

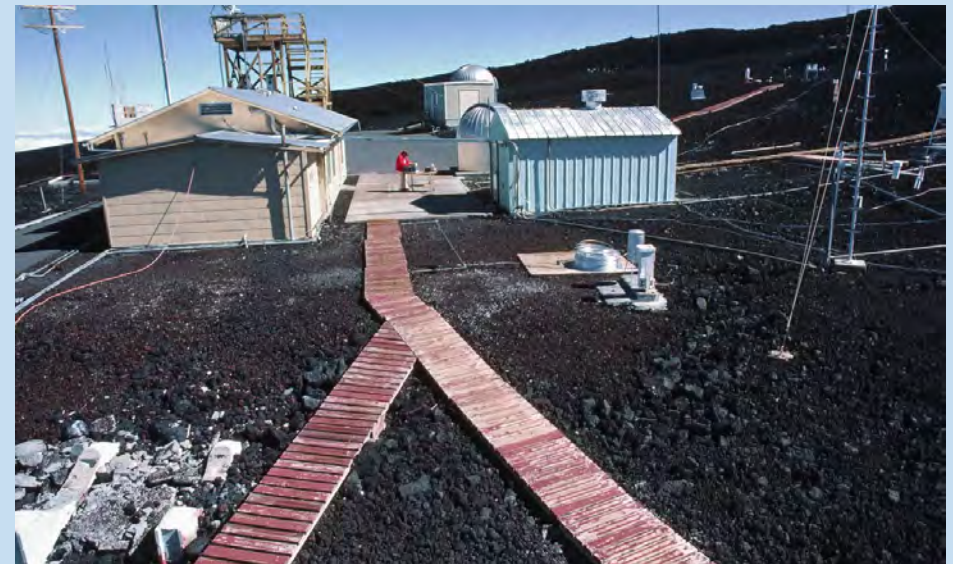
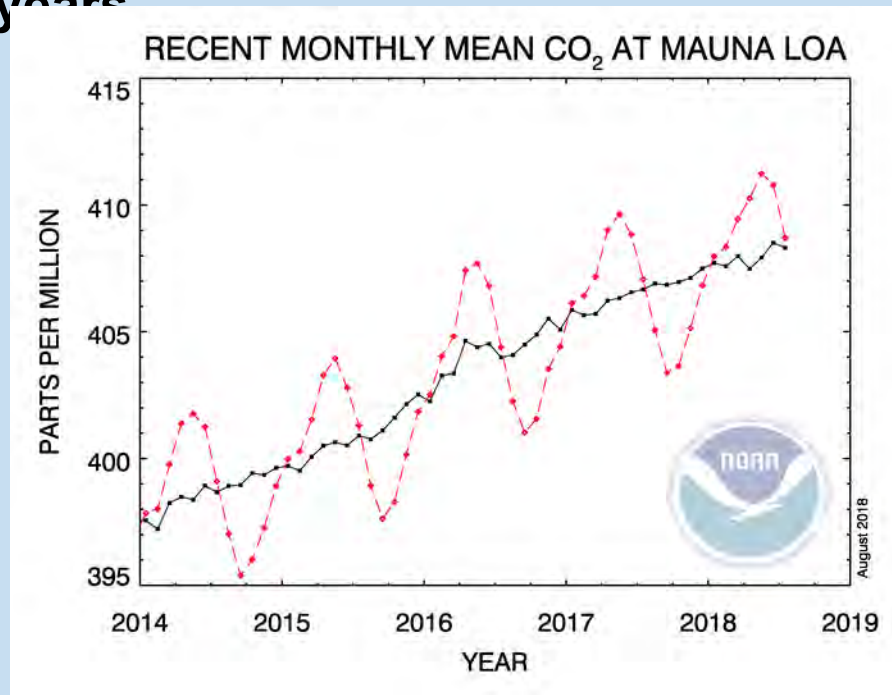
# Climate change update for the Saskatoon Energy Management Task Force

By Peter Prebble

September 5, 2018

Prepared for non-profit educational purposes

2018 marked the first time in human history when the concentration of carbon dioxide in the atmosphere exceeded 410 parts per million. Current CO<sub>2</sub> concentrations in the atmosphere significantly exceed natural variability seen over the past 800,000 years. This is the result of manmade CO<sub>2</sub> emissions from fossil fuel burning and deforestation. Once released, CO<sub>2</sub> remains a heat trapping gas in the atmosphere for an average of 100 years.



