Climatology of High Impact Weather

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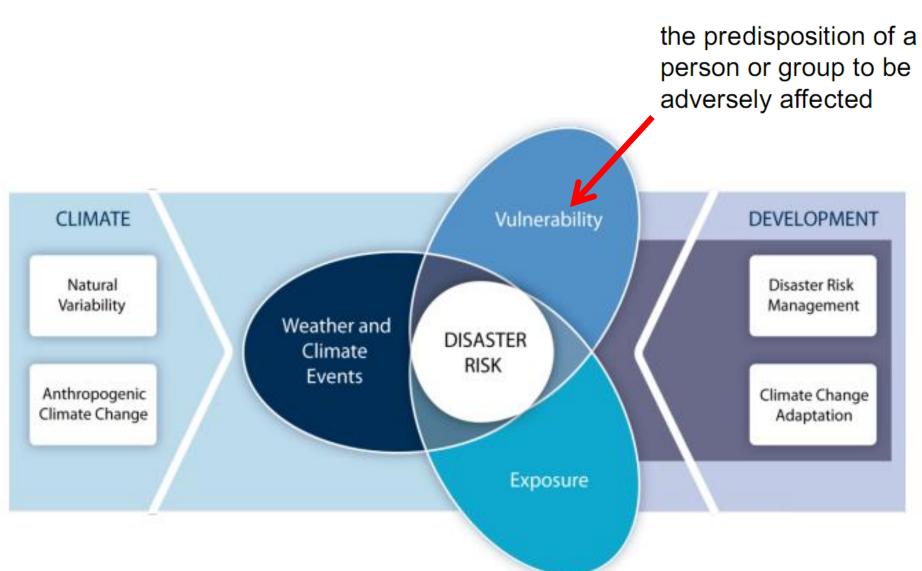




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- A changing climate leads to changes in
 - 1) extreme weather events
 - 2) extreme climate events
- Impacts from weather and climate events depend on
 - 1) nature and severity of event
 - 2) vulnerability
 - 3) exposure
- Socioeconomic development interacts with natural climate variations and human-caused climate change to influence disaster risk
- Increasing (1) vulnerability, (2) exposure, or (3) severity and frequency of climate events increases disaster risk
- For **exposed** and **vulnerable** communities, even **non-extreme** weather and climate events can have **extreme** impacts

IPCC (2012) Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation



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Disasters ranked according to reported (a) deaths and (b) economic losses, globally (1970–2012). TC indicates disasters caused by tropical cyclones.

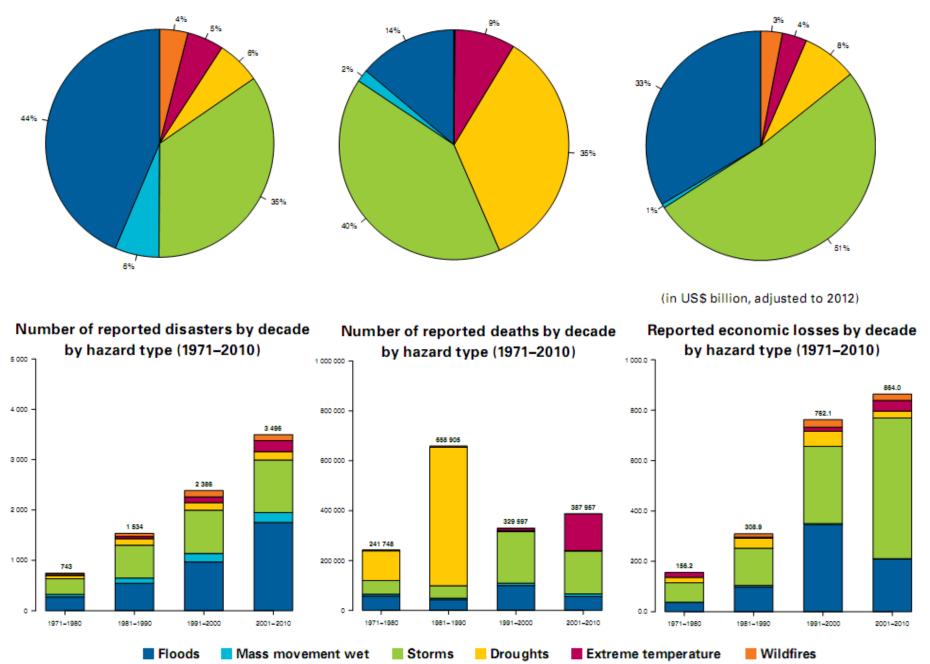
(a)	Disaster type	Year	Country	Number of deaths
1	Drought	1983	Ethiopia	300 000
2	Storm (TC ^a)	1970	Bangladesh	300 000
3	Drought	1984	Sudan	150 000
4	Storm (TC ^b)	1991	Bangladesh	138 866
5	Storm (Nargis)	2008	Myanmar	138 366
6	Drought	1975	Ethiopia	100 000
7	Drought	1983	Mozambique	100 000
8	Extreme temperature	2010	Russian Federation	55 736
9	Flood	1999	Venezuela, Bolivarian Republic of	30 000
10	Flood	1974	Bangladesh	28 700
(b)	Disaster type	Year	Country	Economic losses (in US\$ billion)
(b) 1	Disaster type Storm (<i>Katrina</i>)	Year 2005	Country United States	
				(in US\$ billion)
1	Storm (Katrina)	2005	United States	(in US\$ billion) 146.89
1 2	Storm (<i>Katrina</i>) Storm (<i>Sandy</i>)	2005 2012	United States United States	(in US\$ billion) 146.89 50.00
1 2 3	Storm (<i>Katrina</i>) Storm (<i>Sandy</i>) Storm (<i>Andrew</i>)	2005 2012 1992	United States United States United States	(in US\$ billion) 146.89 50.00 43.37
1 2 3 4	Storm (<i>Katrina</i>) Storm (<i>Sandy</i>) Storm (<i>Andrew</i>) Flood	2005 2012 1992 1998	United States United States United States China	(in US\$ billion) 146.89 50.00 43.37 42.25
1 2 3 4 5	Storm (<i>Katrina</i>) Storm (<i>Sandy</i>) Storm (<i>Andrew</i>) Flood Flood	2005 2012 1992 1998 2011	United States United States United States China Thailand	(in US\$ billion) 146.89 50.00 43.37 42.25 40.82
1 2 3 4 5 6	Storm (<i>Katrina</i>) Storm (<i>Sandy</i>) Storm (<i>Andrew</i>) Flood Flood Storm (<i>Ike</i>)	2005 2012 1992 1998 2011 2008	United States United States United States China Thailand United States	(in US\$ billion) 146.89 50.00 43.37 42.25 40.82 31.98
1 2 3 4 5 6 7	Storm (<i>Katrina</i>) Storm (<i>Sandy</i>) Storm (<i>Andrew</i>) Flood Flood Storm (<i>Ike</i>) Flood	2005 2012 1992 1998 2011 2008 1995	United States United States United States China Thailand United States Democratic People's Republic of Korea	(in US\$ billion) 146.89 50.00 43.37 42.25 40.82 31.98 22.59

