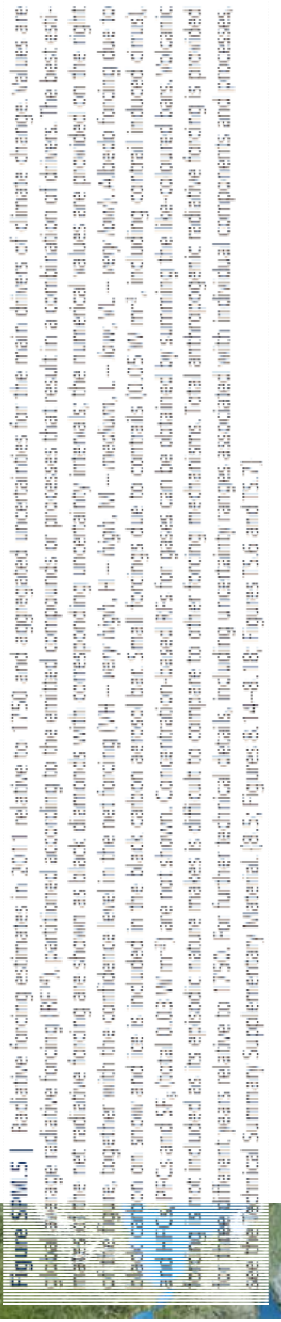
Was ist der "Strahlungsantrieb"? (vereinfacht)
What is "radiative forcing"? (simplified)



Strahlungsantrieb (radiative forcing, RF)





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$$\Delta T_{surf} = \lambda \cdot RF$$