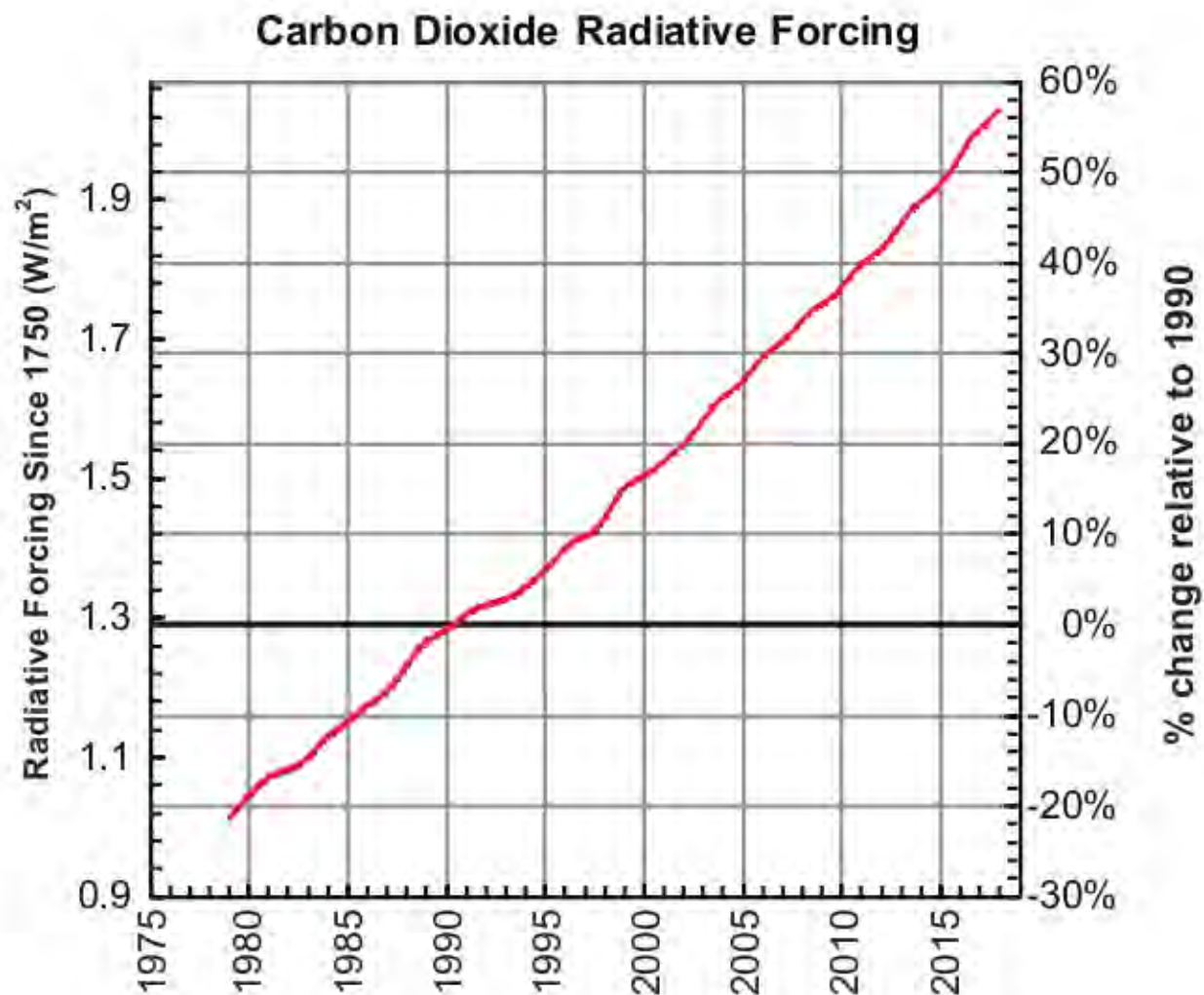
Sources: (Left) National Oceanic and Atmospheric Administration, <https://www.esrl.noaa.gov/gmd/ccgg/trends/>