WMO (2014) Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes (1970–2012)

Total = 8 835 disasters (1970-2012)

Total = 1 944 653 deaths (1970-2012)

4/29 Total = US\$ 2 390.7 billion (1970–2012)



5/29 Africa Europe Total = US\$ 375.7 billion (1970-2012) Total = 149 959 deaths (1970-2012) Total = US\$ 26.6 billion (1970-2012) 2% 1% 295¹⁹⁶, 395 19% 42% 40%

(in US\$ billion, adjusted to 2012)

36%

Reported economic losses by decade by hazard type (1971-2010)

8.0 6.3 6.0 4.0 20 -0.0 -1971-1980 1981-1990 1991-2000 2001-2010

(in US\$ billion, adjusted to 2012)

by hazard type (1971-2010) 1 000 000 10.0 -800 000 600 000 554 951 400 000 200 000

1981-1990

10 194

1991-2000

120 7 05

1971-1980

Number of reported deaths by decade

040

Total = 698 380 deaths (1970-2012)

1% 3%

Floods

10 595

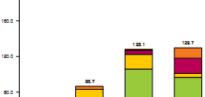
2001-2010

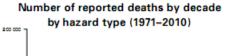
Mass movement wet Storms Droughts

Extreme temperature

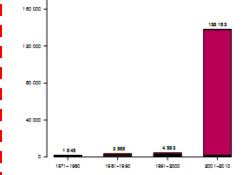
Wildfires

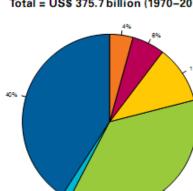
1971-1980





949





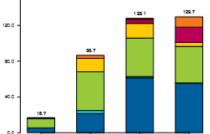
(in US\$ billion, adjusted to 2012)

2%

200.0

37%

Reported economic losses by decade by hazard type (1971-2010)

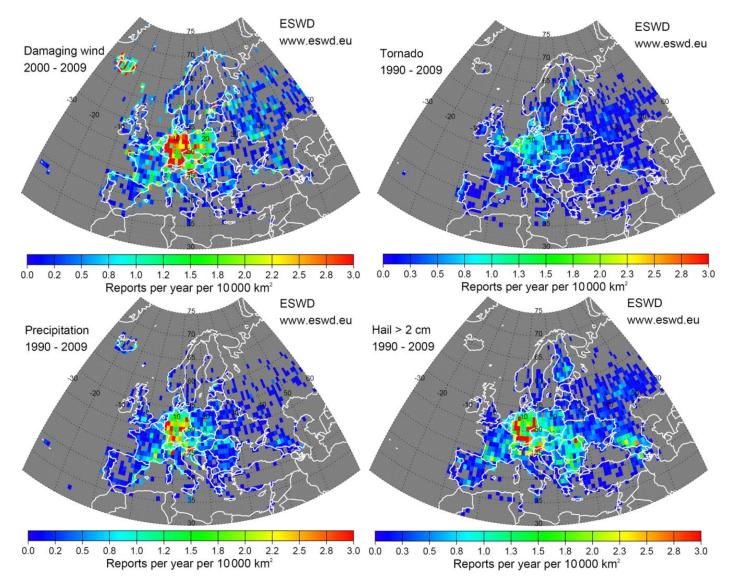


(in US\$ billion, adjusted to 2012)