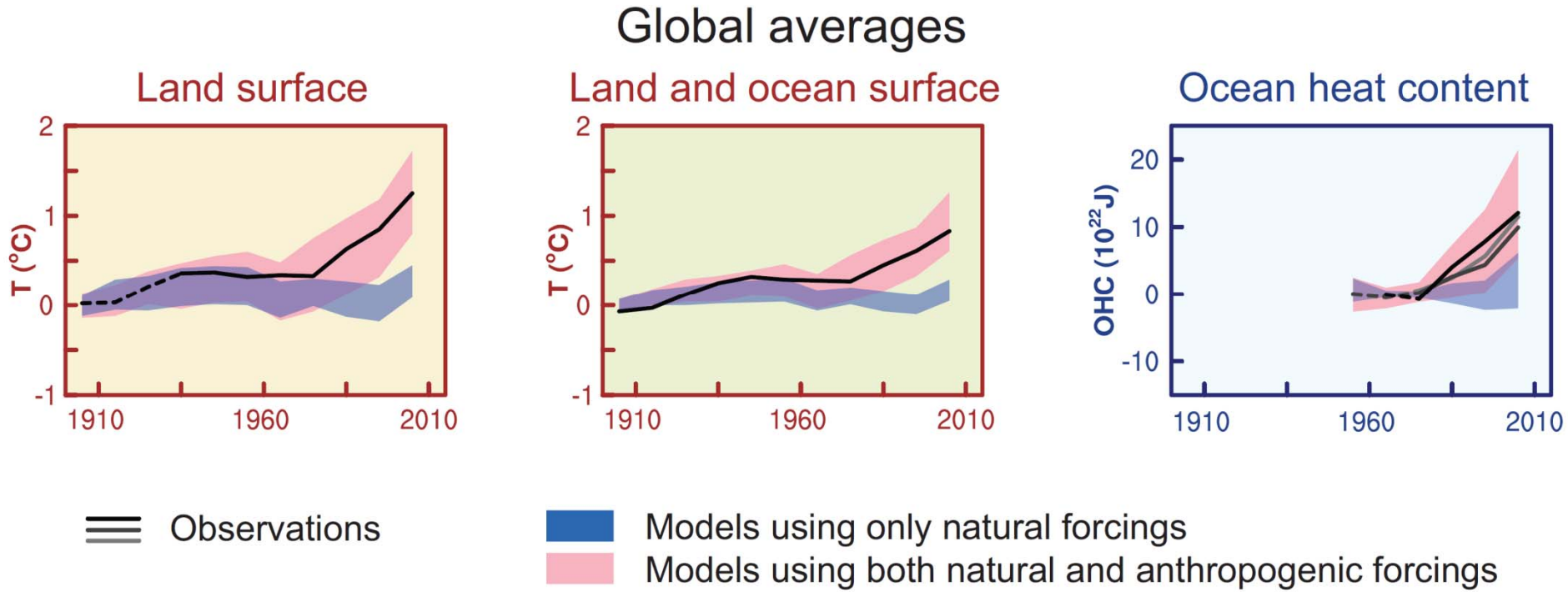

Figure SPM.6 | Comparison of observed and simulated climate change based on three large-scale indicators in the atmosphere, the cryosphere and the ocean: change in continental land surface air temperatures (yellow panels), Arctic and Antarctic September sea ice extent (white panels), and upper ocean heat content in the major ocean basins (blue panels). Global average changes are also given. Anomalies are given relative to 1880–1919 for surface temperatures, 1960–1980 for ocean heat content and 1979–1999 for sea ice. All time-series are decadal averages, plotted at the centre of the decade. For temperature panels, observations are dashed lines if the spatial coverage of areas being examined is below 50%. For ocean heat content and sea ice panels the solid line is where the coverage of data is good and higher in quality, and the dashed line is where the data coverage is only adequate, and thus, uncertainty is larger. Model results shown are Coupled Model Intercomparison Project Phase 5 (CMIP5) multi-model ensemble ranges, with shaded bands indicating the 5 to 95% confidence intervals. For further technical details, including region definitions see the Technical Summary Supplementary Material. {Figure 10.21; Figure TS.12}

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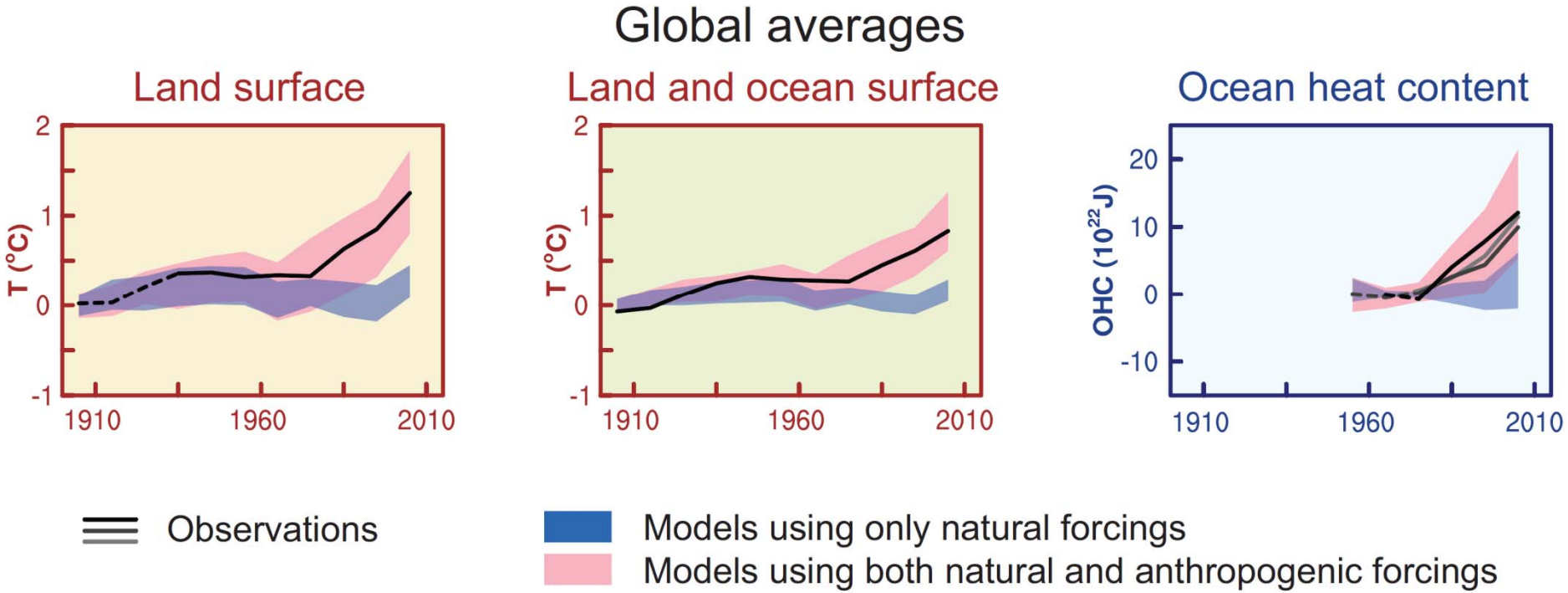