(Right) The Mauna Loa weather observatory, which measures atmospheric CO<sub>2</sub>. Photograph: James L. Amos/Getty Images

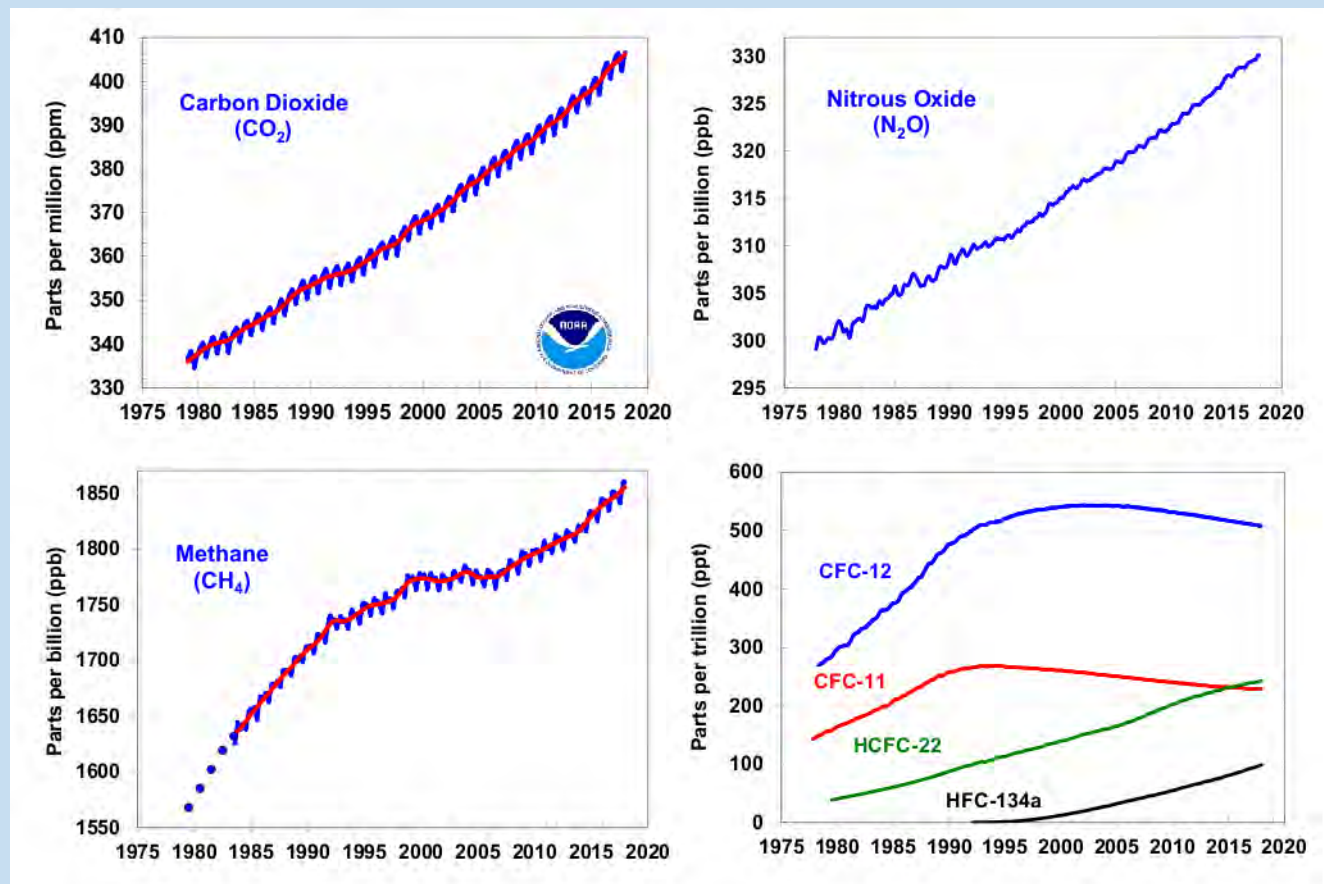
Reference for the atmospheric lifetime of CO<sub>2</sub> - *Climate Change 2013: The Physical Science Basis*, Intergovernmental Panel on Climate Change, page 1106.

