Changing weather extremes
Why it isn't an "alternative fact"

Photo credit

University of Victoria
PACIFIC CLIMATE IMPACTS CONSORTIUM

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PCIC, University of Victoria

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CMOS-SCMO
Canadian Meteorological and Oceanographic Society
Société canadienne de météorologie et d'océanographie

What is an “alternative fact”?

- Phrase used by Kellyanne Conway
  - on *Meet the Press* on 17 January 2017
- In defending White House Press Secretary Sean Spicer
  - concerning claims about the size of the Presidential inauguration crowd
- A demonstrable falsehood
- Distinct from the notion
  - that there might be different interpretations of the facts, or that
  - knowledge is constructed, and has a social context

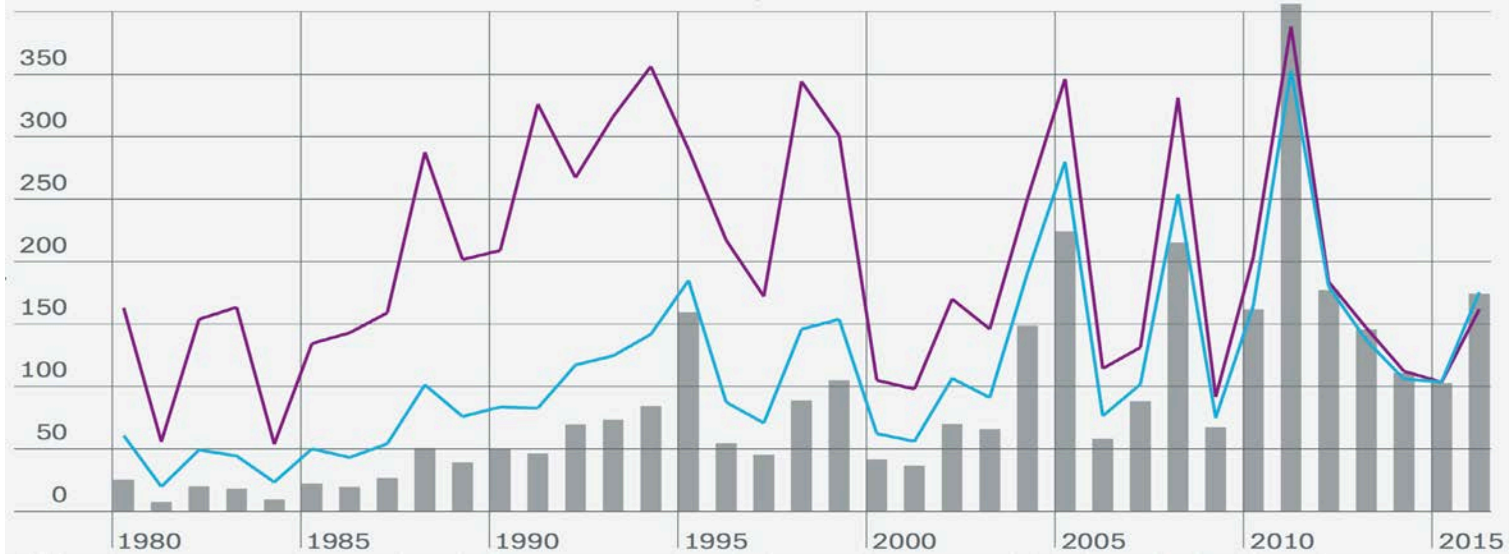
Photo by Gage Skidmore – source Wikipedia

When talking about climate change … or any other scientific issue

- We need to distinguish between
  - the facts, and
  - the information that they convey
- Not all facts convey scientifically interpretable information, or sometimes convey only incomplete information

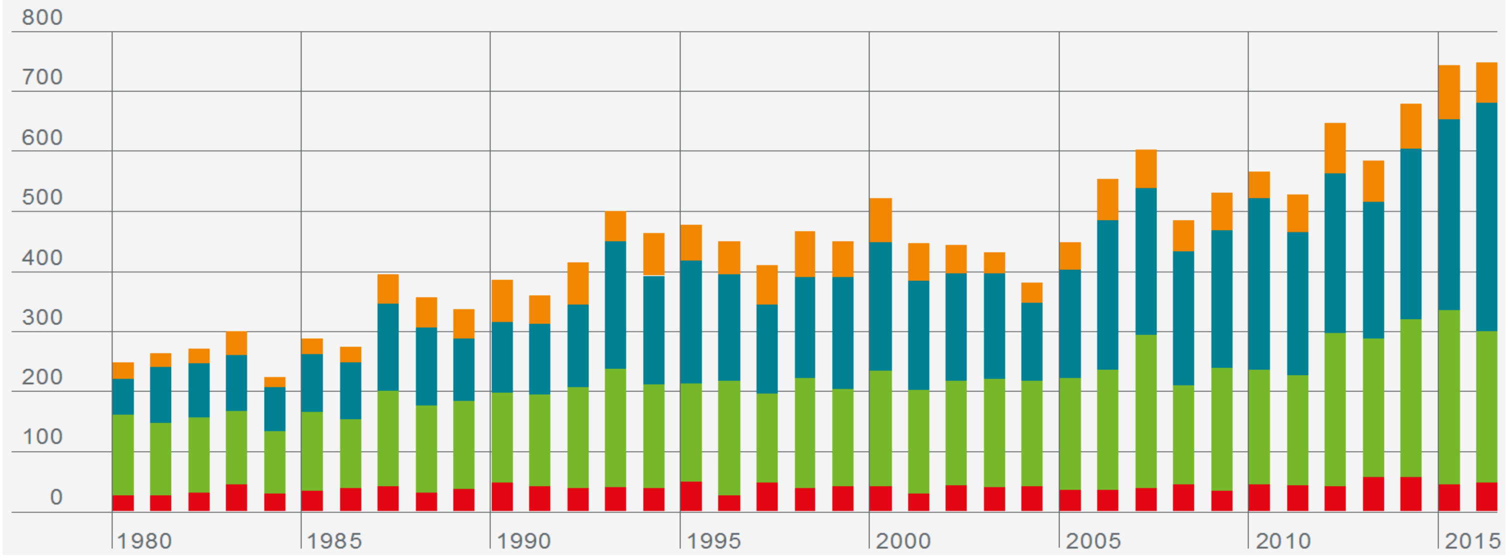
Worldwide financial loss (Billions, USD)

Nominal
Inflation adjusted
Inflation and GDP adjusted



Number of loss events

Geophysical
Meteorological
Hydrologic
Climatological



The rest of this talk is about extremes

- Long term trends in extremes
- Individual extreme events examples
- Conclusions
- Communications
- Questions

- Messages
  - Human influence IS affecting extremes, but
  - Some aspects of the public narrative are ahead of the science

Photo: F. Zwiers (Smoke filled sunset, Aug, 2014, Winthrop, WA)

Long term trends in extremes

Photo: F. Zwiers (Ring-Necked Duck, Victoria)

General idea

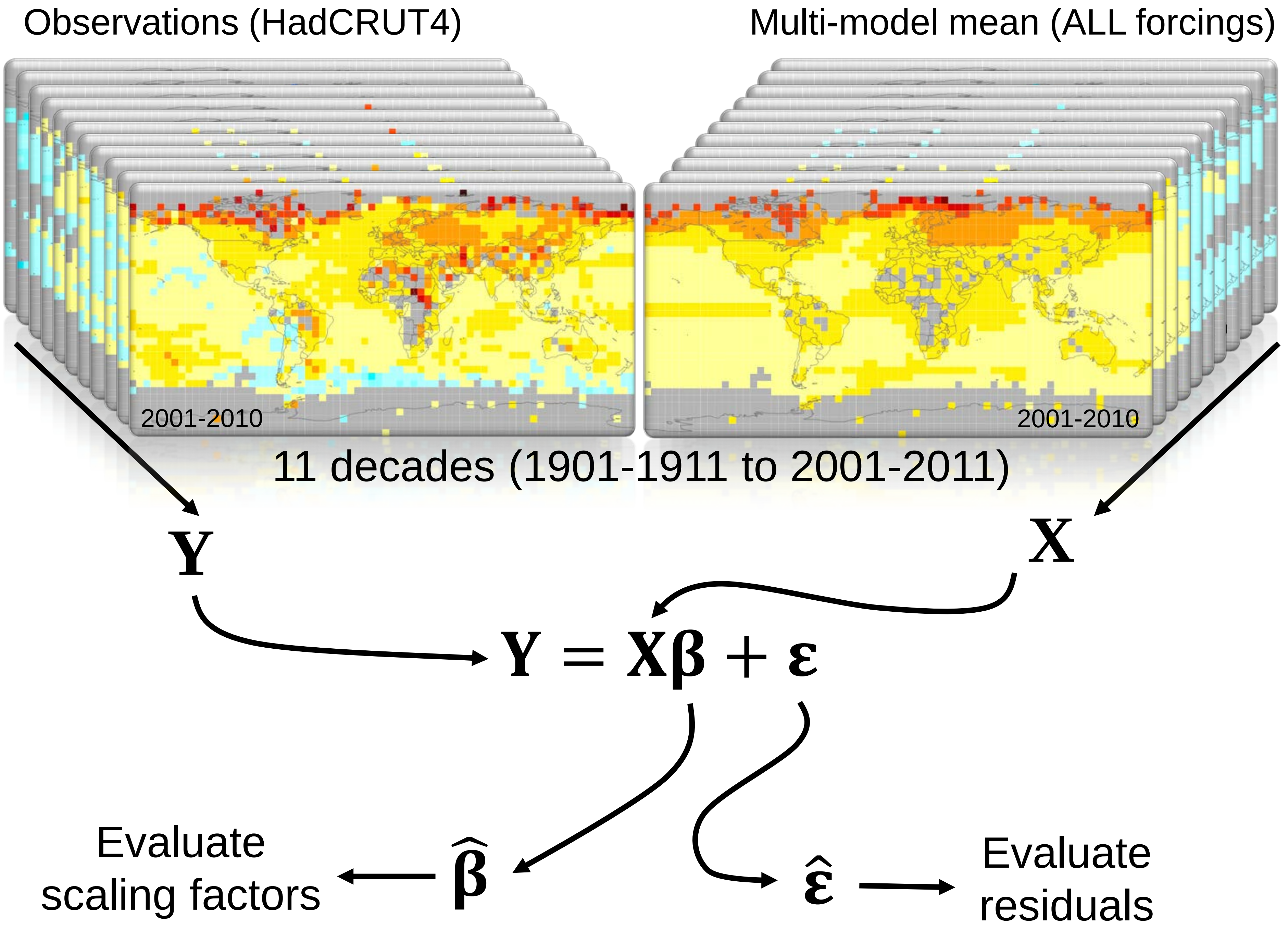
- Postulate a set of change "signals" that might be present in observations
- Look for those signals
- Eliminate other causes

Usual assumptions

- Key external drivers of climate change are known
- Signals and noise are additive
- Model simulated signal patterns ok, magnitude less certain

→leads to a simple regression formulation

- Example: Global surface temperature



After Weaver and Zwiers (2000)

Temperature extremes

Photo: F. Zwiers (Lanzhou)

See WCRP summer school on extremes, ICTP, July, 2014

Temperature extremes

- Studies looking at long term changes find
  - More frequent and more intense warm extremes
  - Less frequent and less intense cold extremes
- Changes are found to be largely due to human influence (i.e., greenhouse gas increases)
- Supported by very high confidence in our understanding of the change in mean temperatures

- Extremes warmed during the "global warming hiatus"
  - Seneviratne et al, 2014; Sillmann et al, 2014, Johnson et al, 2015