"Human influence has been detected in warming of the atmosphere and the ocean, in changes in the global water cycle, in reductions in snow and ice, in global mean sea level rise, and in changes in some climate extremes (see Figure SPM.6 and Table SPM.1). This evidence for human influence has grown since AR4. It is *extremely likely* that human influence has been the dominant cause of the observed warming since the mid-20th century. {10.3–10.6, 10.9}"

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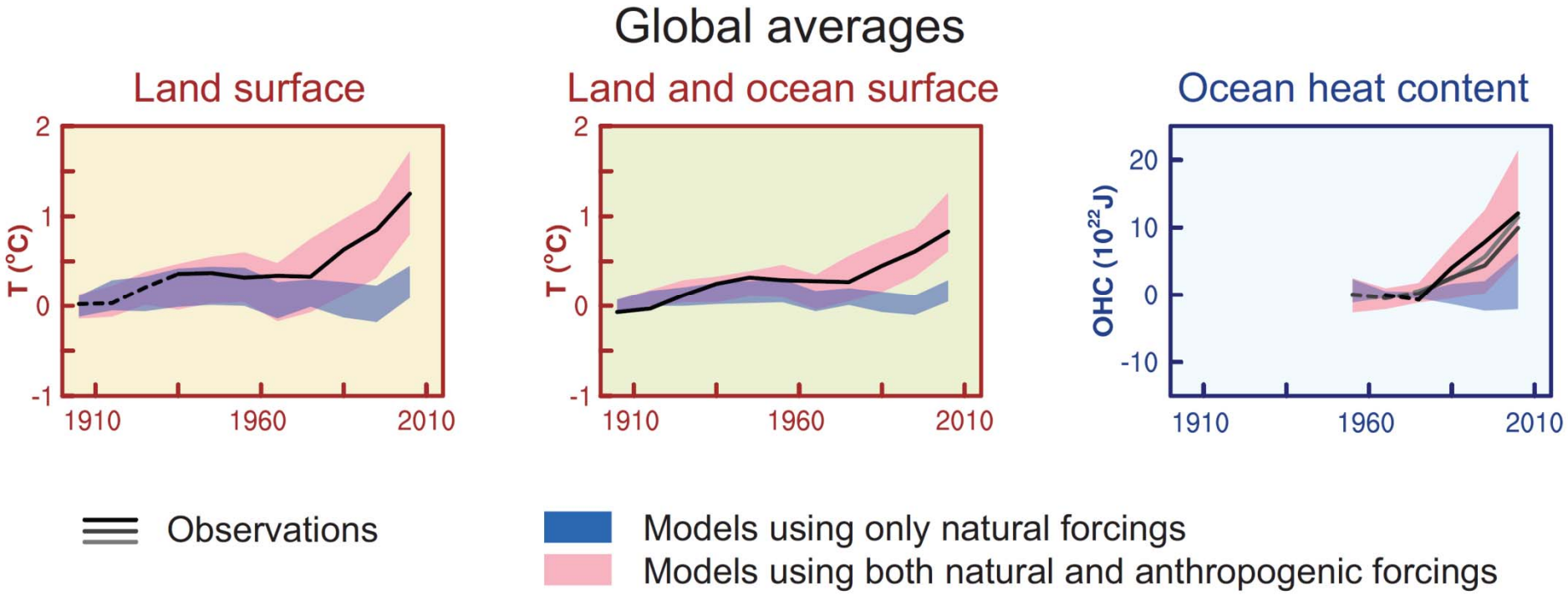

"Ein Einfluss des Menschen wurde nachgewiesen bei der Erwärmung von Atmosphäre und Ozean, bei den Änderungen des globalen Wasserkreislaufs, bei der Abnahme von Schnee und Eis, beim Anstieg des Meeresspiegels und bei Änderungen einiger Klima-Extreme. Der Nachweis eines Einfluss des Menschen konnte seit dem 4. Sachstandsbericht besser belegt werden. Es ist *extrem wahrscheinlich*, dass der Einfluss des Menschen die dominierende Ursache der beobachteten Erwärmung seit Mitte des 20. Jahrhunderts ist."