**The direct warming influence of carbon dioxide on climate has increased by over 50% since January 1, 1990 – the direct result of manmade CO<sub>2</sub> emissions over the past few decades.**

Source: THE NOAA ANNUAL GREENHOUSE GAS INDEX (AGGI)  
Updated Spring 2018  
<https://www.esrl.noaa.gov/gmd/aggi/aggi.html>

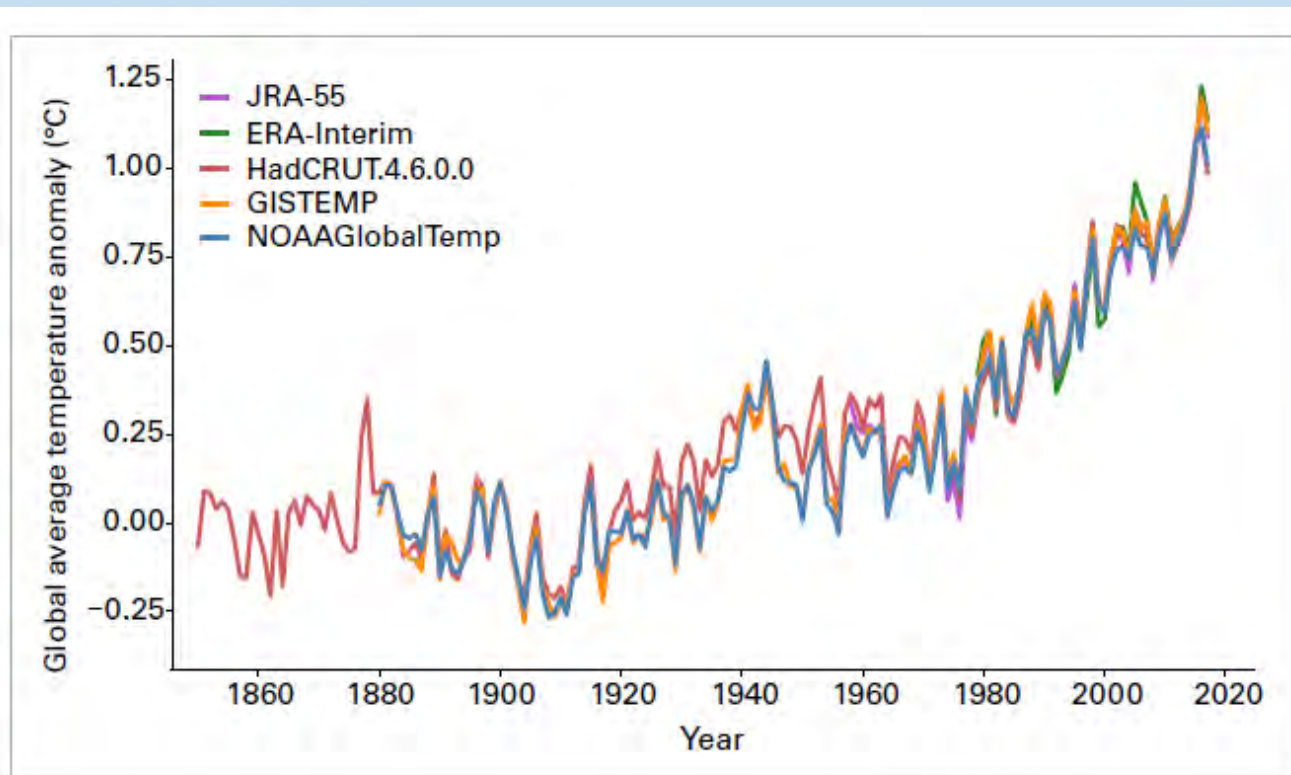


The atmospheric concentration of methane and nitrous oxide, the other two long-lived greenhouse gases that most impact on climate warming have also continued increasing, primarily due to human-produced releases. Graph source: NOAA Annual GHG Index, Spring 2018 <https://www.esrl.noaa.gov/gmd/aggi/aggi.html>