Change in Frequency

Cold nights and cold days

1950-2010

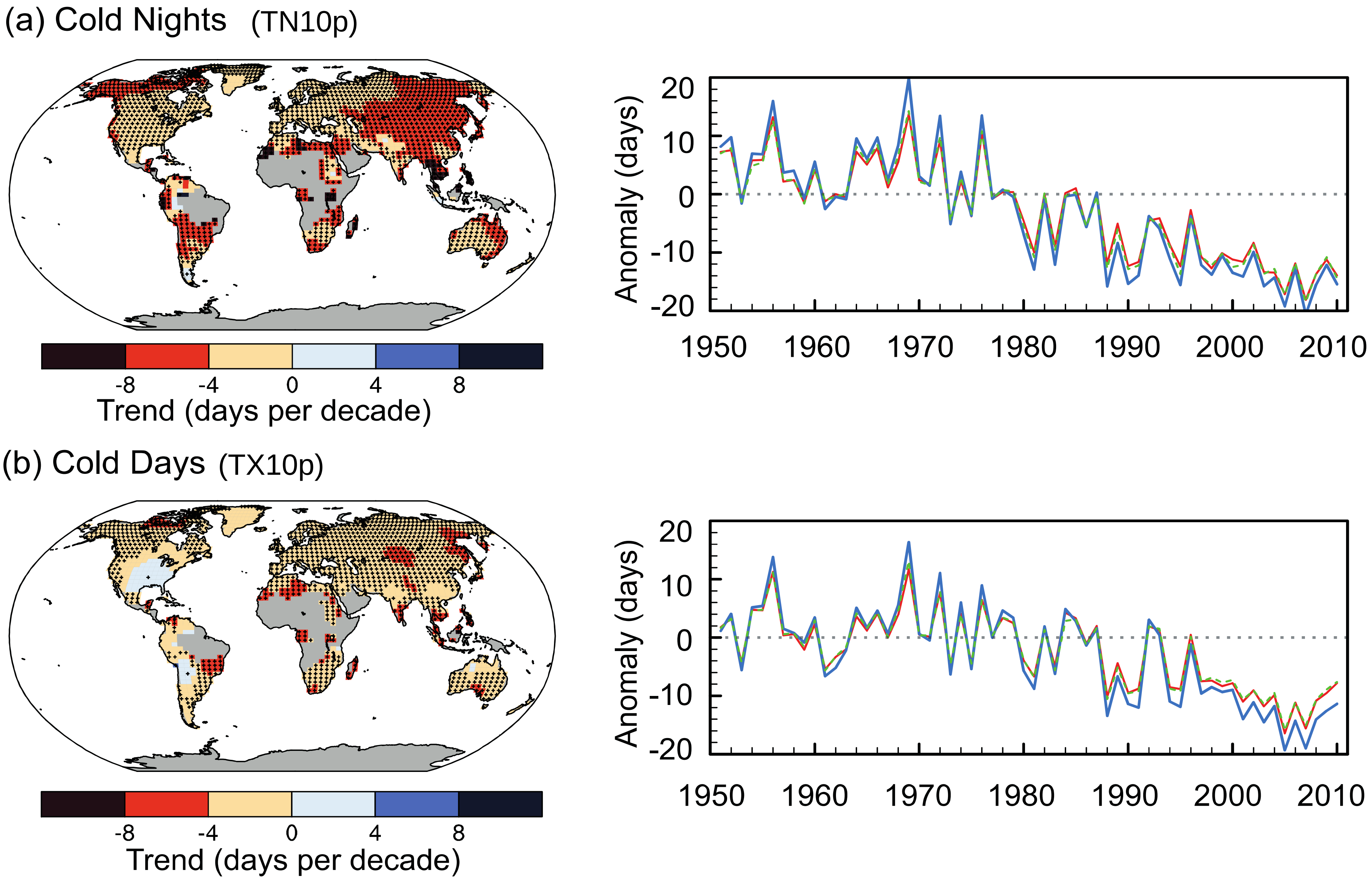


Fig. 2.32, IPCC AR5 WG1, Chapter 2 (See also Donat et al, 2013)

Change in Frequency

Warm nights and warm days

1950-2010

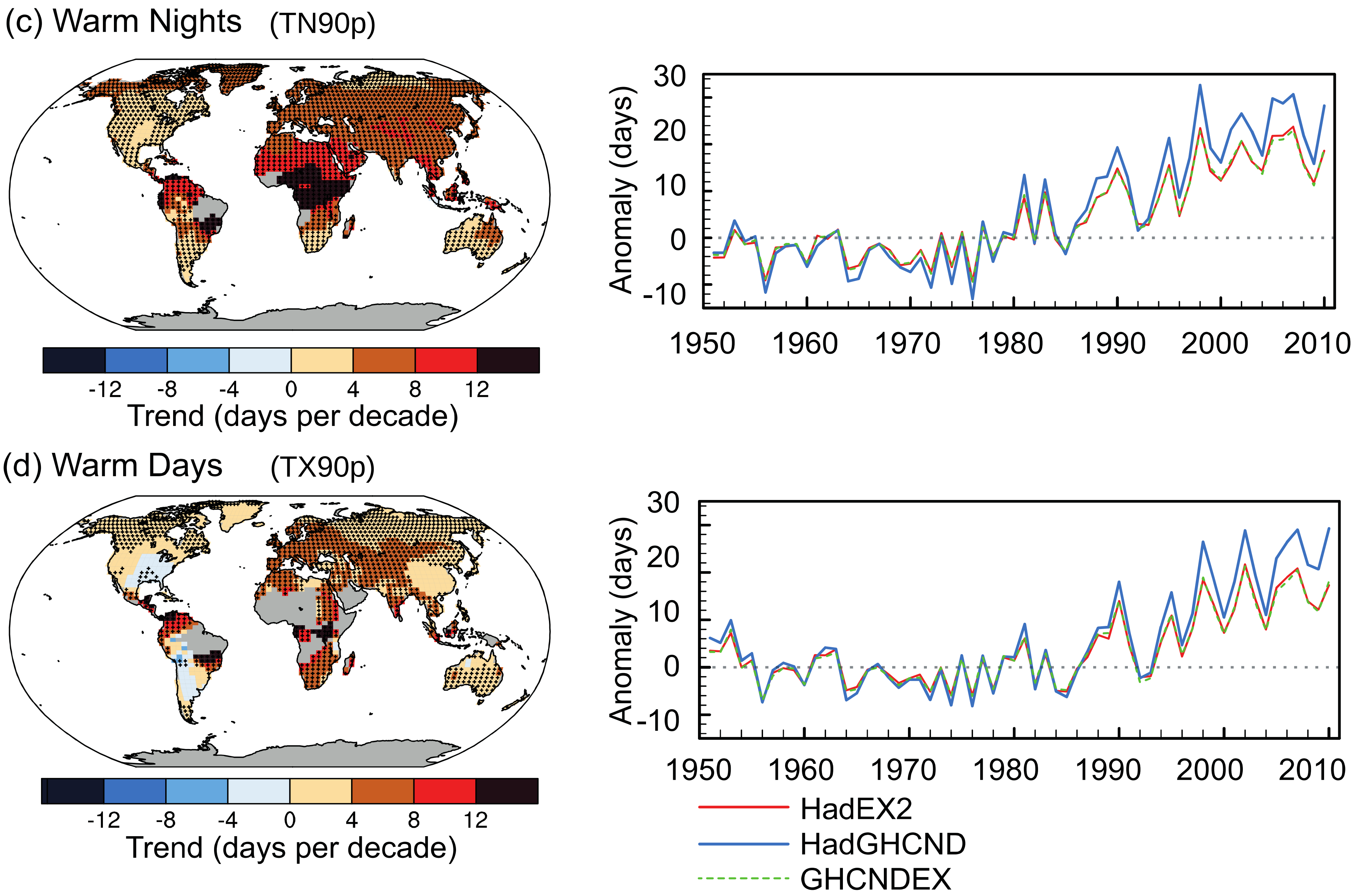
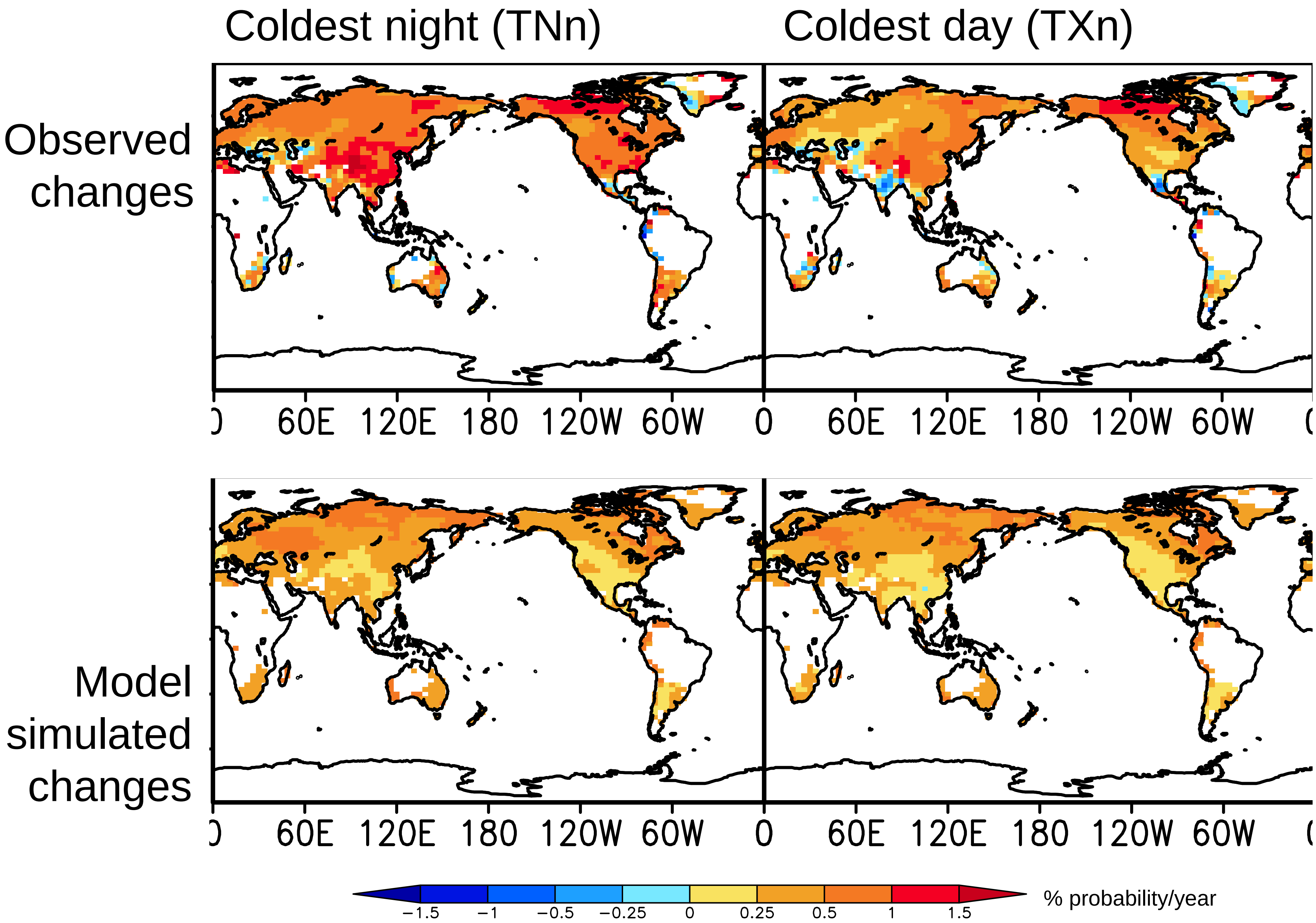


Fig. 2.32, IPCC AR5 WG1, Chapter 2 (See also Donat et al, 2013)