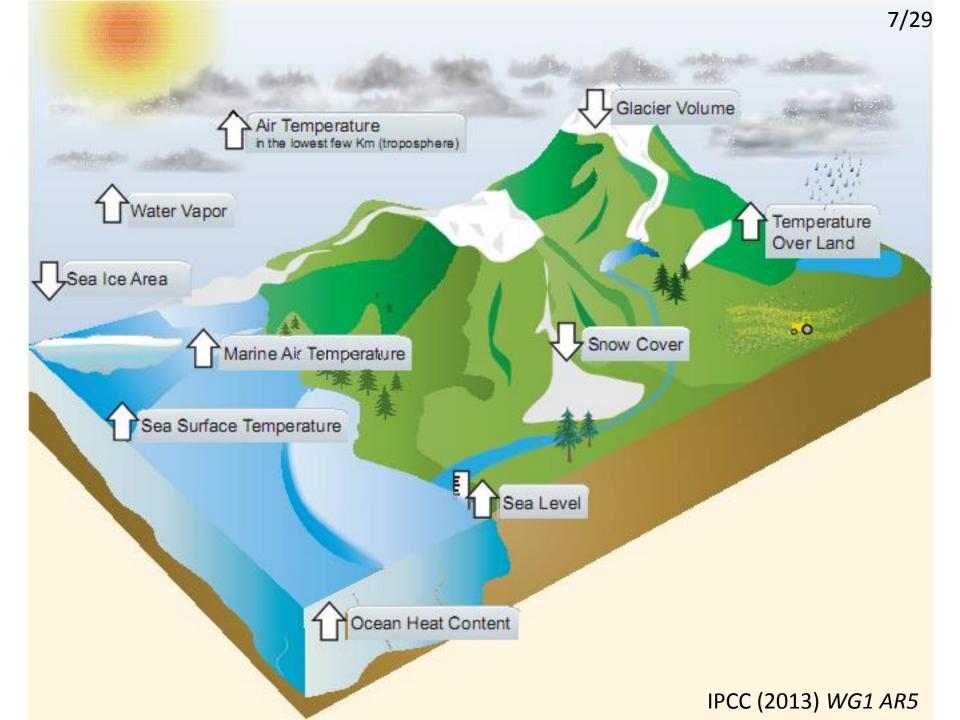
1991-2000

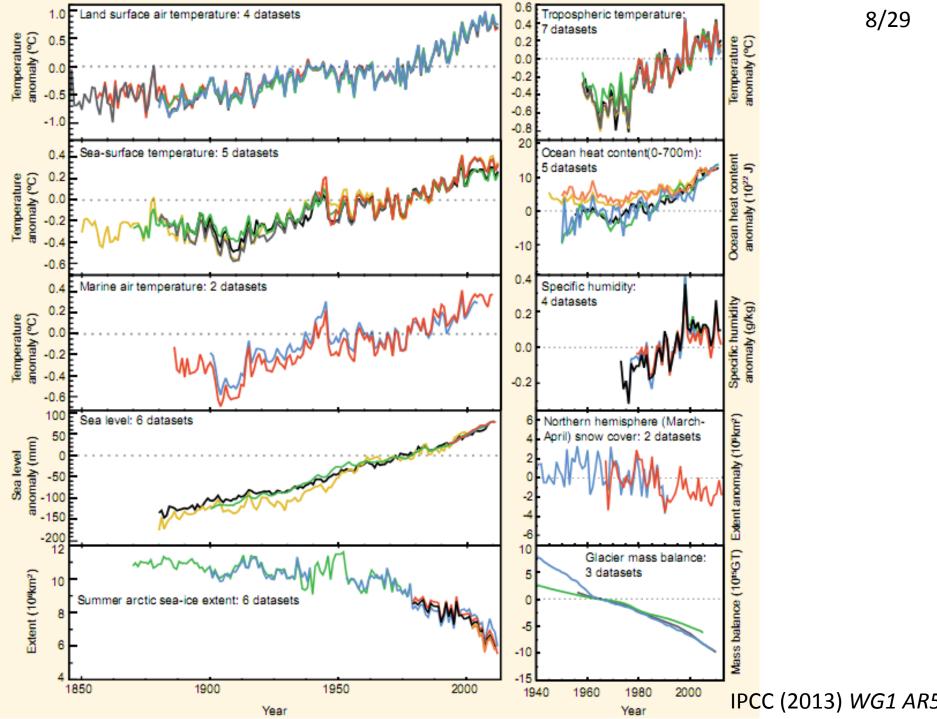
2001-2010

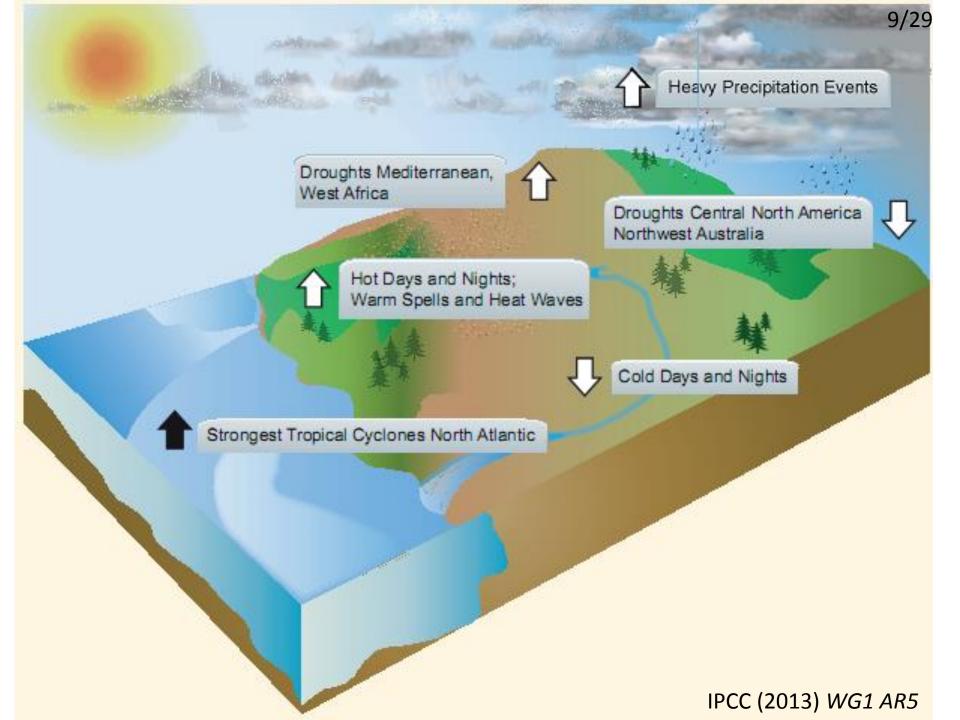
1981-1990



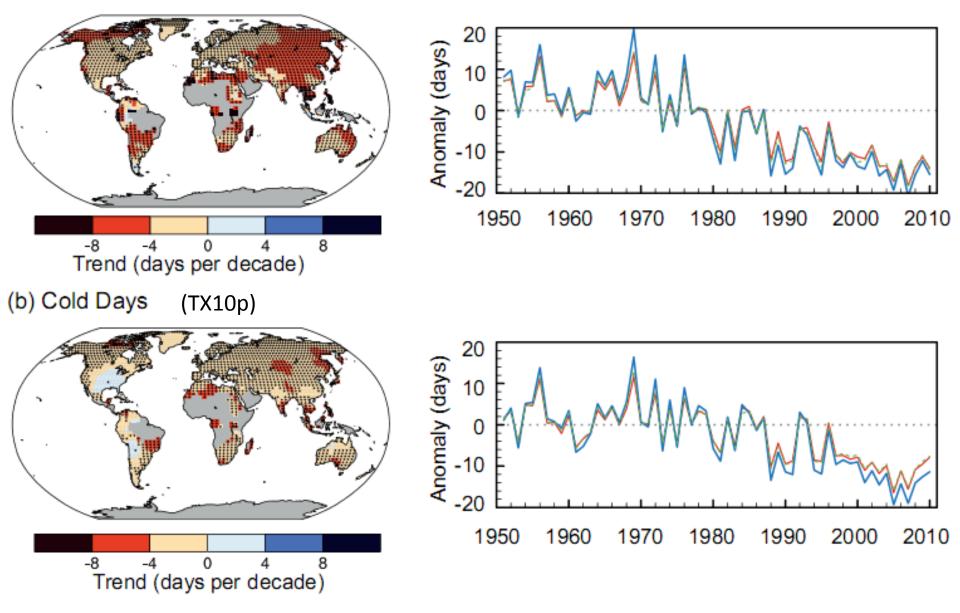
Overview of the damaging wind gusts \geq 25 m/s (a) and tornado (b), heavy precipitation (c) and hail diameter \geq 2 cm (d) in Europe in the period 1990–2009, except for damaging wind in the period 2000–2009 (prepared by Aloise Holzer; European Severe Weather Database).







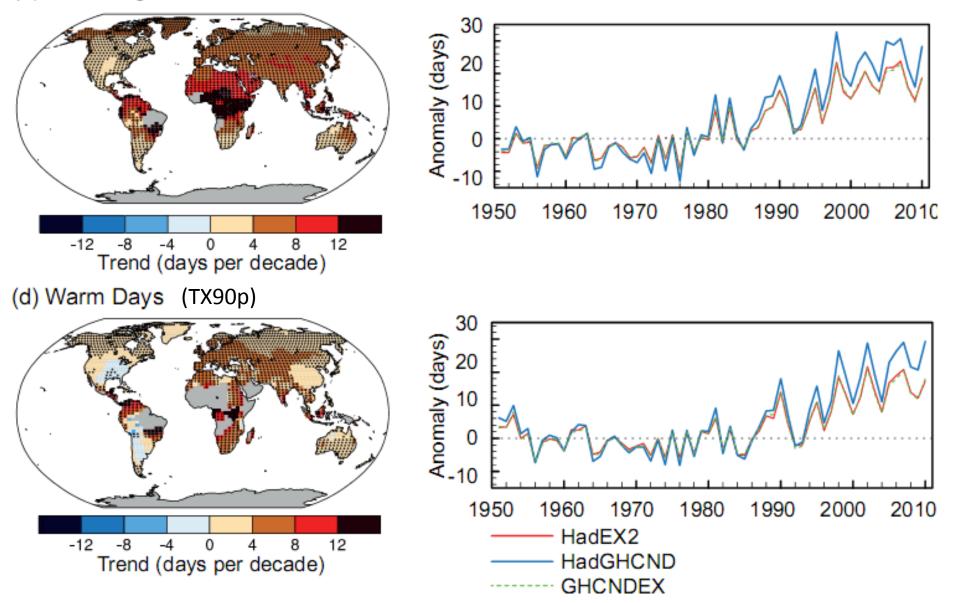
(a) Cold Nights (TN10p)