**The elevated concentration of these greenhouse gases in the atmosphere has led to a rise in global average temperature, as illustrated below. Global mean temperature in 2017 was about 1.1 °C above the pre-industrial global average temperature.**

**Graph Source: WMO Statement on the State of the Global Climate in 2017 Published March 22, 2018. The graph shows global mean temperature anomalies, with respect to a 1850-1900 baseline, and includes reports from 5 different global monitoring agencies.**

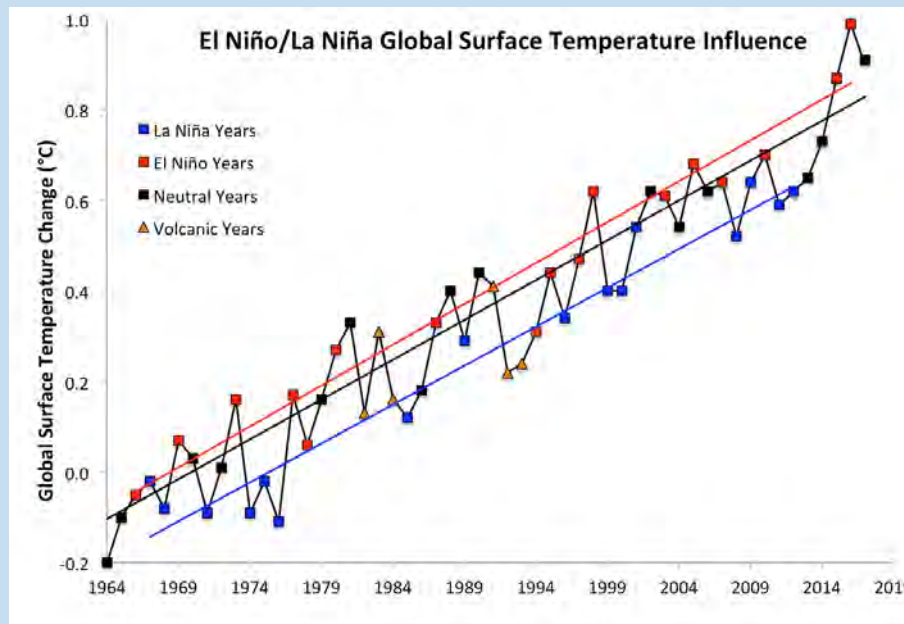




**Examples of the impact of higher greenhouse gas concentrations in the atmosphere: 2014, 2015, 2016 and 2017 are the warmest years on record globally. 2016 had the highest global average surface temperature of any year on record. 2017 was the warmest “neutral year” since worldwide temperature records have been kept. Seventeen of the 18 warmest years on record have occurred since the turn of the century.**

**Data source for graph: NASA**

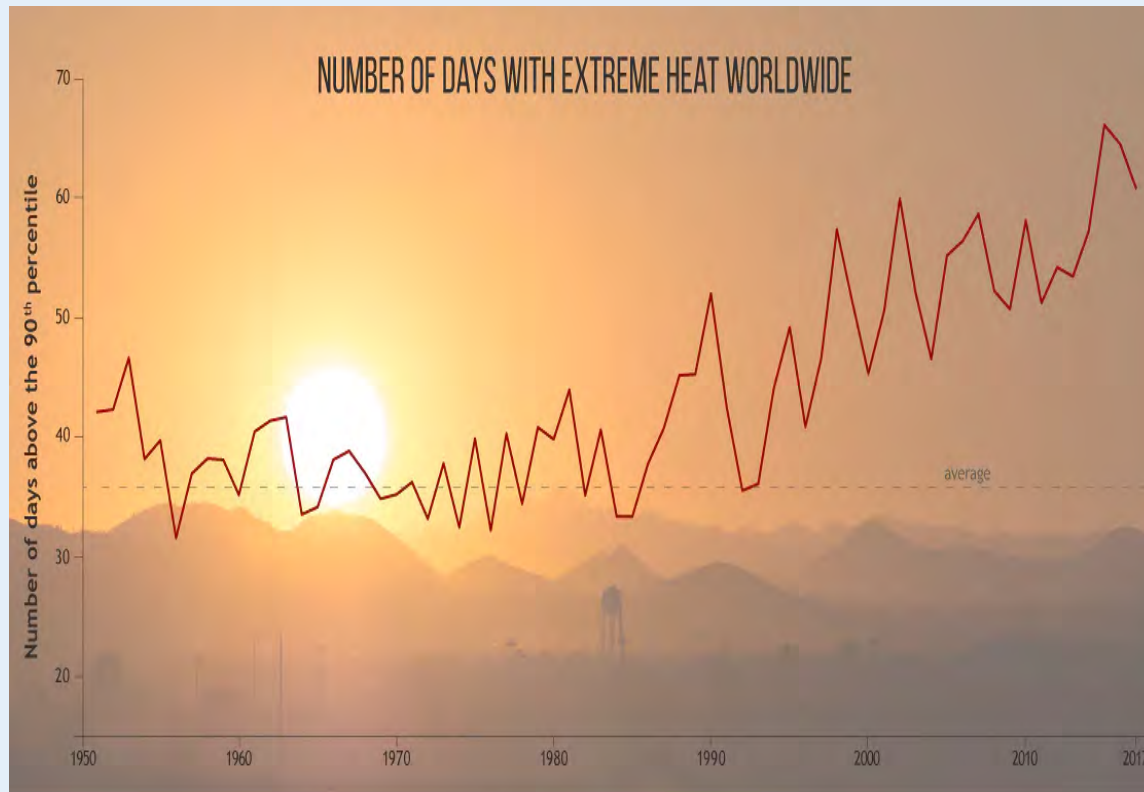
**Note that El Niño years tend to have a higher global average temperature, while La Niña years have a cooling influence.**