Decrease in Intensity

Coldest night and coldest day of year

1961-2010

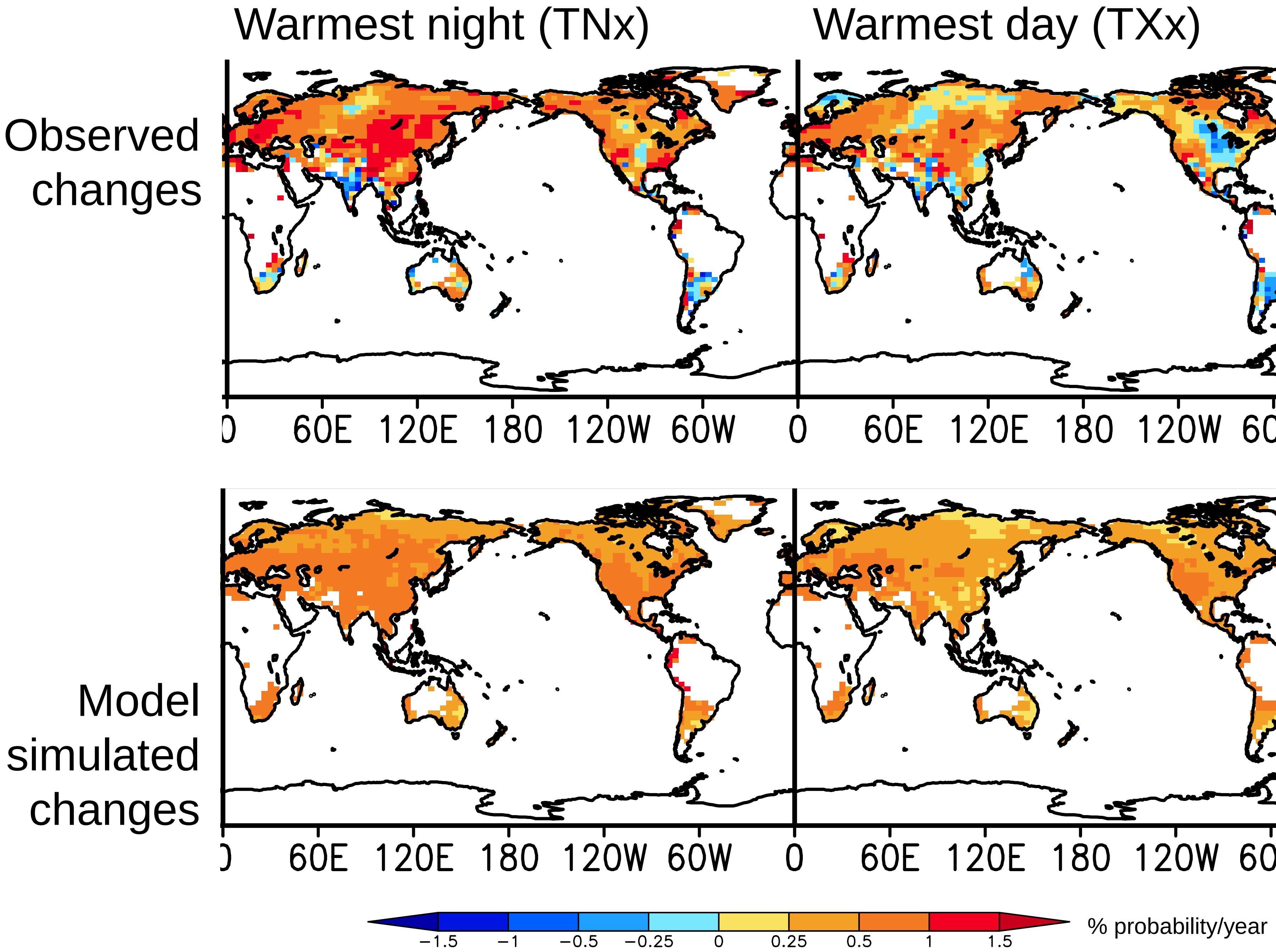


Kim et al, 2015, Fig 1 and 2

Increase in Intensity

Warmest night and warmest day of year

1961-2010

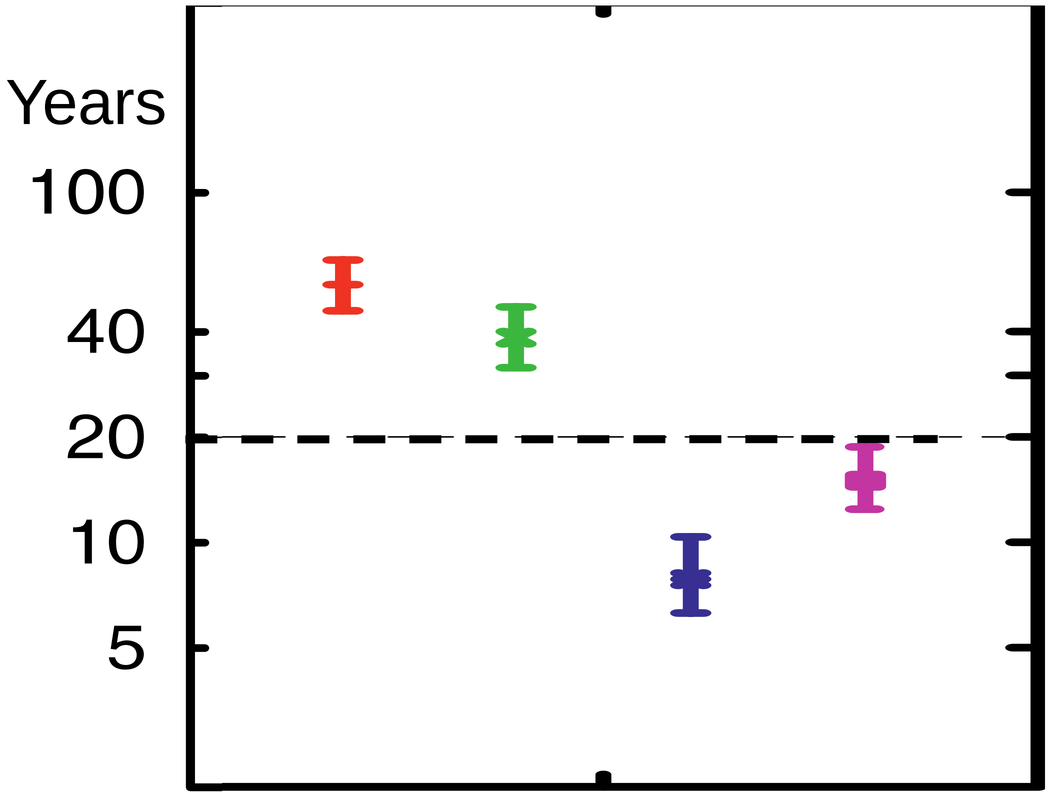


Kim et al, 2015, Fig 1 and 2

Assessment of cause and effect

- Change in frequency and intensity of rare events primarily caused by human influence
- 1960's cold events only half as frequent by 1990's
- 1960's warm events perhaps twice as frequent by 1990's

Change in waiting times for 20-year events (1990's vs 1960's)



Zwiers, et al., 2011, *J Climate*

TNn - Coldest night annually

TXn - Coldest day annually

TNx - Warmest night annually

TXx - Warmest day annually

Limitations

- Observational data
  - Need long homogeneous records of daily data
  - Incomplete geographical coverage
  - Traceability, updatability of indices
  - Order of operations
- Process understanding and representation in models, such as
  - Coupled land-atmosphere feedback processes
  - Blocking
- Analysis methodology

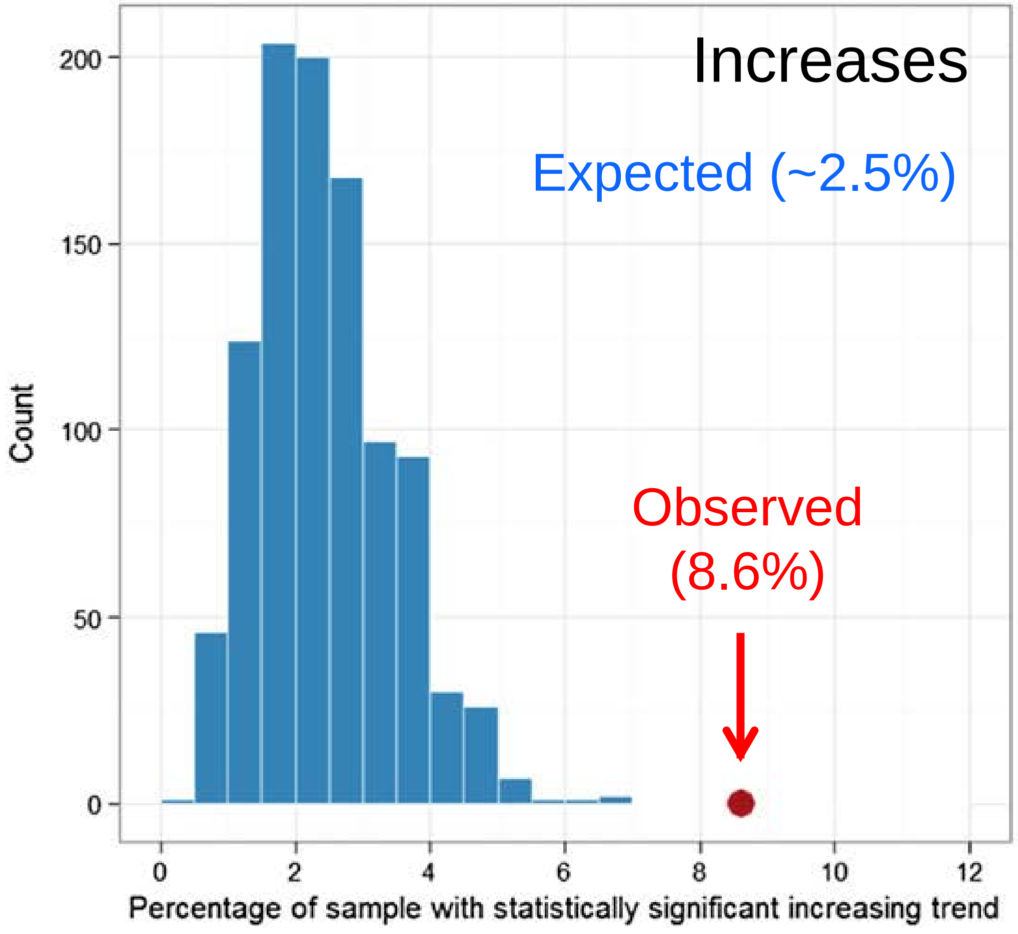

Precipitation extremes
Photo: F. Zwiers (Longji)

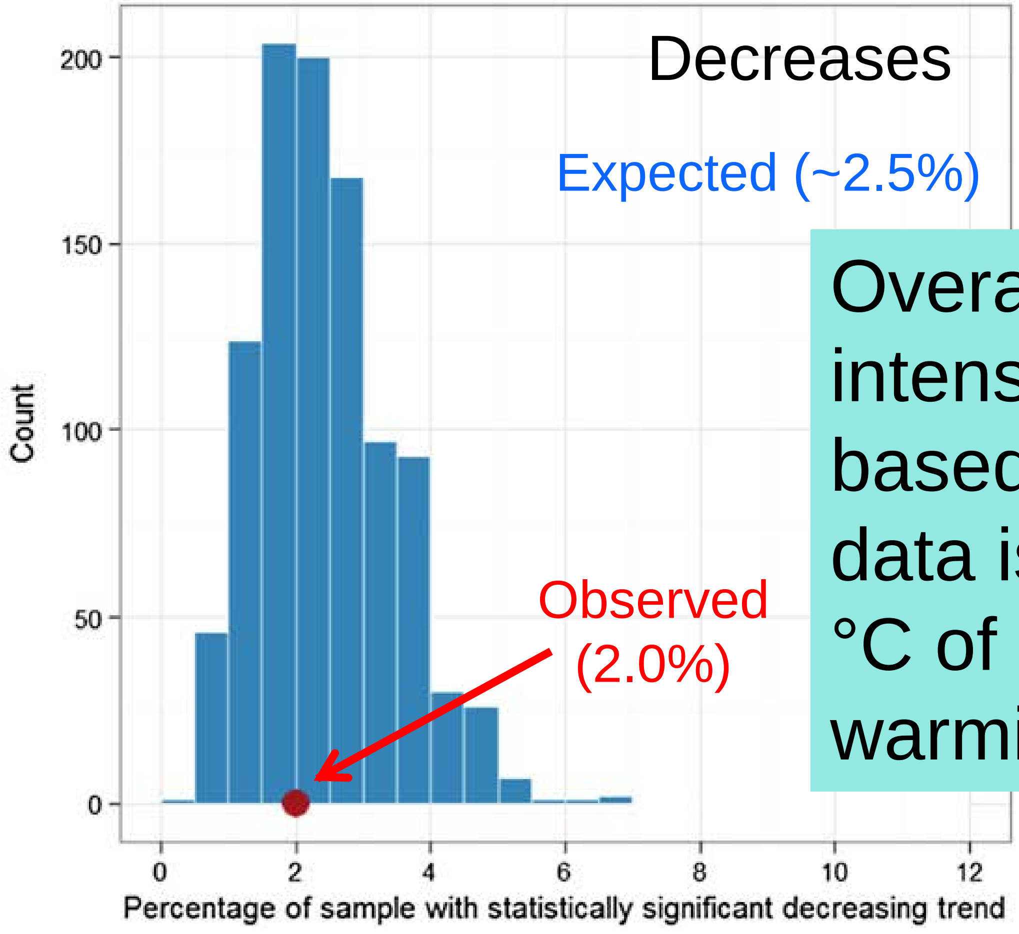
Precipitation extremes

- Observational studies suggest intensification is occurring
- Expectation of intensification is supported by attribution of
  - global warming
  - atmospheric water vapour content increase
  - large scale changes in mean precipitation
  - ocean surface salinity changes
- Only a few D&A studies to date on extreme precipitation
  - detect human influence at the ”global” scale
- Considerable challenges remain in understanding regional precipitation change (e.g., Sarojini et al., 2016)
- Local detection of change is very hard

Percentage of stations globally with statistically significant trends in annual maximum 1-day precipitation