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Wärmere und/oder häufigere heiße Tage und Nächste	90 - 100 %	90 - 100 %
Starkniederschlags-Ereignisse, Zu-nahme von Häufig-keit und/oder Menge	66 - 100 % für Europa und Nordamerika	mittlere statist. Sicherheit
Zunahme von inten-siven tropischen Zyklonen	66 - 100 % (99-100 % für Nordatlantik seit 1970)	niedrige statist. Sicherheit

magnitude of extreme high sea level	*Likely* (late 20th century) *Likely*	*Likely*[k] *More likely than not*[k]		*Very likely*[m] *Likely*

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IPCC, 2013

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Was bestimmt die Güte von "Klimaprognosen"?

„Prognosen sind schwierig, besonders wenn sie die Zukunft betreffen.“

(zugeschrieben Karl Valentin, Mark Twain, Winston Churchill, Niels Bohr, Kurt Tucholsky u.a.)

Was bestimmt die Güte von "Klimaprognosen"? (2)

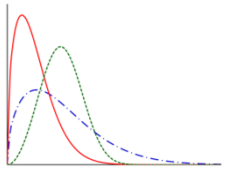
- Anfangsbedingungen
- Variabilität
- Qualität des Models

Wovon hängt eine "~~Klimaprognose~~ Klimaprojektion" ab?

- Anfangsbedingungen
  - wichtig für die erste Phase
  - Bedeutung nimmt mit der Zeit ab
- Variabilität
  - verhindert deterministische Prognosen über lange Zeiträume
- Qualität des Models
  - verursacht Fehler, der mit der Zeit wächst
- Externe Antriebe
  - angenommenes Szenario der Treibhausgas-Emissionen oder -Konzentrationen
  - dominieren auf lange Sicht

⇨ Deterministische Klimaprognosen sind nicht möglich.

⇨ Simulationen der Wahrscheinlichkeitsverteilungen (u.a. Mittelwerte, Varianzen, Extremwerte) als Funktion der Antriebe:
Szenarien-Simulationen oder Klimaprojektionen.