Period: 1951-2010

Fig. 2.32 from IPCC (2013) *WG1 AR5*

(c) Warm Nights (TX10p)



Period: 1951-2010

Fig. 2.32 from IPCC (2013) *WG1 AR5*

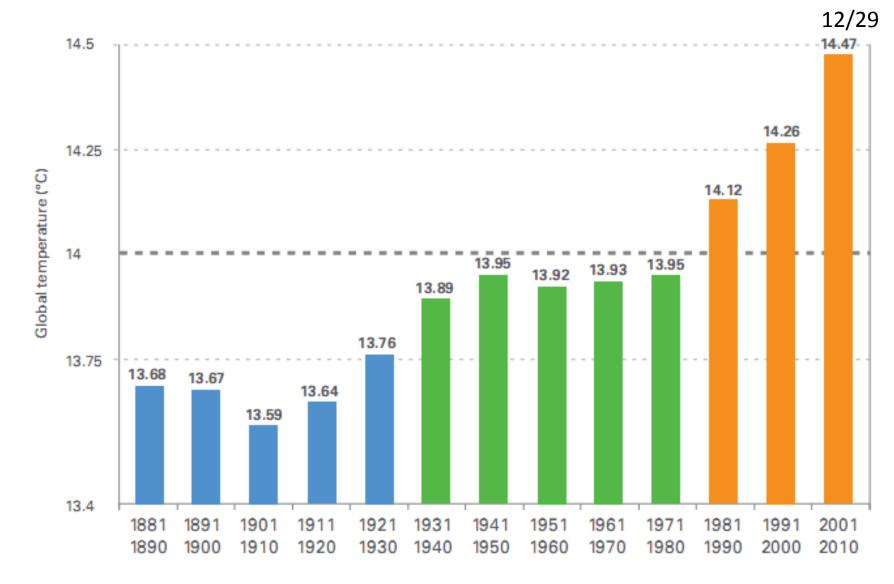
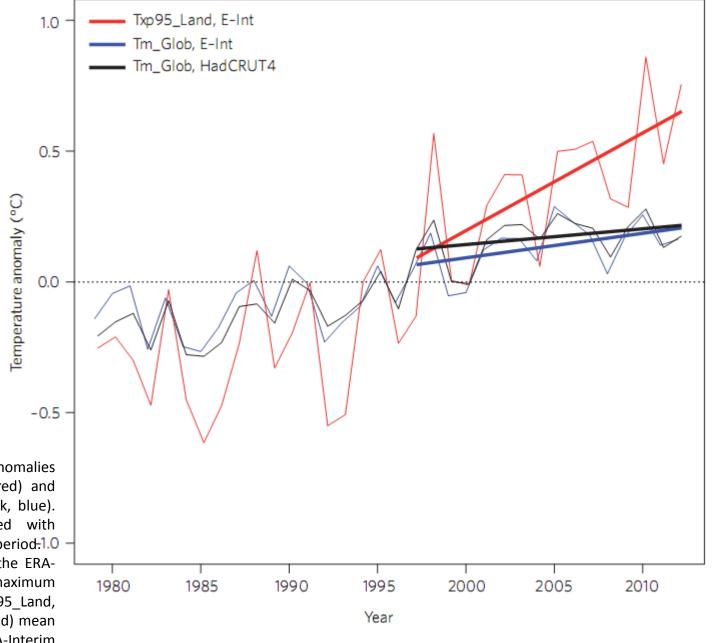


Fig. 1 Decadal global combined surface-air temperature over land and sea-surface temperature (°C) obtained from the average over the three independent datasets maintained by HadCRU, NOAA-NCDC and NASA-GISS. The horizontal grey line indicates the long-term average value (14.0°C) computed based on the 1961–1990 base period.



Time series of temperature anomalies for hot extremes over land (red) and global mean temperature (black, blue). The anomalies are computed with respect to the 1979–2010 time period-1.0 – The time series are based on the ERA-Interim 95th percentile of the maximum temperature over land (Txp95_Land, red) and the global (ocean + land) mean temperature (Tm_Glob) in ERA-Interim (blue) and HadCRUT4 (black).

Fig. 2 from Seneviratne et al. (2014) Nature Climate Change

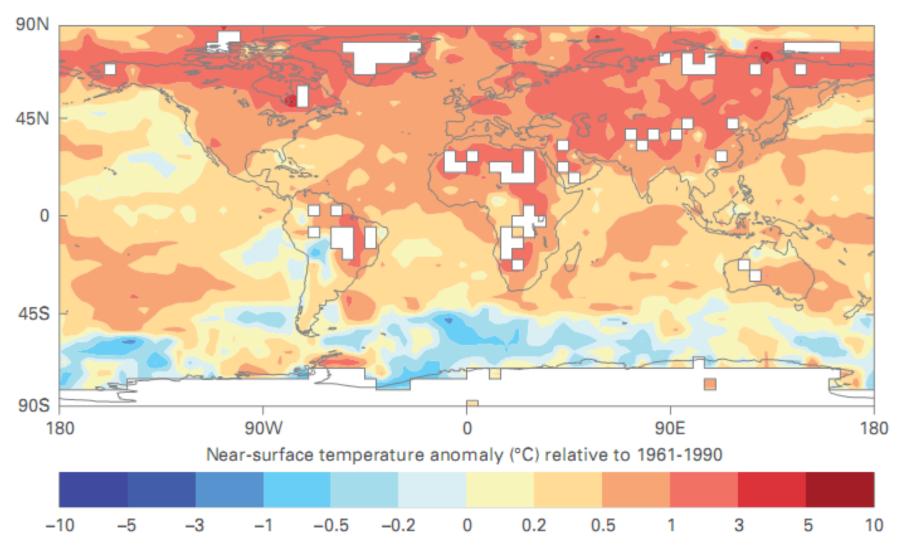


Fig. 6 Global combined surface air temperature over land and sea-surface temperature anomaly (°C) for 2001–2010, relative to 1961–1990 base period. Grid areas without suffcient data are left blank (source: HadCRU).