Based on 8376 stations with 30-years or more data in period 1900-2009



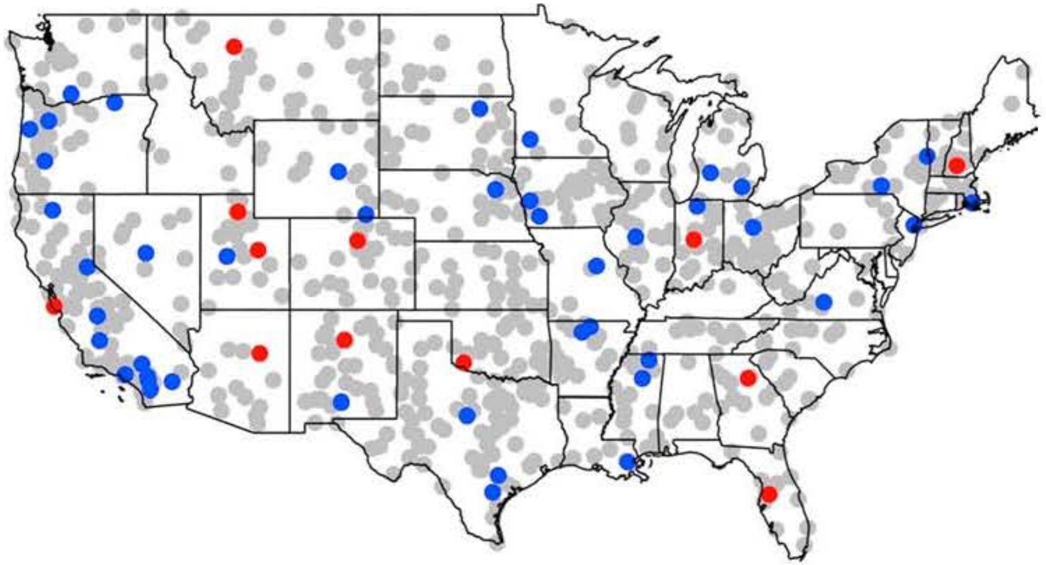


Overall intensification based on station data is ~7% per °C of global warming

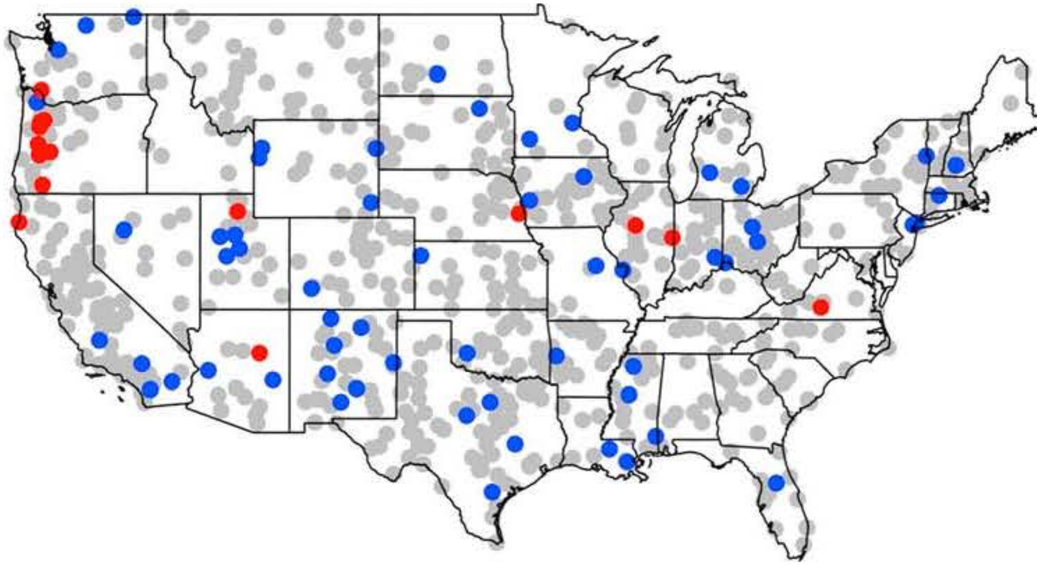
Westra et al 2013, Fig. 3

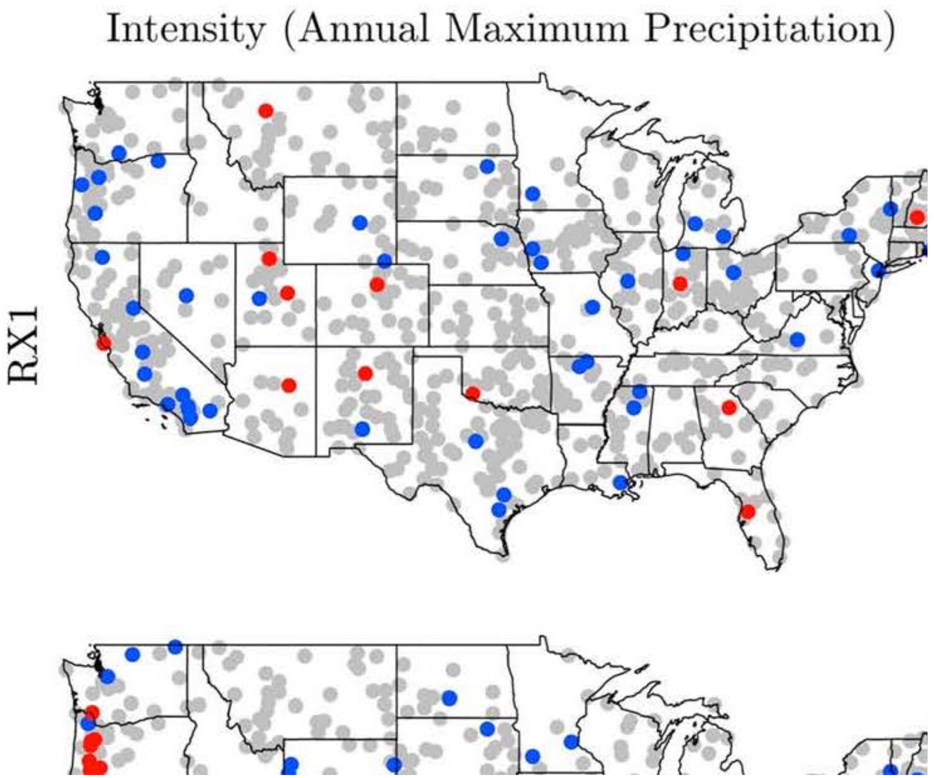
US trends in daily and hourly extreme precipitation

Annual maximum 1-hour amount



Annual maximum 24-hour amount





Barbero et al, 2017, Fig. 1

Detection and attribution results

We can detect the human influence on precipitation extremes over land:

- Climate models with anthropogenic external forcing intensify precipitation similarly to observed
- Climate models with only natural external forcing do not intensify precipitation

Attributed intensification:

- 5.2% increase per degree of warming
- uncertainty range [1.3 – 9.3]%

Estimated waiting time for 1950's 20-year event:
~15-yr in the early 2000's

Zhang et al., 2013 (see also Min et al 2011)

Limitations

- Data (availability, spatial coverage, record length, quality, observational uncertainty between datasets)
- Confidence in models (e.g., circulation impacts, topography, parameterization of sub-grid scale processes)
- Low signal-to-noise ratio with possibly offsetting influences from GHGs and aerosols (may be different for means than for extremes)
- Understanding of spatial and temporal scaling (e.g., Zhang et al., 2017)
- Characterization of spatial dependence

Terrestrial hydrological cycle

Photo: F. Zwiers (Canmore, AB)

Hydrologic extremes

- Few studies linking change in mean hydrologic conditions to GHGs
  - Barnett et al, 2008, Fyfe et al., 2017 (Western US)
  - Najafi et al, 2016, 2017 (part of BC)
  - Detect the effect of warming on snowpack and/or streamflow characteristics
  - Also detect the effect of warming on snow cover extent
- Strong need for study of extremes given impacts
- Challenges include
  - Data (very often inhomogenious due to river regulation)
  - Complex spatial variation in hydrologic sensitivity (Grieve et al, 2014; Kumar et al, 2015) which complicates robust detection of responses (Kumar et al, 2016)
  - Complexity and uncertainty in the modelling chain
  - Confounding effects

Storms

Photo: F. Zwiers

Photo: F. Zwiers (Ucluelet)

Storms

- Some evidence of attributable change in surface pressure distribution (indicative of long-term circulation change)
- Few, if any, D&A studies of long-term change in position of extratropical storm tracks, storm frequency or intensity
- Challenges include
  - Data (type, source, length of record, homogeneity)
  - Models (eg, broad range of frequency biases in the occurrence of explosive cyclones in CMIP5 class models – Seiler and Zwiers, 2015a, 2015b)
  - Dynamical downscaling with a regional climate model helps reduce bias somewhat (Seiler et al, 2017)

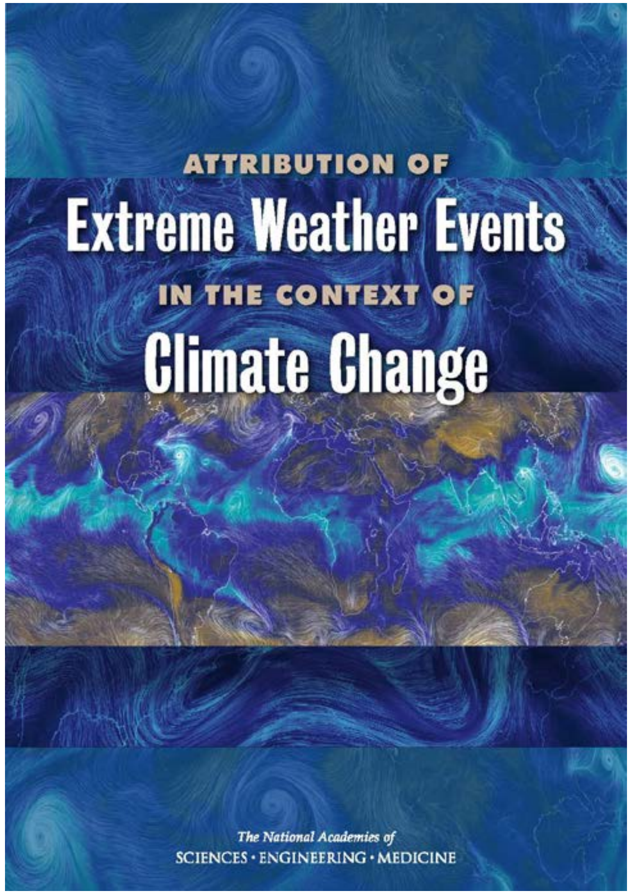
Event attribution

Photo: F. Zwiers (Jordan River, gathering storm)

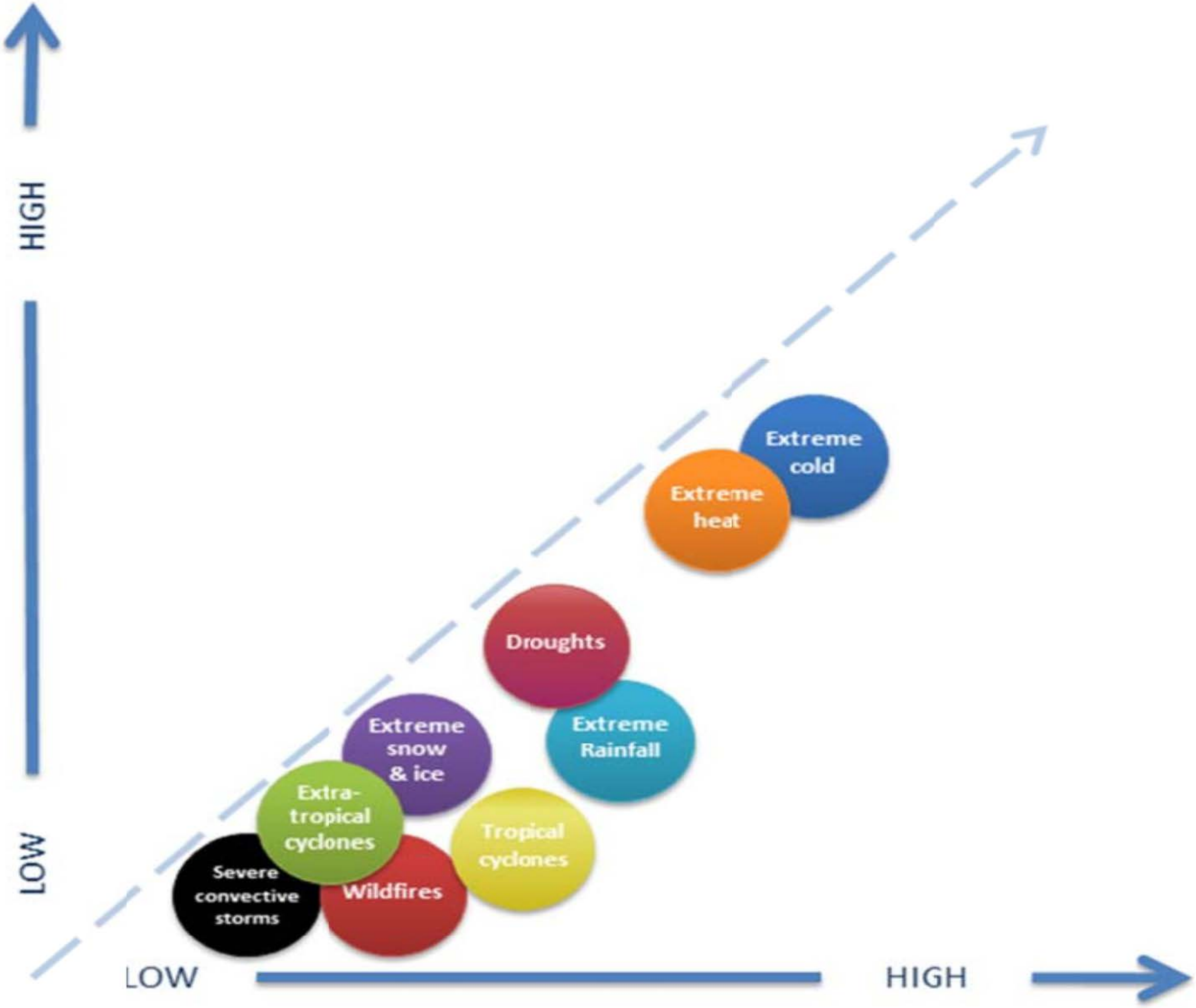
Extreme event attribution

- The public asks: Did human influence on the climate system …
  - Cause the event?
- Most studies ask: Did it …
  - Affect its odds?
  - Alter its magnitude?
- Usual approach is compare factual and “counterfactual” climates using climate models
  - Counterfactual → the world that might have been if we had not emitted the ~600GtC (and counting) that have been emitted since preindustrial
- Shepherd (2016) defines this as “risk based”
  - Contrasts it with a “storyline” based approach