**1964–2017 global surface temperature data from Nasa, divided into El Niño (red), La Niña (blue), and neutral (black) years, with linear trends added**

**Graph source: <https://www.theguardian.com/environment/climate-consensus-97-per-cent/2018/jan/02/2017-was-the-hottest-year-on-record-without-an-el-nino-thanks-to-global-warming> Illustration: Dana Nuccitelli**

**The risk of heat-related death or illness has risen steadily since 1980. The World Meteorological Organization reports 30% of the world's population now lives in climatic conditions that deliver potentially deadly heat waves at least 20 days per year.**



**Number of hot days each year since 1950, that are above the 90<sup>th</sup> percentile (relative to a 1961-90 baseline)**

Source: NOAA <http://www.noaa.gov/news/2017-was-one-of-three-warmest-years-on-record-international-report-confirms>  
Information reference: WMO Statements on the State of the Global Climate in 2017, page 4, Executive Summary

# Examples of heat records set in 2017

- On January 27, 2017 Puerto Madryn, Argentina recorded the highest temperature south of 43 degrees south anywhere in the world (43.4 degrees Celsius).
- On May 28, 2017 Turbat, Pakistan recorded the world's highest temperature for the month of May: 53.5 degrees Celsius.

Sources: <https://www.actu-environment.com/media/pdf/news-31837-state-climate-2017-noaa.pdf> and "Turbat reels under record heatwave", May 29, 2017, <https://www.dawn.com/news/1335991>



# Examples of heat records set in 2018

- In the summer of 2018 the temperature climbed to 51.3 Celsius, the highest temperature ever reliably measured in Africa.
- Chino, just north of Los Angeles hit a record of 48.9C. in 2018.
- Montreal, Quebec recorded its highest temperature in history (36.6 Celsius) and reported over 70 heat-related deaths. On August 10, 2018 Calgary set an all time-high of 36.5 Celsius.
- In 2018 the temperature soared to an unprecedented 32 degrees Celsius 60 miles north of the Arctic Circle.
- **Sources:** “Red-hot planet: All-time heat records have been set all over the world during the past week”, by Jason Samenow *The Washington Post*, July 5, 2018, [https://www.washingtonpost.com/news/capital-weather-gang/wp/2018/07/03/hot-planet-all-time-heat-records-have-been-set-all-over-the-world-in-last-week/?noredirect=on&utm\\_term=.ff20e18298ea](https://www.washingtonpost.com/news/capital-weather-gang/wp/2018/07/03/hot-planet-all-time-heat-records-have-been-set-all-over-the-world-in-last-week/?noredirect=on&utm_term=.ff20e18298ea)
- <https://www.theweathernetwork.com/news/articles/extreme-heat-high-temperatures-prairies-records-broken-heat-warnings-alberta-saskatchewan-manitoba/107990>
- “From Siberia to Africa to North America, it’s been unusually hot”, CBC, July 19, 2018, <http://www.cbc.ca/news/technology/climate-change-heat-waves-1.4751633>,
- “Europe's record temperature of 48C could be beaten this weekend”, *The Guardian*, August 4, 2018.
- July sees extreme weather with high impacts, August 1, 2018 World Meteorological Organization web site, <https://public.wmo.int/en/media/news/july-sees-extreme-weather-high-impacts>
- “Heatwave sees record high temperatures around world this week”, *The Guardian*, July 13, 2018.
- <https://www.theweathernetwork.com/news/articles/world-record-heat-broken-june-snow-newfoundland-same-day/105590/> Section of the article is below:  
written June 28, 2018 Refers to June 26, 2018