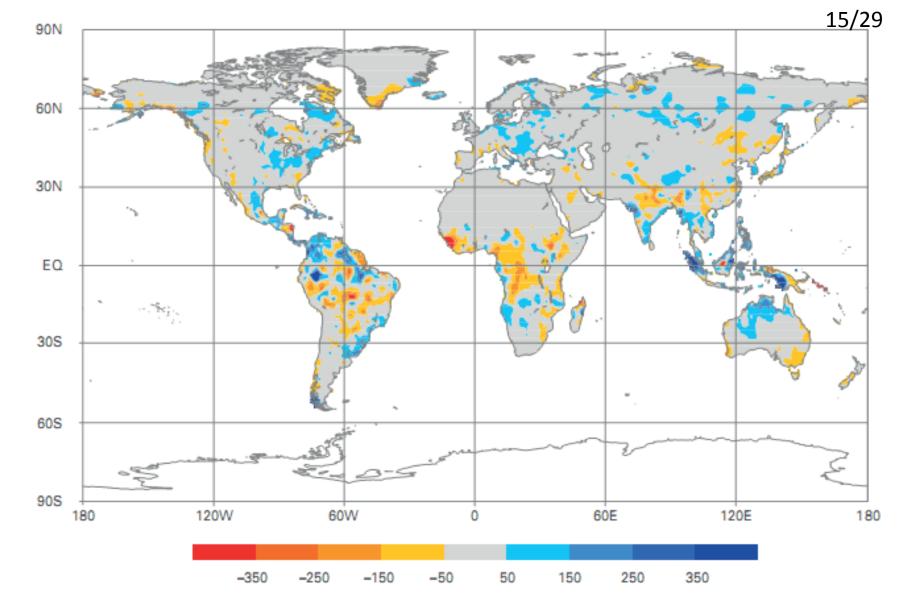


Fig. 10 Decadal precipitation anomalies for global land areas for 2001–2010; gridded 1° raingauge-based analysis as normalized departures in mm/year from averages computed using 1951–2000 base period (source: GPCC-DWD)

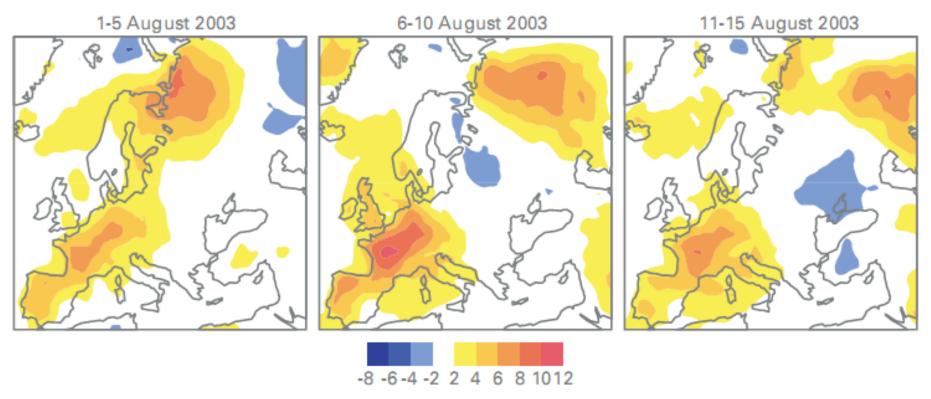


Fig. 23 Five-day mean surface air-temperature anomaly (°C) for August 2003, relative to 1981–2010 from the ERA- Interim reanalysis (source: ECMWF)

The number of deaths compared with normal summer conditions revealed a total of more than 66 700 excess deaths that were attributed to the heatwave. The 2003 heatwave affected France and Italy most with a loss of nearly US\$ 4.5 billion each, followed by Germany with nearly US\$ 1.7 billion.

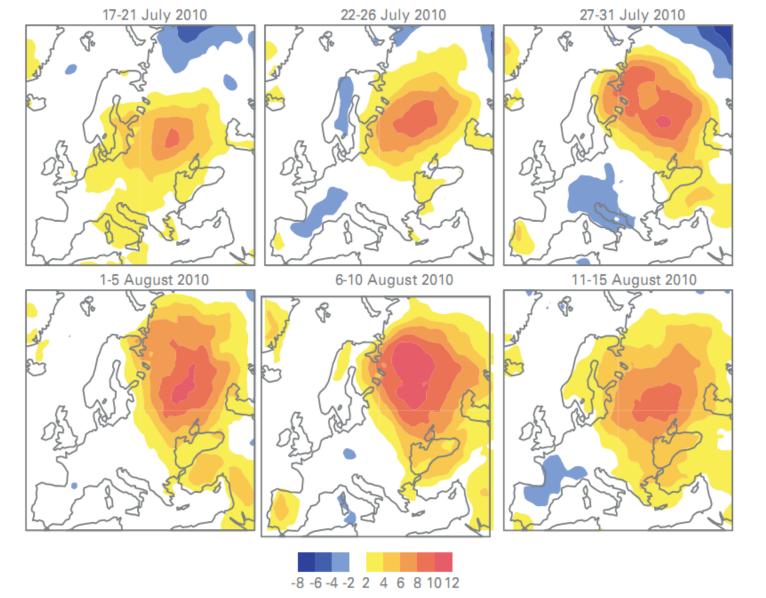


Fig. 24 Five-day mean surface air-temperature anomaly (°C) for July and August 2010, relative to 1981–2010 from the ERA-Interim reanalysis (source: ECMWF).

The extreme heatwave of 2010 caused more than 55 000 excess deaths. Over 20 per cent of crops growing on some 9 million hectares of farmland were destroyed. There were more than 600 wildfires and some 950 forest fires in 18 regions at the beginning of August, with thousands of people made homeless. The wildfires are listed as the costliest natural disaster of the country since 1900, with an estimated economic damage of US\$ 1.8 billion.

WMO (2013) The Global Climate 2001–2010: A Decade of Climate Extremes

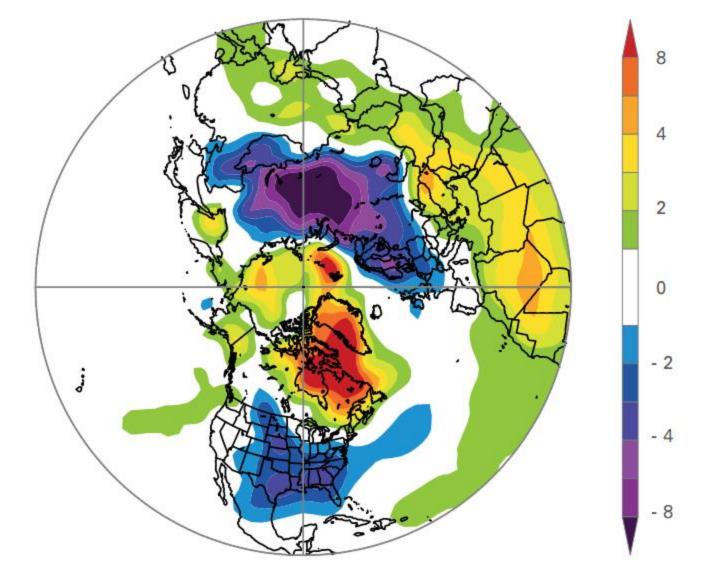


Fig. 28. Northern hemisphere winter 2009/2010 temperature anomaly in °C for December–January– February at 1 000 hPa based on NCEP-NCAR reanalysis, with 1981–2010 as reference period (source: NOAA, ESRL-PSD)

The cold spells in late January caused at least 450 casualties in Europe.