Recently assessed by US NAS



Confidence in capability for event attribution



Understanding of effect of climate change on event type

“Framing” affects the answer

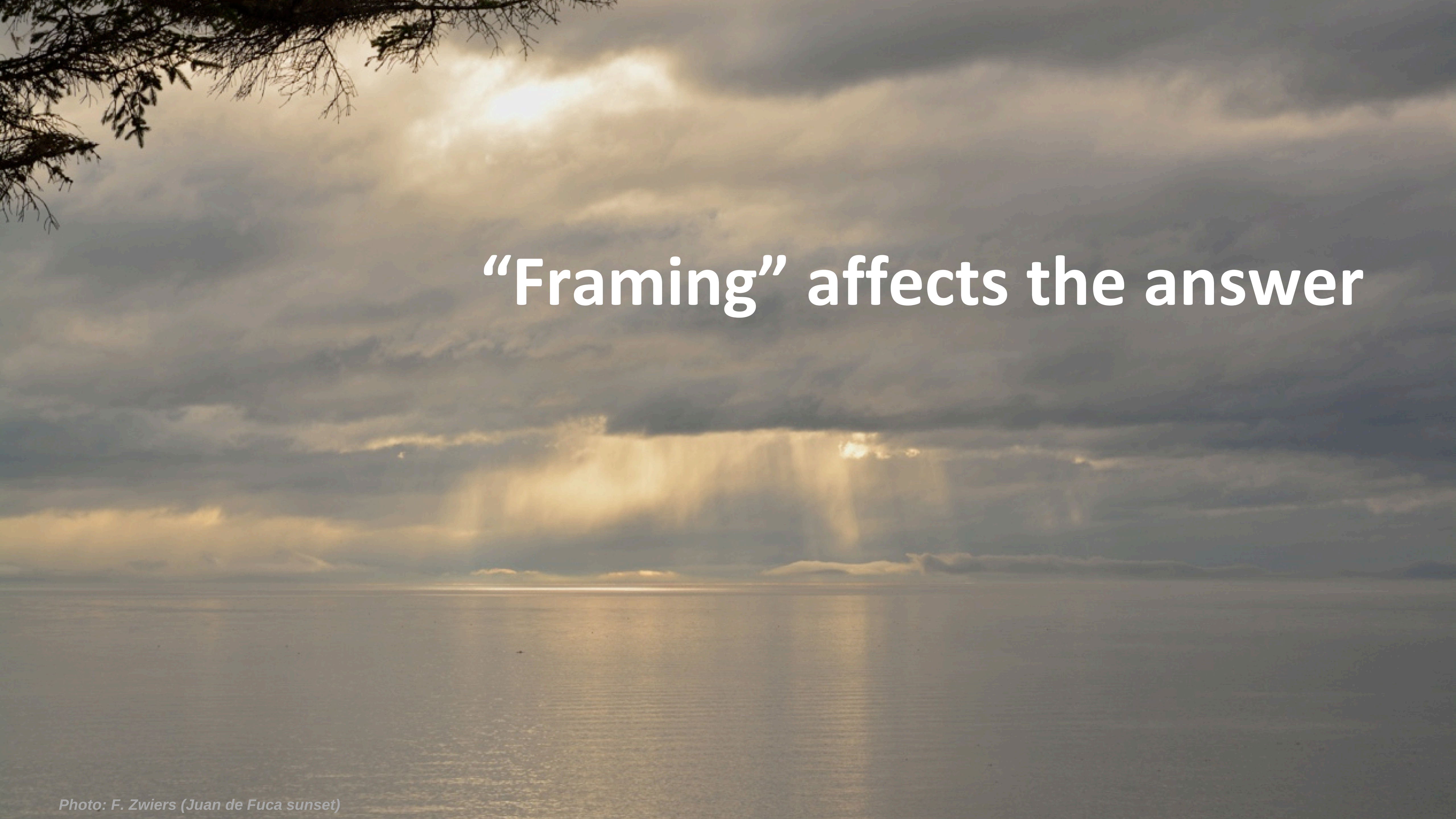


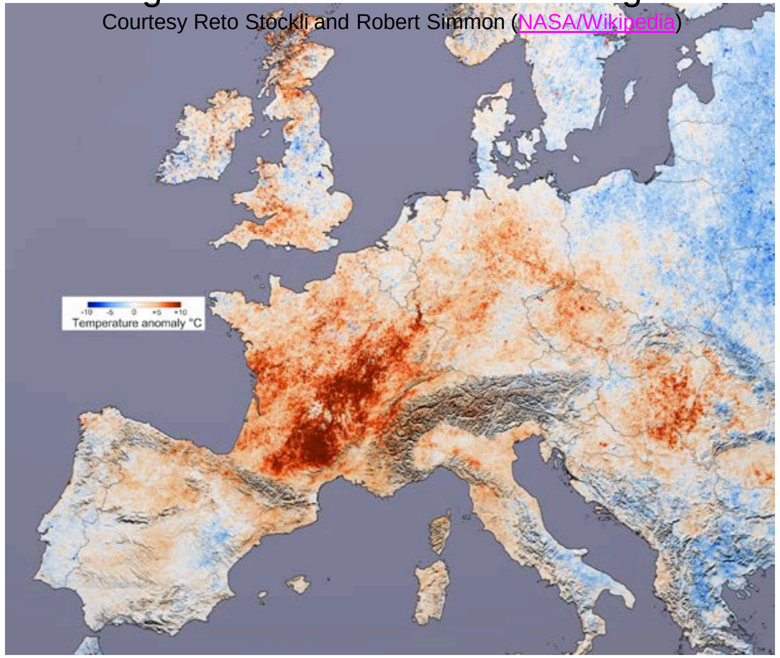
Photo: F. Zwiers (Juan de Fuca sunset)

Framing → How the question is posed

- How is the ”event” defined?
- What sources of unforced variability are controlled?
  - No sources control?
  - Sea-surface temperature pattern?
  - Circulation pattern?
- What question is asked about the defined event?
  - Likelihood?
  - Frequency?

20 July – 20 Aug 2003 vs the same period averaged over 2000-2004 excluding 2003

Courtesy Reto Stöckli and Robert Simmon (NASA/Wikipedia)



JJA temperature anomalies relative to 1961-1990

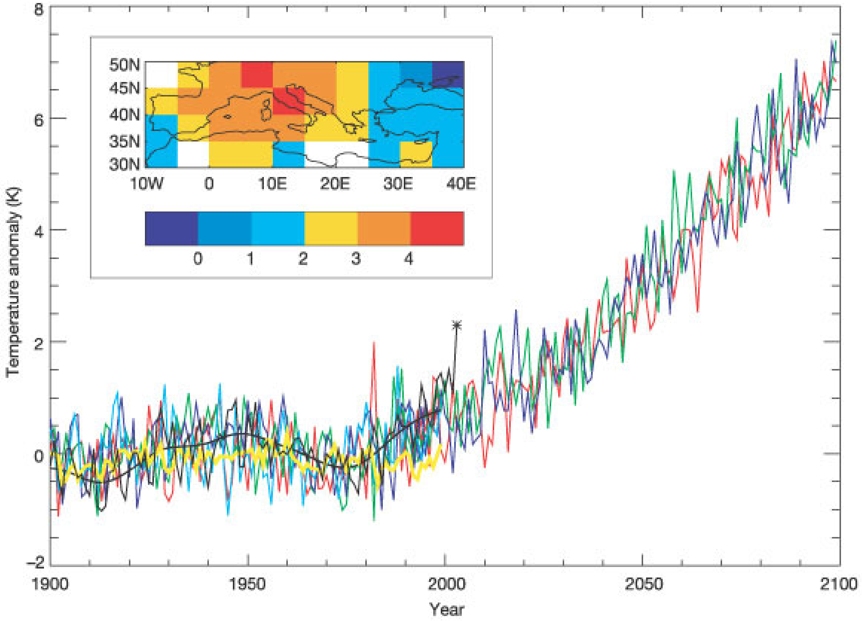


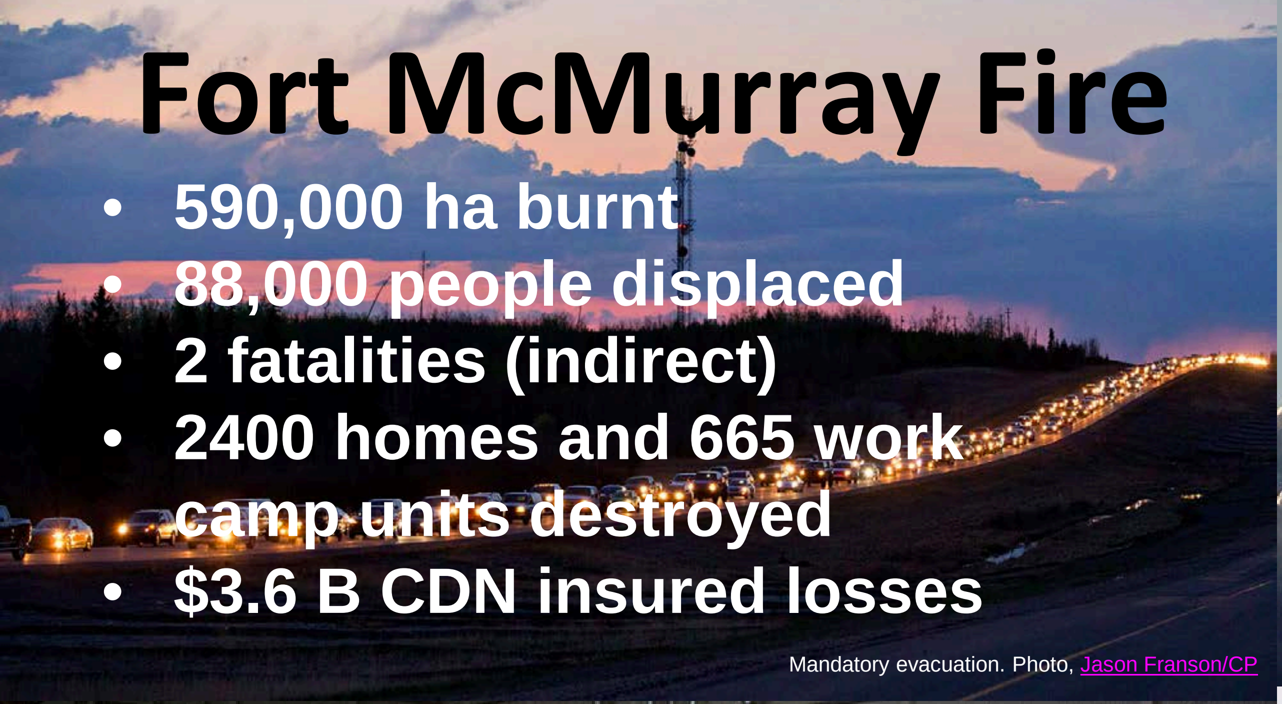
Figure 1, Stott et al., 2004

Event Attribution Examples

Photo: F. Zwiers

Fort McMurray Fire

- 590,000 ha burnt
- 88,000 people displaced
- 2 fatalities (indirect)
- 2400 homes and 665 work camp units destroyed
- $3.6 B CDN insured losses