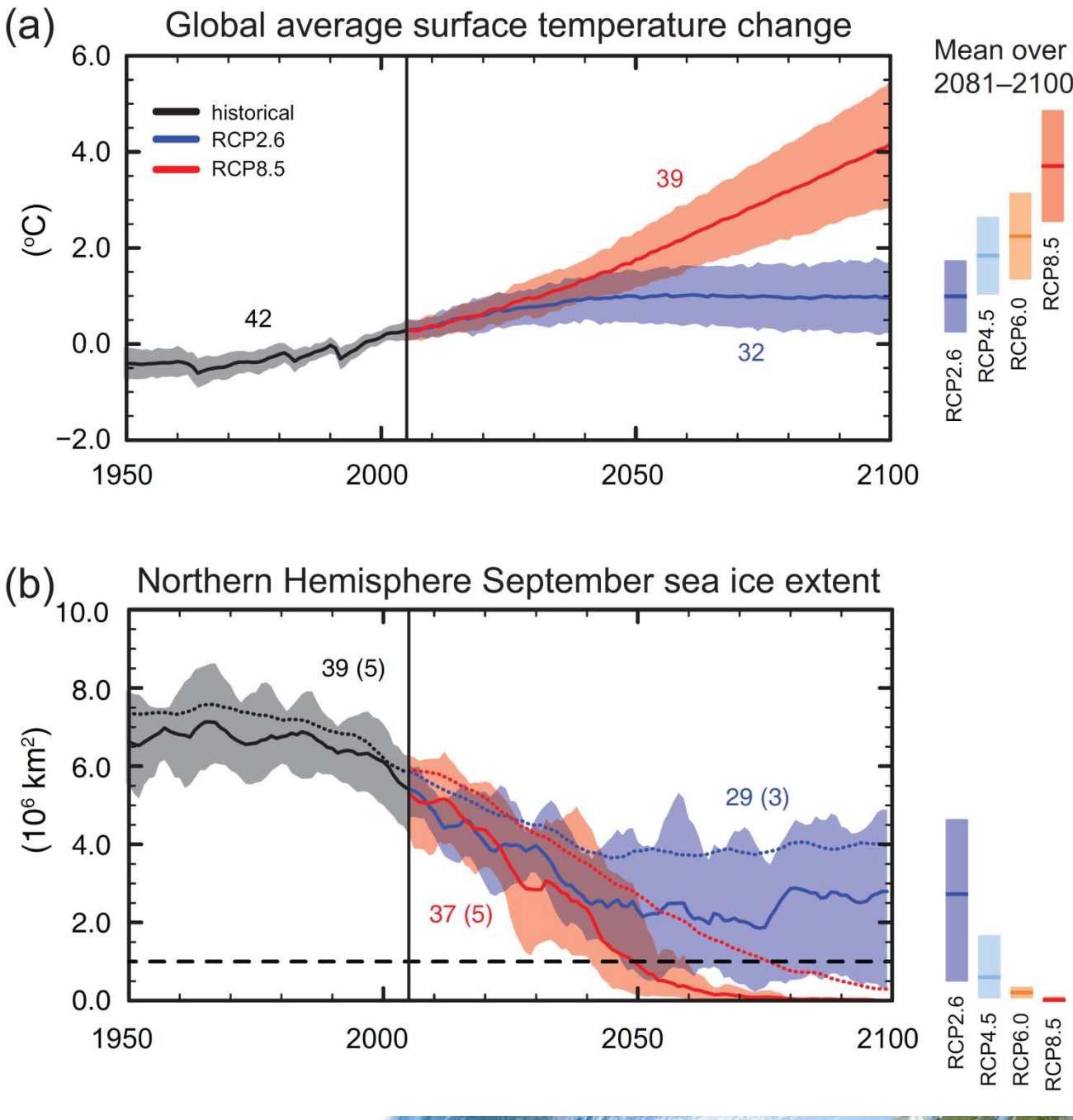


Figure SPM.7 | CMIP5 multi-model simulated time series from 1950 to 2100 for (a) change in global annual mean surface temperature relative to 1986–2005, (b) Northern Hemisphere September sea ice extent (5-year running mean), and (c) global mean ocean surface pH. Time series of projections and a measure of uncertainty (shading) are shown for scenarios RCP2.6 (blue) and RCP8.5 (red). Black (grey shading) is the modelled historical evolution using historical reconstructed forcings. The mean and associated uncertainties averaged over 2081–2100 are given for all RCP scenarios as coloured vertical bars. The numbers of CMIP5 models used to calculate the multi-model mean is indicated. For sea ice extent (b), the projected mean and uncertainty (minimum-maximum range) of the subset of models that most closely reproduce the climatological mean state and 1979 to 2012 trend of the Arctic sea ice is given (number of models given in brackets). For completeness, the CMIP5 multi-model mean is also indicated with dotted lines. The dashed line represents nearly ice-free conditions (i.e., when sea ice extent is less than 10^6 km^2 for at least the consecutive years). For further technical details see the Technical Summary Supplementary Material (Figures 6.28, 12.5, and 12.28–12.31; Figures TS.15, TS.17, and TS.20)