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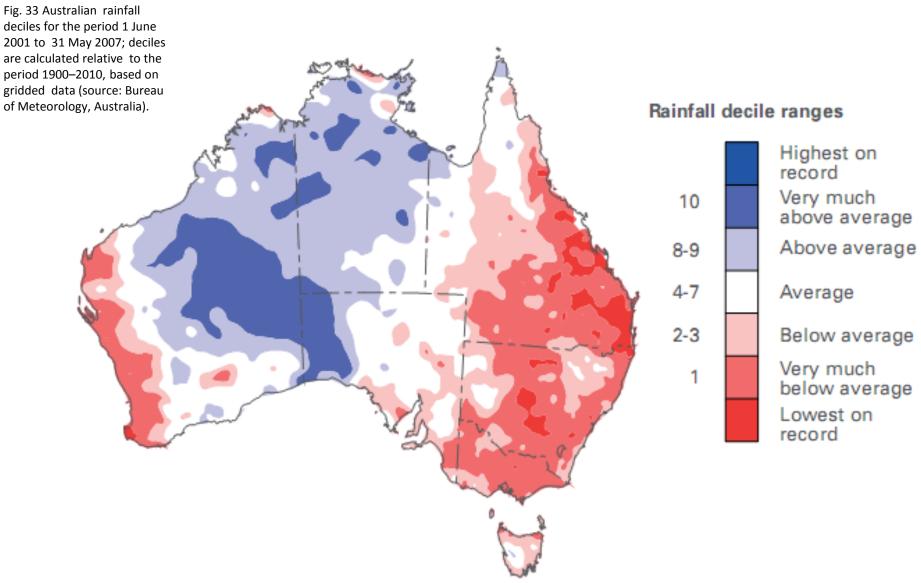
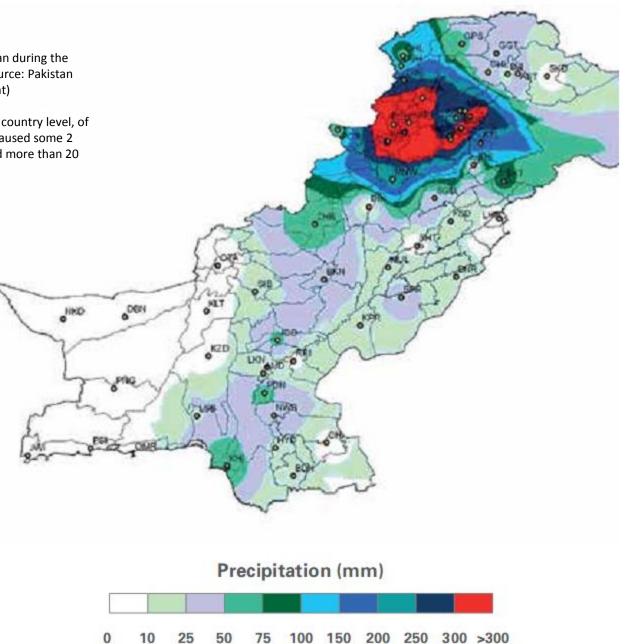


Fig. 31. Rainfall over Pakistan during the period 26–29 July 2010 (source: Pakistan Meteorological Department)

Economic damage costs at country level, of US\$ 9.5 billion. The event caused some 2 000 casualties and affected more than 20 million people.



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Negative/positive anomalies in CMSAF SIS are indicators of extremely cold/warm air temperature conditions (Fig. 1 / Fig 2)

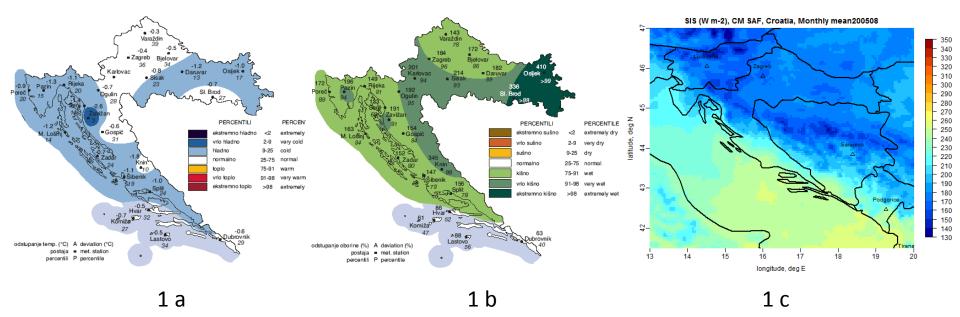


Figure 1: August 2005. Largest negative anomaly of SIS (-58.8 Wm-2) (Fig. 7 c) from the average for that month (Period: 1983-2011) was connected with cold (Fig. 7 a) and wet (Fig. 7 b) weather conditions in Croatia. In ground data for the period 2004-2014 this was the third largest negative August anomaly, followed by those in 2006 and 2007 (Fig. 6).

SIS MVIRI DataSet (1983-2005), spatial resolution 0.03° SIS SEVIRI DataSet (2005-2011), spatial resolution 0.05°

Melita Perčec Tadić, Renata Sokol Jurković: Estimation and validation of hourly surface incoming shortwave radiation using in situ and satellite data . GEOENV2014, Paris.

Negative/positive anomalies in CMSAF SIS are indicators of extremely cold/warm air temperature conditions (Fig. 1 / Fig 2)

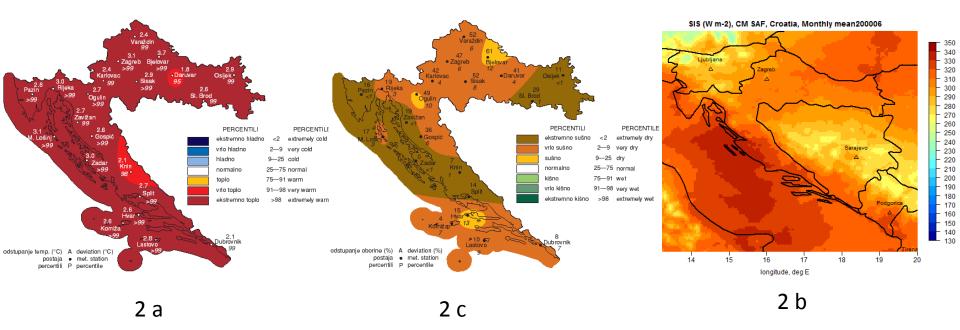


Figure 2: June 2000. Second largest positive anomaly of SIS (50.4 Wm-2) (Fig. 8 c) from the average for that month (Period: 1983-2011) was connected with warm (Fig. 8 a) and dry (Fig. 8 b) weather conditions. The ground irradiance data were not available for this year. The larges positive anomaly in CMSAF SIS was in April 2007 that was visible also in ground SIS data.

SIS MVIRI DataSet (1983-2005), spatial resolution 0.03° SIS SEVIRI DataSet (2005-2011), spatial resolution 0.05°

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Fig. 37 Most signifcant tropical cyclones recorded during 2001– 2010 (source: NOAA-NCDC).