Mandatory evacuation. Photo, Jason Franson/CP

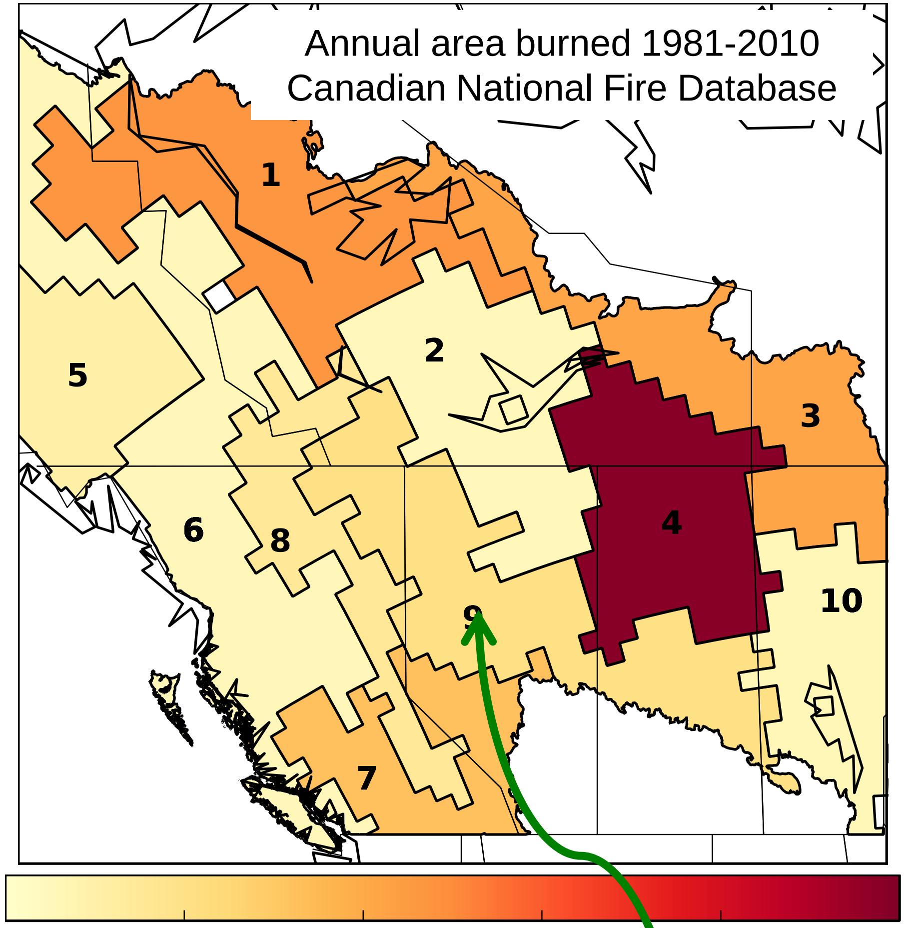

Avian escape. Photo, Mark Blinch/Reuters


Edmonton Expo Centre at Northlands. Photo, Chris Bolin


Timberlea. Photo, Chris Bolin

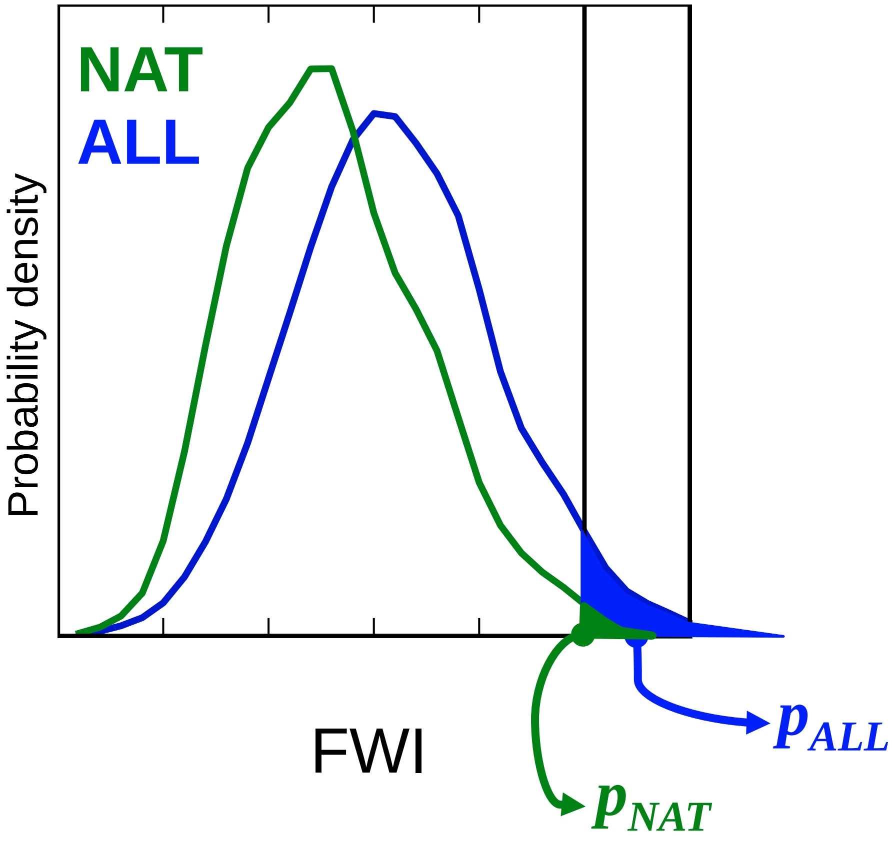
Fire risk (Kirchmeier-Young et al, 2017)

- We ask whether human induced climate change has affected fire risk in the“Southern Prairie” Homogeneous Fire Regime zone
- Measure fire risk using “CWFIS” system indicators
  - Fire Weather Index
  - Fine Fuels Moisture Code
  - Duff Moisture Code
  - Drought Code

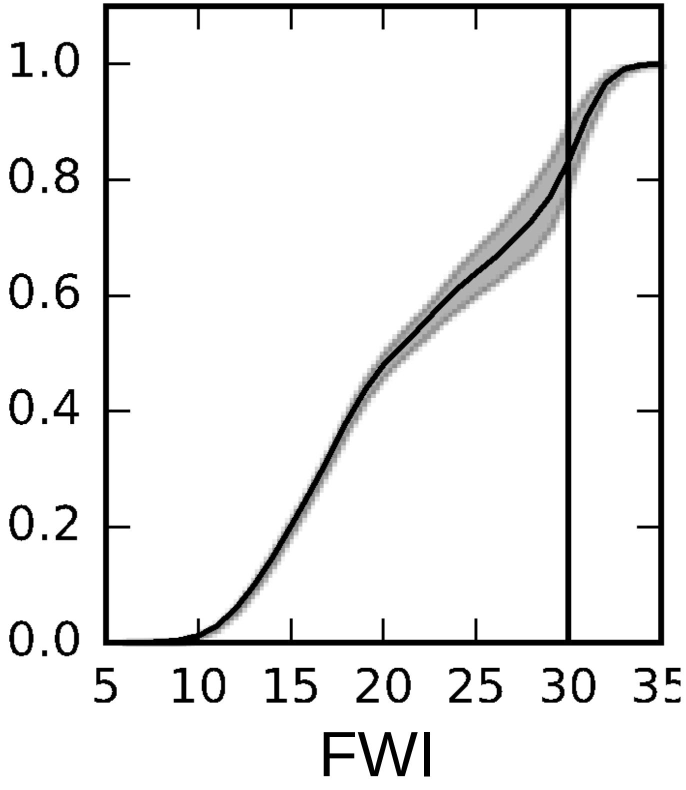


- These indices depend on temperature, relative humidity, wind speed, and precipitation

Fire Weather Index for Southern Prairies HFR for the current decade (2011-2020)



$$FAR = \frac{p_{ALL} - p_{NAT}}{p_{ALL}}$$



CWFIS "Extreme" FWI level = 30

Observed FWI level in Fort Mac area ≈ 40

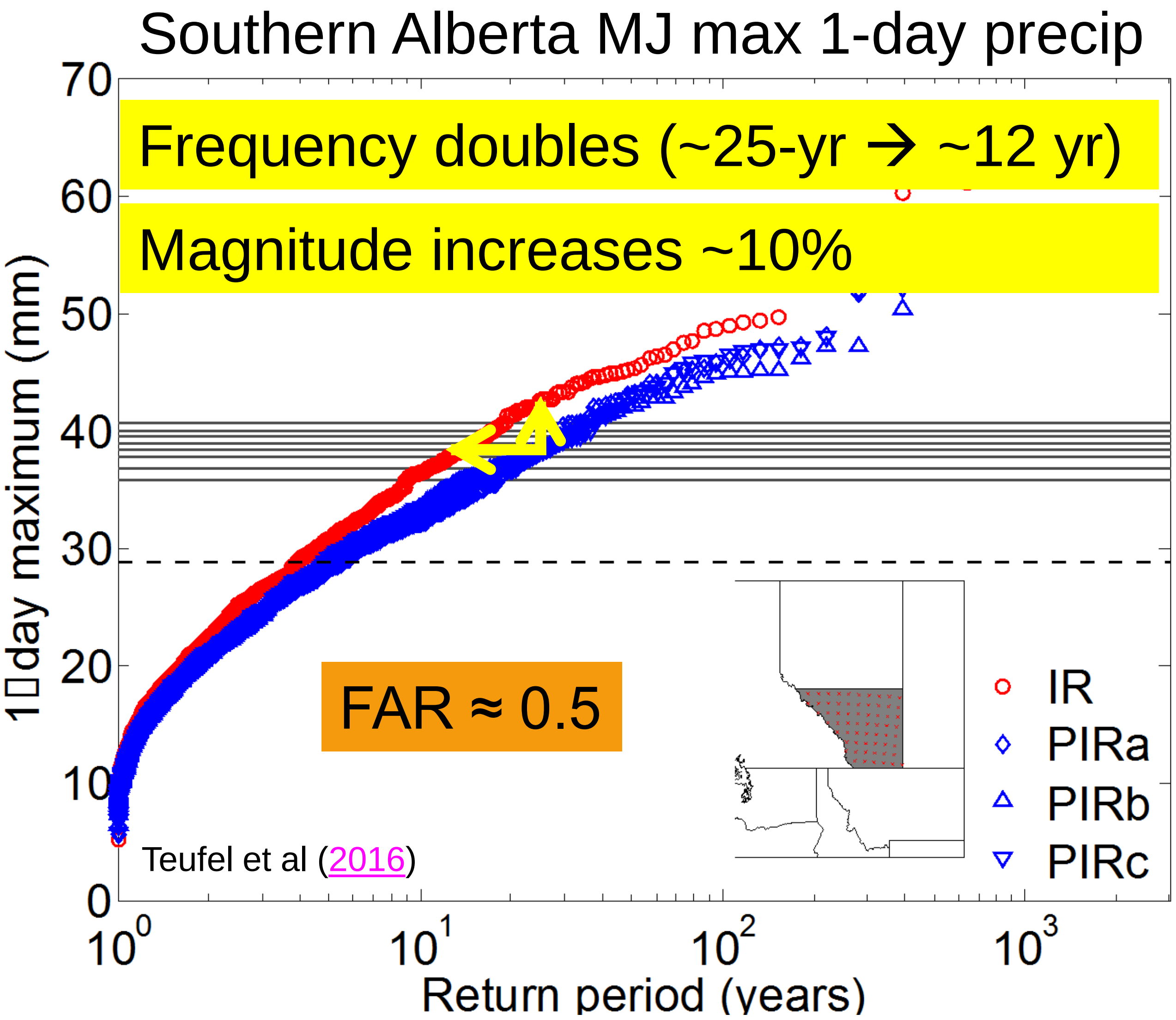
Calgary flood, June, 2013

- 100,000 displaced, 5 deaths
- Costliest (?) disaster event in Canadian history
- Estimated $5.7B USD loss ($1.65B USD insured)