IPCC, 2013

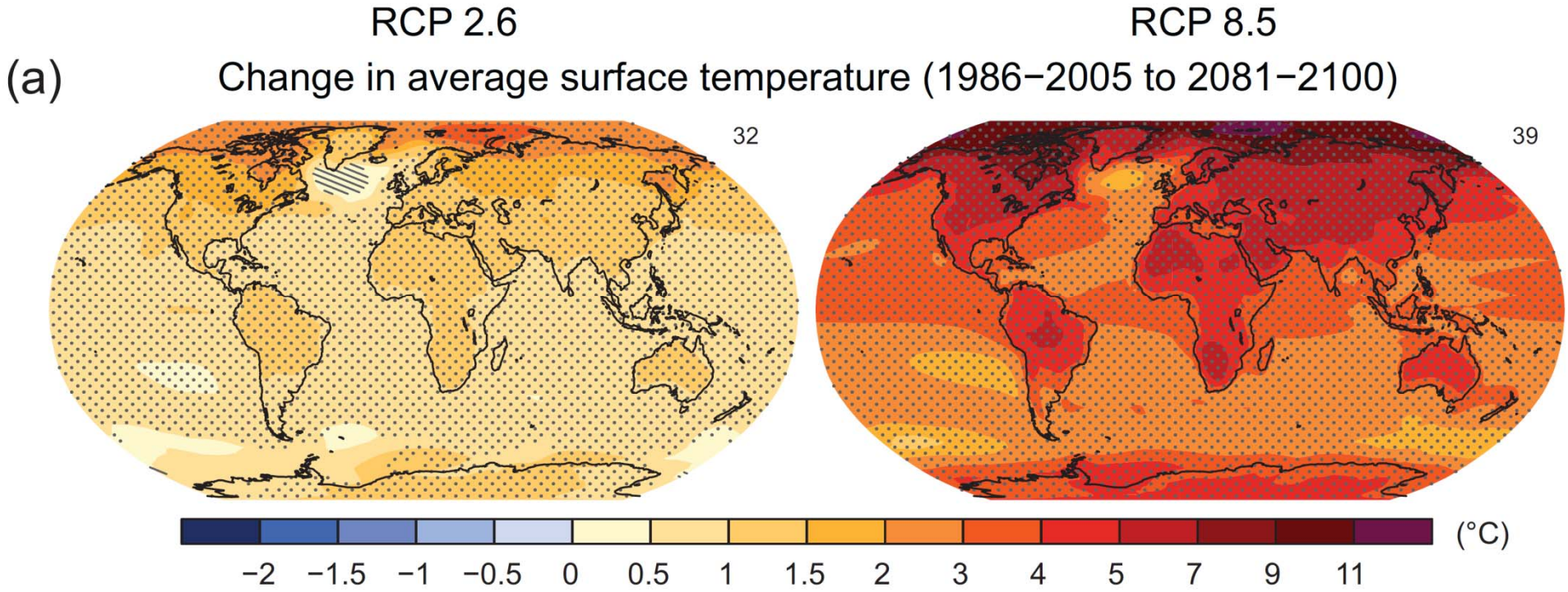


Figure SPM.8 | Maps of CMIP5 multi-model mean results for the scenarios RCP2.6 and RCP8.5 in 2081–2100 of (a) annual mean surface temperature change, (b) average percent change in annual mean precipitation, (c) Northern Hemisphere September sea ice extent, and (d) change in ocean surface pH. Changes in panels (a), (b) and (d) are shown relative to 1986–2005. The number of CMIP5 models used to calculate the multi-model mean is indicated in the upper right corner of each panel. For panels (a) and (b), hatching indicates regions where the multi-model mean is small compared to natural internal variability (i.e., less than one standard deviation of natural internal variability in 20-year means). Stippling indicates regions where the multi-model mean is large compared to natural internal variability (i.e., greater than two standard deviations of natural internal variability in 20-year means) and where at least 90% of models agree on the sign of change (see Box 12.1). In panel (c), the lines are the modelled means for 1986–2005; the filled areas are for the end of the century. The CMIP5 multi-model mean is given in white colour, the projected mean sea ice extent of a subset of models (number of models given in brackets) that most closely reproduce the climatological mean state and 1979 to 2012 trend of the Arctic sea ice extent is given in light blue colour. For further technical details see the Technical Summary Supplementary Material. {Figures 6.28, 12.11, 12.22, and 12.29; Figures TS.15, TS.16, TS.17, and TS.20}

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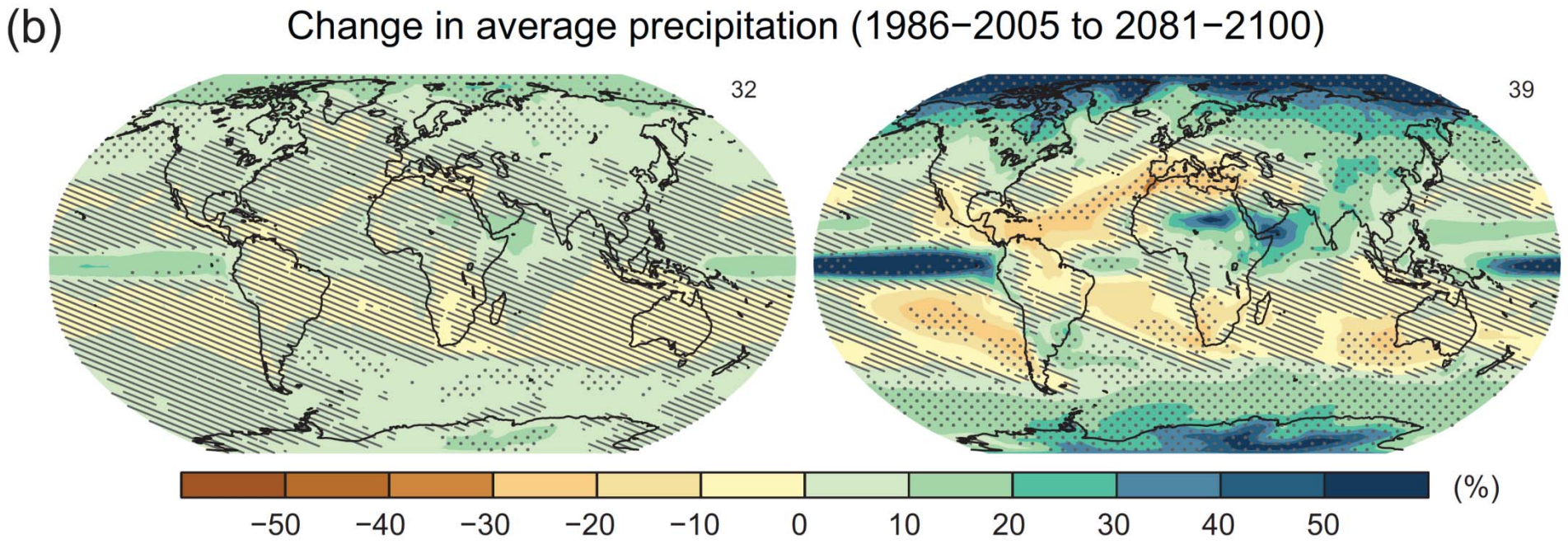