Tropical storm Allison (June 2001)

Maximum winds - 95 km/h. Deadliest and costliest tropical storm on record in the USA.

Hurricane Rick (October 2009)

Maximum winds - 270 km/h The second most intense hurricaneon record for the basin, behind *Unda* of 1997.

Hurricane Kenna (October 2002)

Maximum winds - 270 km/h. The strongest hurricane to strike Mexico from the Pacific since hurricane Madelinein 1976 and third strongest on record.

Hurricane Sergio (November 2006)

Maximum winds - 175 km/h. The longest-lived November tropical cyclone on record for the basin.

Tropical storm Alma (May 2008)

Maximum winds - 100 km/h. The first eastern North Pacific basin tropical storm or hurricane to make landfall along the Pacific Coast of Central America since records began.

Cyclones maximum wind legend

 63-118 km/h
 119-153 km/h
 154–177 km/h
 178-209 km/h
 210-249 km/h
 > 249 km/h

Hurricane Katrina (August 2005)

Maximum winds - 280 km/h Deadliest hurricane to strike the USA since 1928.

Hurricane Bertha

(July 2008) Maximum winds - 205 km/h. Longest-lived Atlantic July tropical cyclone on record.

Hurricane Juan (September 2003)

 Maximum winds - 170 km/h.
Worst hurricane to hit Halifax, Nova Scotia, in modern history.

Tropical storm Fay (August 2008)

Maximum winds - 110 km/h. First storm in recorded history to strike Florida (or any state) four times.

Hurricane Wilma (October 2005)

Maximum winds - 295 km/h. The most intense Atlantic hurricane ever recorded.

Hurricane Michelle (October/November 2001)

October 1952.

bber/November 2001) Maximum winds - 220 km/h. Strongest hurricane to hit Cuba since hurricane Fox in

Hurricane Lili (September/October 2002)

Maximum winds - 230 km/h. First hurricane to make landfall in the USA since hurricane *lrene* in 1999.

Hurricane Ivan (September 2004)

Maximum winds - 270 km/h. The most powerful storm to affect the Caribbean in 10 years.

Hurricane Catarina (March 2004)

Maximum winds - 155 km/h. The first documented South Atlantic Ocean hurricane since geostationary satellite records began in 1966.

Fig. 37 Most signifcant tropical cyclones recorded during 2001– 2010 (source: NOAA-NCDC).

Cyclone Gonu Typhoon Rananim

(June 2007) Maximum winds - 270 km/h. The worst tropical cyclone to hit Oman since 1945.

Typhoon Lekima (September/October 2007)

Maximum winds - 130 km/h. Produced heavy rains across Viet Nam, resulting in its worst flooding in 45 years

Typhoon Kompasu (August/September 2010)

Maximum winds - 195 km/h. Strongest typhoon to strike Seoul Republic of Korea in 15 years.

Hurricane/typhoon Loke (August/September 2006)

Maximum winds - 260 km/h. The strongest hurricane ever recorded in the Central Pacific Ocean.

Typhoon Tokage

(October 2004) Maximum winds - 230 km/h Desdliest typhoon to strike Japan since 1979.

Cyclone Laila (May 2010)

Maximum winds - 120 km/h First may storm to affect south-eastern India in two decades.

Cyclone Nargis (April/May 2008)

Maximum winds - 215 km/h. The most devastating cyclone to hit Asia since 1991 and the worst natural disaster on record for Myanmar.

Cyclone Dina (January 2002)

Maximum winds - 240 km/h Responsible for setting a new 24-h precipitation record in Mauritius (745 mm).

Cyclone Gamède (February/March 2007)

Maximum winds - 195 km/h. A new worldwide rainfall record was set in La Réunion with 3929 mm measured in 3 days.

Cyclone Ingrid (March 2005)

Maximum winds - 250 km/h. The first cyclone recorded to reach category 5 intensity off the coast of three different Australian states: Queensland, Northern Territory, and Western Australia.

Typhoon Durian (November 2006)

Maximum sustained wind - 230 km/h.

Near 1 200 deaths in the Philippines.

Typhoon Megi (October 2010)

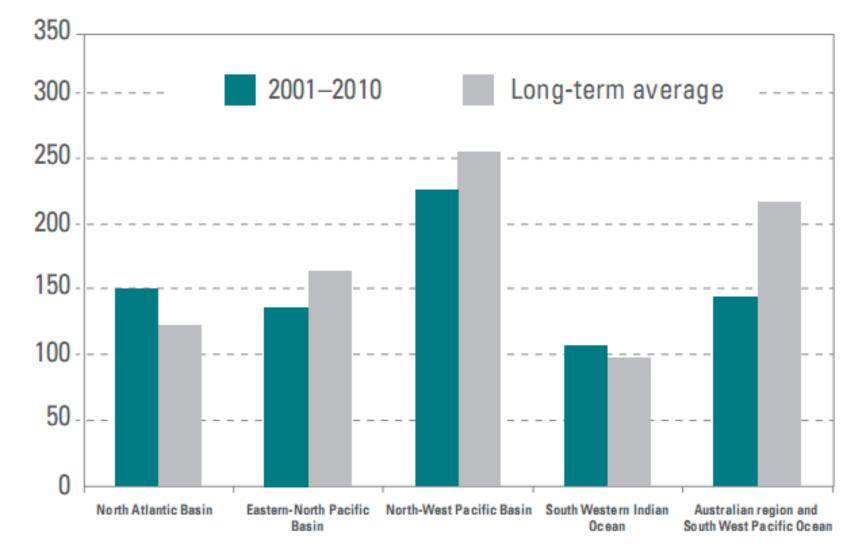
Maximum winds - 295 km/h. The strongest tropical cyclone in the world since 2005 and the strongest in the North-West Pacific since 1983.

Cyclone Ului (March 2010)

Maximum winds - 260 km/h. One of the fastest intensifying tropical cyclones on record.

Cyclone Larry (March 2006)

Maximum winds - 215 km/h. The most intense cyclone to strike the Queensland coast since 1918.