Calgary East Village (June 25, 2013), courtesy Ryan L.C. Quan

Calgary floods

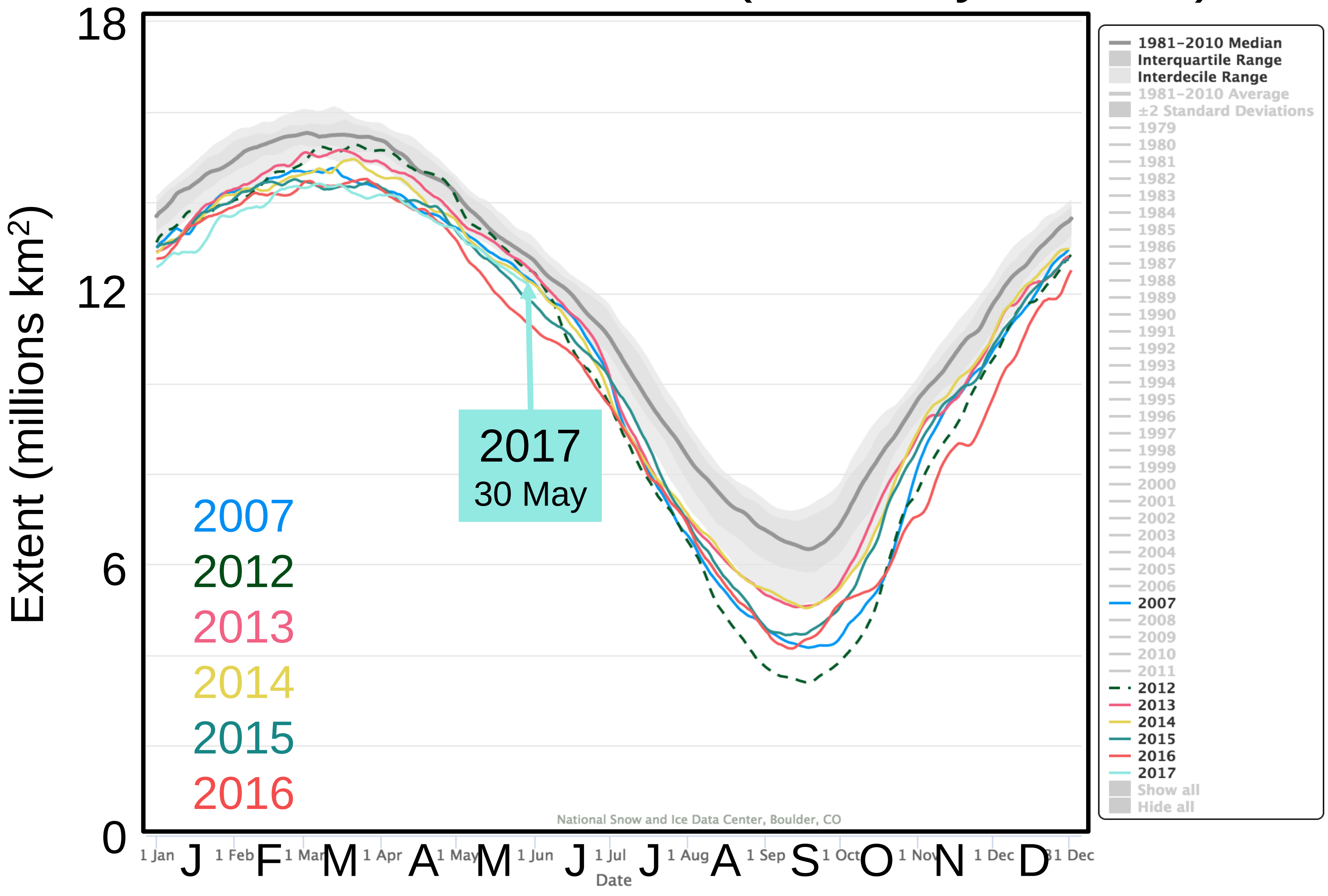
Distribution of annual May-June maximum 1-day southern-Alberta precipitation in CRCM5 under factual and counter-factual conditions (conditional on the prevailing global pattern of SST anomalies)



Record low Arctic sea ice cover - 2012

Photo: F. Zwiers (approach to Alert, Aug., 2009)

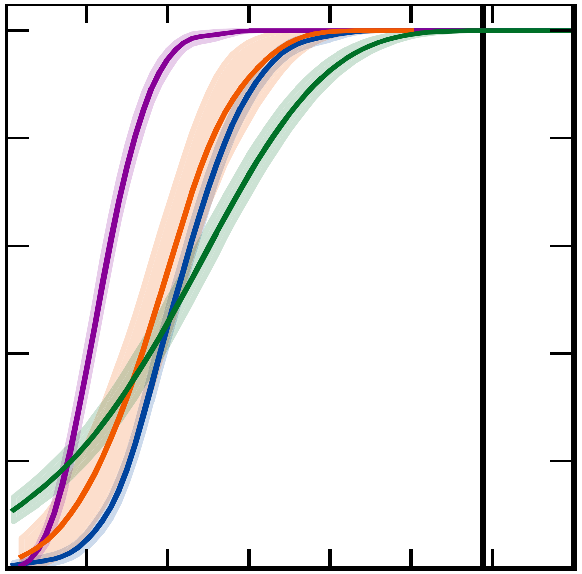
Arctic Sea Ice Extent (courtesy NSIDC)



Arctic sea-ice extent event attribution

Fraction of attributable risk

$$\frac{p_{ALL} - p_{NAT}}{p_{ALL}}$$



Risk ratio

1,000,000
100,000
10,000
1,000
100
10
1

$$\frac{p_{ALL}}{p_{NAT}}$$

All models indicate an event of a magnitude equal to or more extreme than the 2012 record minimum would be *virtually impossible* under natural forcing alone.

Anthropogenic forcing is a necessary, but not sufficient cause.

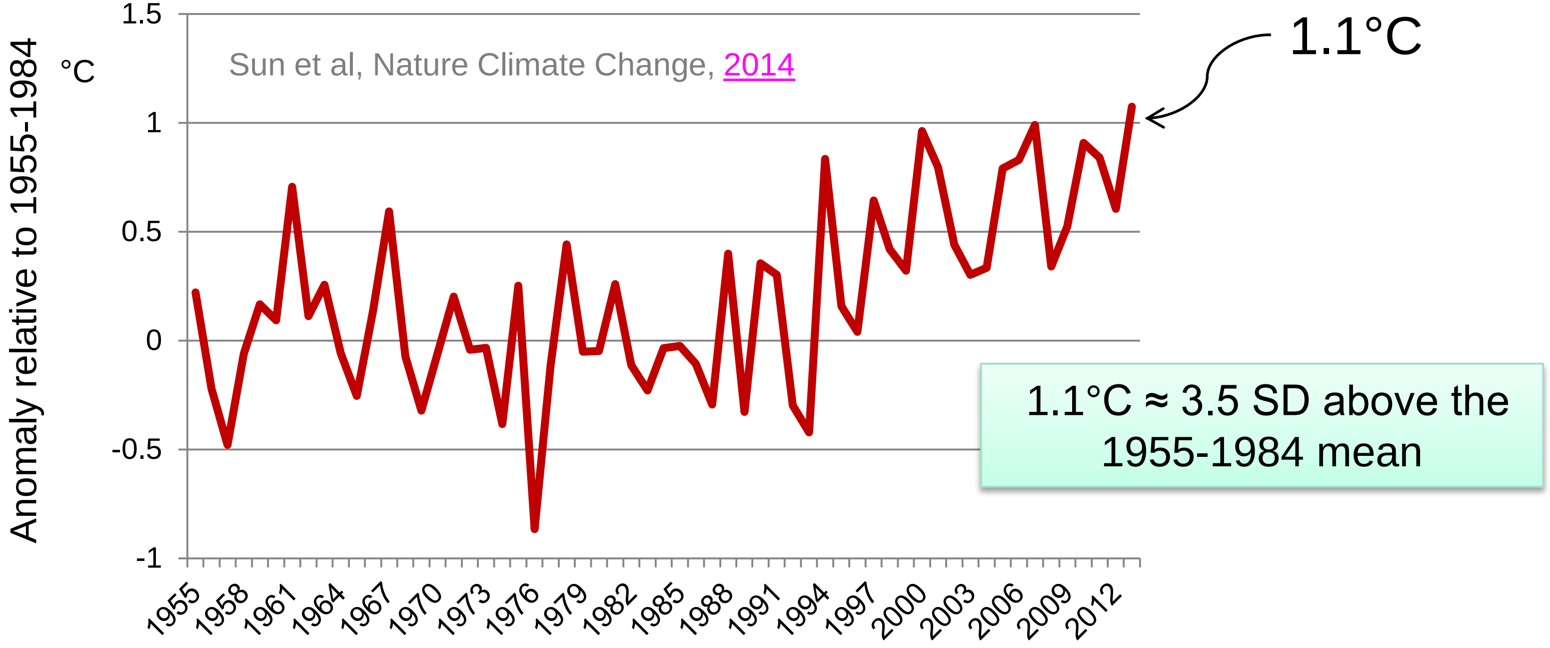
Kirchmeier-Young et al (2017)

China’s Hot Summer of 2013

- Impacts included estimated $10B USD agricultural yield loss

Photo: F. Zwiers (Yangtze River)

How rare was JJA of 2013?



- Estimated event frequency
  - once in 270-years in control simulations
  - once in 29-years in "reconstructed" observations
  - once in 4.3 years relative to the climate of 2013
- Fraction of Attributable Risk in 2013: $(p_1 – p_0)/p_1 \approx 0.984$
- Prob of "sufficient causation": $PS=1-((1-p_1)/(1-p_0)) \approx 0.23$

Projected event frequency

RCP4.5

RCP8.5

Frequency

Mean temp

23%, 4.3-yr →

Conclusions

Photo: F. Zwiers (Ucluelet)

Conclusions

- Understanding of the impact of anthropogenic forcing on many types of observed extremes remains limited
  - Relatively high confidence for temperature extremes
  - Some confidence in precipitation extremes
  - Can say relatively little about storms, droughts, floods
- Often very limited by data (models and methods can be improved; historical data is much harder)
- Need further methodological development and improved process understanding
- Event attribution is increasingly undertaken
  - Still much to do to develop methods and capabilities, understand implications of framing choices, and develop objective evaluation techniques

Communications
– bringing science into focus

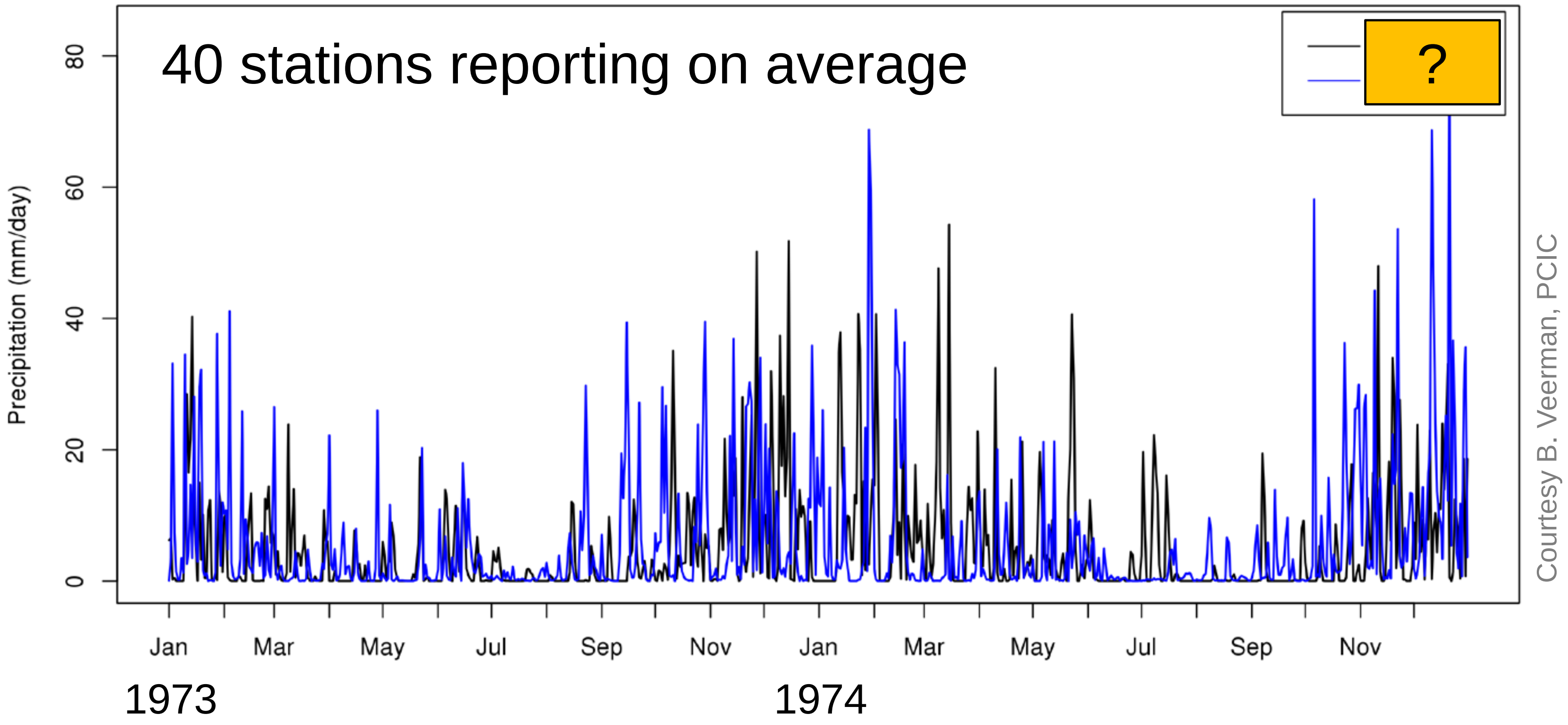
Photo: F. Zwiers (Fern uncurling, Botanical Beach)

Communications

- Three kinds of opportunities linked to extreme events
  - During the event
  - During the (extended) media cycle
  - When eventual full studies are complete
- Responsibility as scientists is distinct from that as individuals
  - It is to communicate the facts and the derived scientific information.
  - To ensure both can be comprehended by users, and that the distinction between facts and information is understood.
- We need to …
  - understand that the receptivity of users to our messages is affected by how we direct our communication
  - teach users to challenge facts and information, and defend science.