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Fragen

- Hat sich das Klima geändert?
- Welchen Einfluss hat der Mensch?
- Wie wird sich das Klima in Zukunft entwickeln?
- Was wissen wir über zukünftige Extremereignisse, speziell Hochwasser?

Extreme Wetter- und Klima-Ereignisse

Table SPM.1 | Extreme weather and climate events: Global-scale assessment of recent observed changes, human contribution to the changes, and projected further changes for the early (2016–2035) and late (2081–2100) 21st century. Bold indicates where the AR5 (black) provides a revised* global-scale assessment from the SREX (blue) or AR4 (red). Projections for early 21st century were not provided in previous assessment reports. Projections in the AR5 are relative to the reference period of 1986–2005, and use the new Representative Concentration Pathway (RCP) scenarios (see Box SPM.1) unless otherwise specified. See the Glossary for definitions of extreme weather and climate events.

Phänomen und Richtung des Trends	**Wahrscheinlichkeit, dass die Änderung eintrat (seit 1950)**	**Wahrschein. für Beitrag des Menschen**	**Weit. Änder. frühes 21. Jahrhundert**	**Weit. Änder. spätes 21. Jahrhundert**
Wärmere und/oder häufigere heiße Tage und Nächste	90 - 100 %	90 - 100 %	66 - 100 %	99 - 100 %
Starkniederschlags-Ereignisse, Zu-nahme von Häufig-keit und/oder Menge	66 - 100 % für Europa und Nordamerika	mittlere statist. Sicherheit	66 - 100 %	90 - 100 %
Zunahme von inten-siven tropischen Zyklonen	66 - 100 % (99-100 % für Nordatlantik seit 1970)	niedrige statist. Sicherheit	niedrige statist. Sicherheit	50 - 100% (Nordatlantik, w. Nordpazifik)
magnitude of extreme high sea level	*Likely* (late 20th century) *Likely*	*Likely*[k] *More likely than not*[k]		*Very likely*[m] *Likely*

Term*	Likelihood of the outcome
Virtually certain	99–100% probability
Very likely	90–100% probability
Likely	66–100% probability
About as likely as not	33–66% probability
Unlikely	0–33% probability
Very unlikely	0–10% probability
Exceptionally unlikely	0–1% probability