Number of storms

Fig. 38 Total number of named tropical storms during 2001–2010 by basin compared to the long-term average of the 1981–2010 base period (data source: NOAA-NCDC)

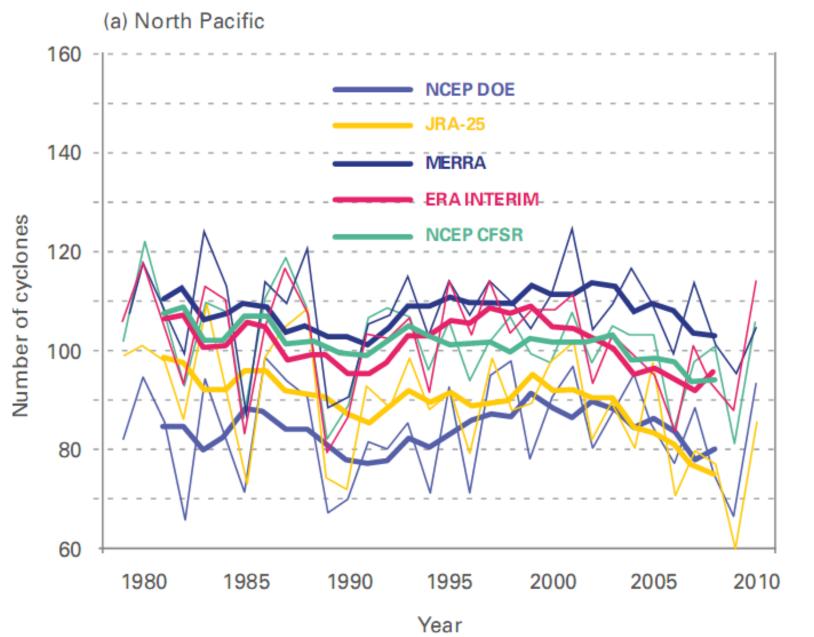


Fig. 45 Time series of the number of deep extra-tropical cyclones (atmospheric pressure at the surface smaller than 980 hPa): (a) North Pacifc; (b) North Atlantic

WMO (2013) The Global Climate 2001–2010: A Decade of Climate Extremes

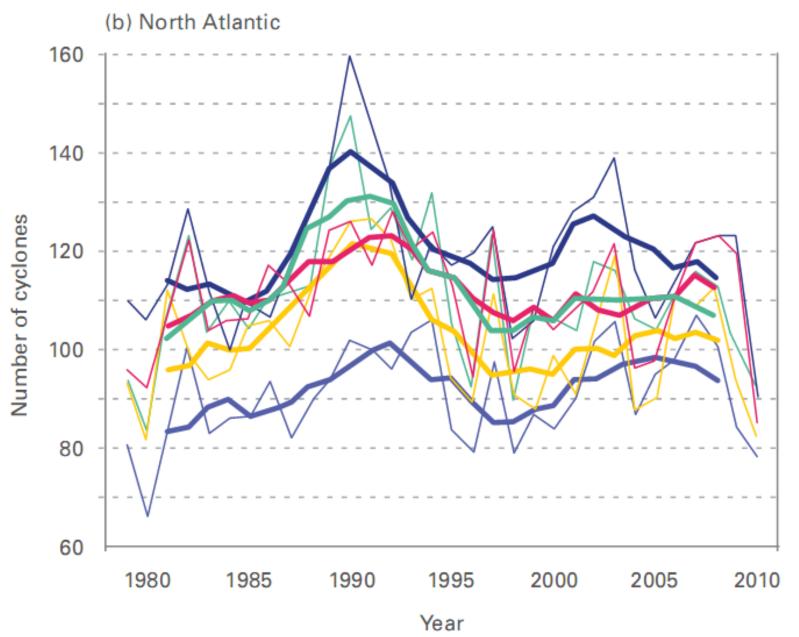
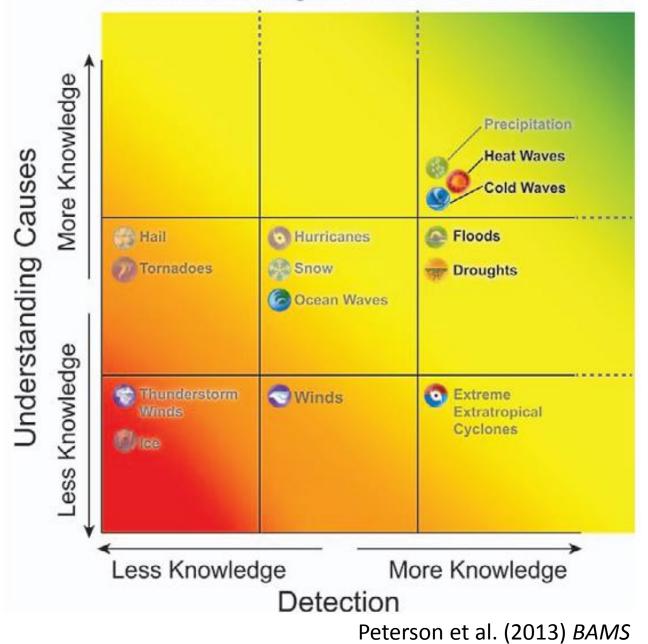


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Adequacy for Detection and Understanding Causes of Changes for Classes of Extremes



Detection and attribution of changes in extremes depend on both scientists' physical understanding of the factors that not just cause a particular extreme but would cause the intensity or frequency of that extreme to change over time and the quality and quantity of the data. The x axis refers to the adequacy of data to detect trends, while the y axis refers to scientific understanding of what causes those trends. The dashed lines on the right side and top of the graph imply that the knowledge about the phenomena is not complete.

Changes in Phenomenon	Uncertainty in observed changes (since about the mid-20th century)			Uncertainty in projected changes (up to 2100)			
IPCC Assessment Report	TAR	AR4	SREX	TAR	AR4	SREX	
Higher maximum temperatures and more hot days	<i>Likely</i> over nearly all land areas	Very Likely over most land areas	Very Likely at a global scale	Very Likely over nearly all land areas	Virtually Certain over most land areas	Virtually Certain at a global scale	
Higher minimum temperatures, fewer cold days	Very Likely over nearly all land areas	Very Likely over most land areas	Very Likely at a global scale	Very Likely over nearly all land areas	Virtually Certain over most land areas	Virtually Certain at a global scale	
Warm spells/heat waves. frequency, length or intensity increases		<i>Likely</i> over most land areas	Medium Confidence in many regions		Very Likely over most land areas	Very Likely over most land areas	
Precipitation extremes	<i>Likely</i> ¹ , over many Northern Hemisphere mid- to high latitude land areas	<i>Likely</i> ² over most areas	Likely ³	Very Likely ¹ over many areas	Very Likely ²	<i>Likely^{2,4}</i> in many land areas of the globe	
Droughts or dryness	<i>Likely⁵,</i> in a few areas	<i>Likely</i> ⁶ , in many regions since 1970s	Medium Confidence in more intense and longer droughts in some regions , but some opposite trend exists	Likely ⁵ , over most mid- latitude continental interiors (Lack of consistent projections in other areas)	Likely ⁶	Medium Confidence ⁷ that droughts will intensify in some seasons and areas; Overall <i>low</i> confidence elsewhere	
Changes in tropical cyclone activity (i.e. intensity, frequency, duration)	Not Observed ⁸ , in the few analyses available	<i>Likely</i> ⁹ , in some regions since 1970	Low confidence ¹⁰	<i>Likely</i> ⁸ , over some areas	Likely ⁹	Likely ¹¹	
Increase in extreme sea level (excludes tsunamis)		Likely	Likely ¹²		Likely	Very Likely ¹³	
Term* Likelihood of the Outcome		he Outcome	Term*	Likelihood of the Outcome			
Virtually certain Very likely Likely	99–100% probability 90–100% probability 66–100% probability 33–66% probability		Unlikely Very unlikely Exceptionally u	0-	-33% probability -10% probability -1% probability		
About as likely as not						IPCC (2013) WG1 A	