Questions?
https://www.pacificclimate.org/
Photo: F. Zwiers

Mean daily precipitation in the MIROC4h grid box centered on 49.1N, 123.2W (Vancouver)

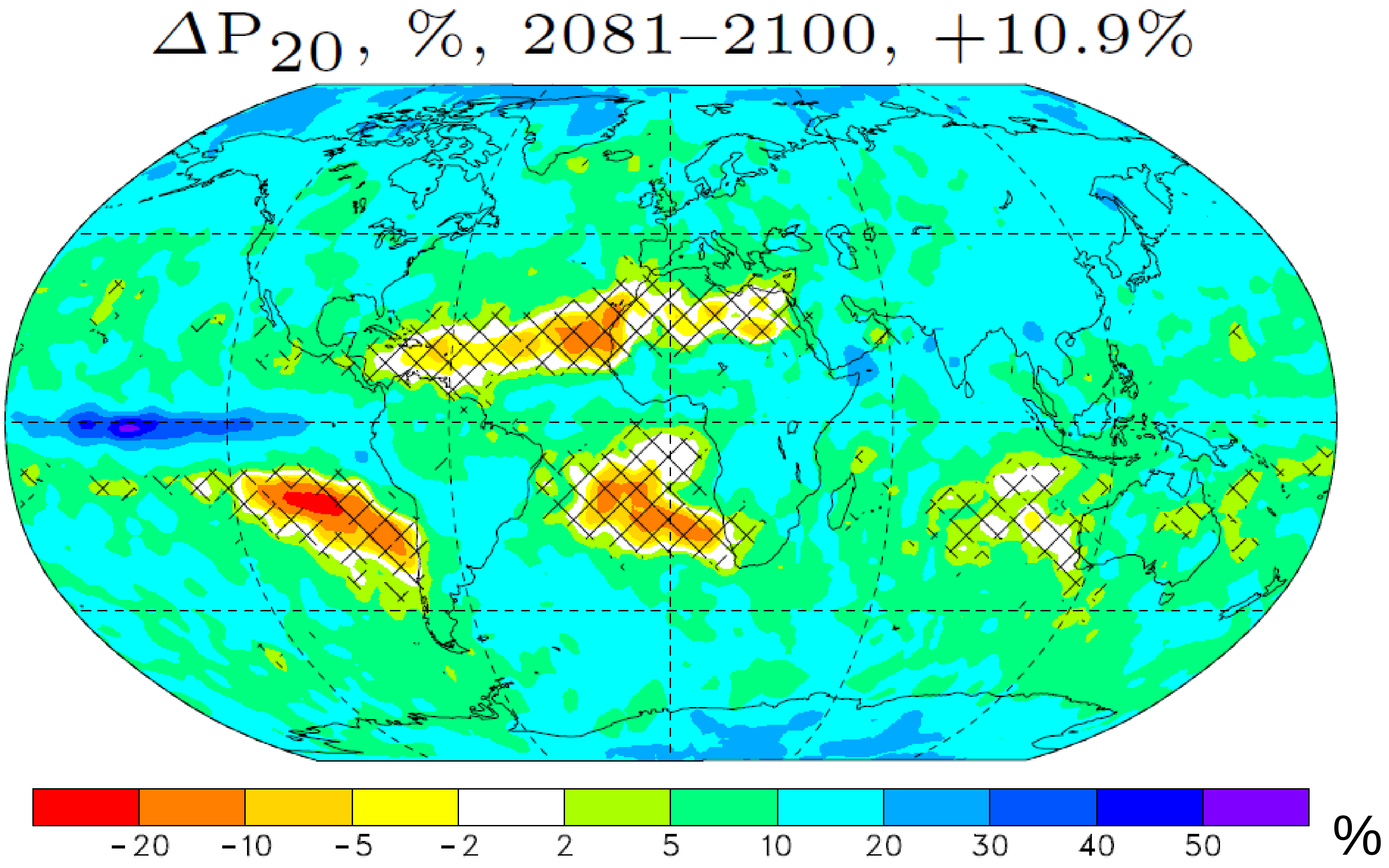


For some evaluation of CMIP5 models wrt precipitation extremes see

- for indices, Sillmann et al (2013, JGR),
- for long-period return values, Kharin et al (2013, Climatic Change)

CMIP5 RCP4.5 precipitation projections

Change in 20-yr extremes relative to 1986-2005

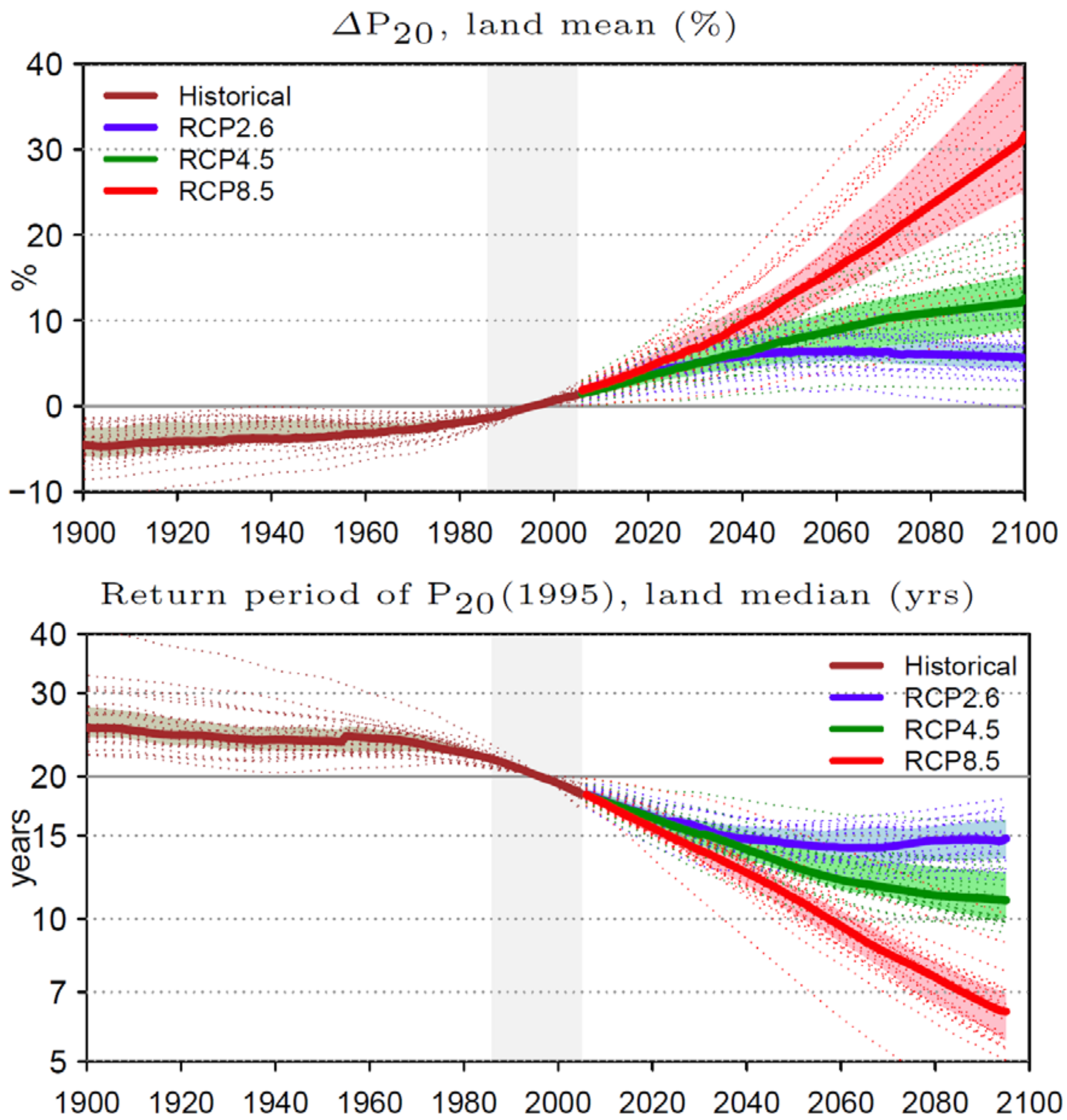


Kharin et al (2013, Fig. 4)

CMIP5 Projections of 20-yr 1-day events

Event magnitude
(relative to 1986-2006)

Return period
(relative to 1986-2006)

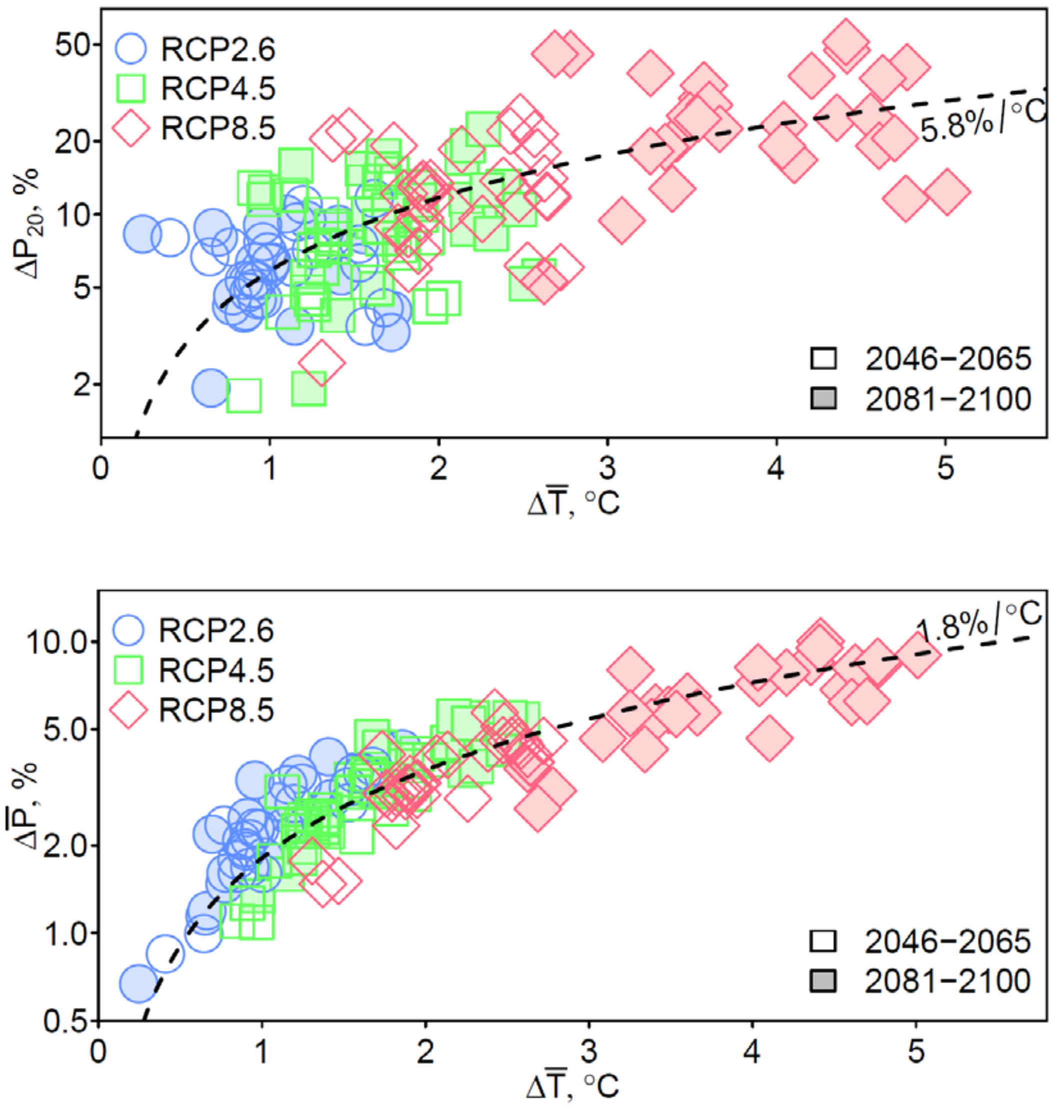


Kharin et al (2013, Fig. 2)

CMIP5 precipitation sensitivity

Planetary sensitivity of 20-year extremes

Sensitivity of global mean precipitation



Kharin et al (2013, Fig. 5)