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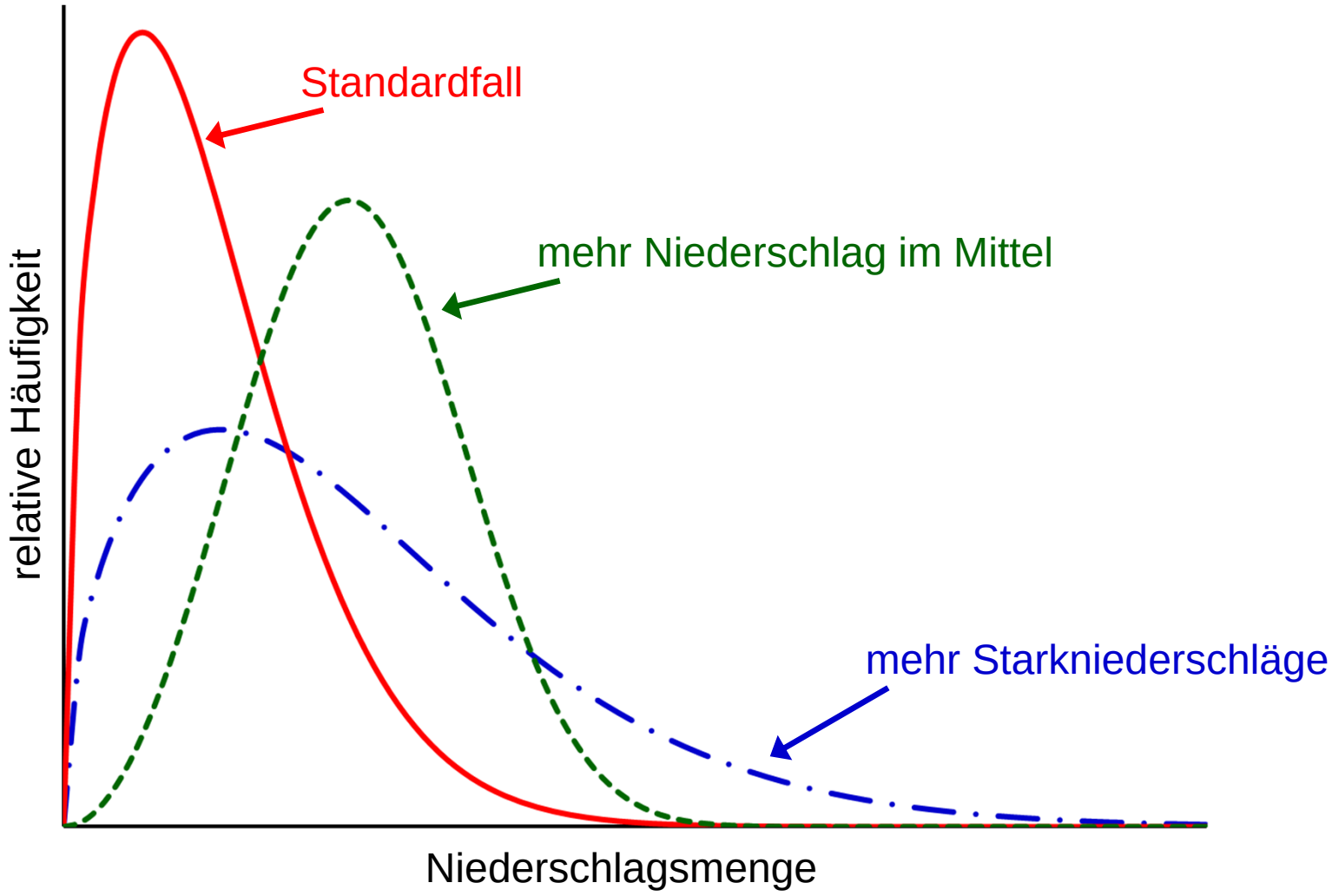
Veränderung der Wahrscheinlichkeitsdichte durch eine Klima-Änderung

(schematische Darstellung)



Was ist Hochwasser-Risiko?

soll verringert werden

Risiko = **Eintritts-Wahrscheinlichkeit** x **Schadenshöhe**

- kleinerer anthropog. Strahlungsantrieb, d.h. geringere Emissionen (Mitigation)
- Eintrittswahrscheinlich kann nur indirekt beeinflusst werden

- Anpassung an den Klimawandel (Adaptation)
- Schutzmaßnahmen (Rückhaltebecken, Deiche etc.)
- Hochwasser gefährdete Gebiete meiden

Schlussbemerkungen

- Das Klima ändert sich; es wird wärmer.
- Der größte Teil des rezenten Klimawandels ist durch den Mensch verursacht.
- Die Erwärmung wird zunehmen, der hydrologische Zyklus wird intensiver.
- Wahrscheinlich werden Starkniederschlagsereignisse in Europa zunehmen.
- Risiko ist das Produkt aus Eintrittswahrscheinlichkeit und Höhe des potentiellen Schadens.
  - Die Eintrittswahrscheinlichkeit kann nur indirekt durch Klimaschutzmaßnahmen beeinflusst werden.
  - Die Höhe es potentiellen Schadens kann durch Anpassungsmaßnahmen verringert werden.