# 2018 set a new world record for the highest 'low point' in overnight temperature

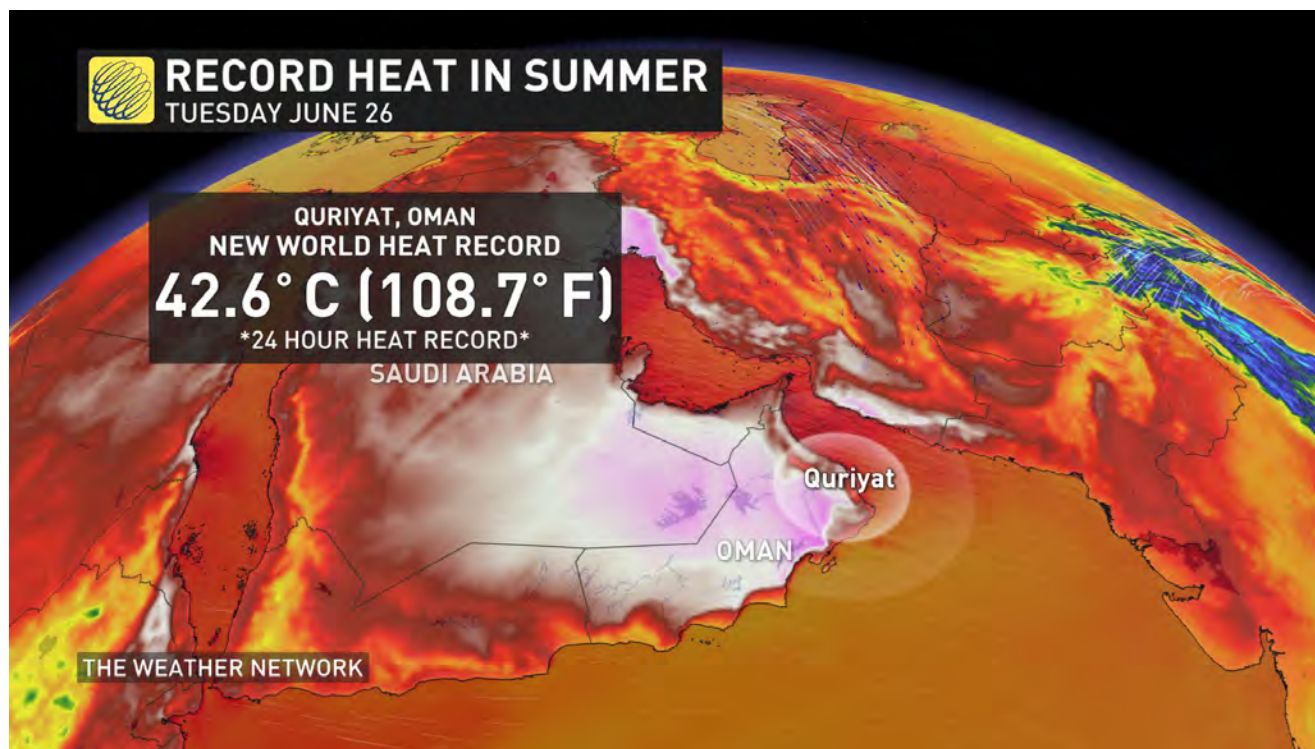
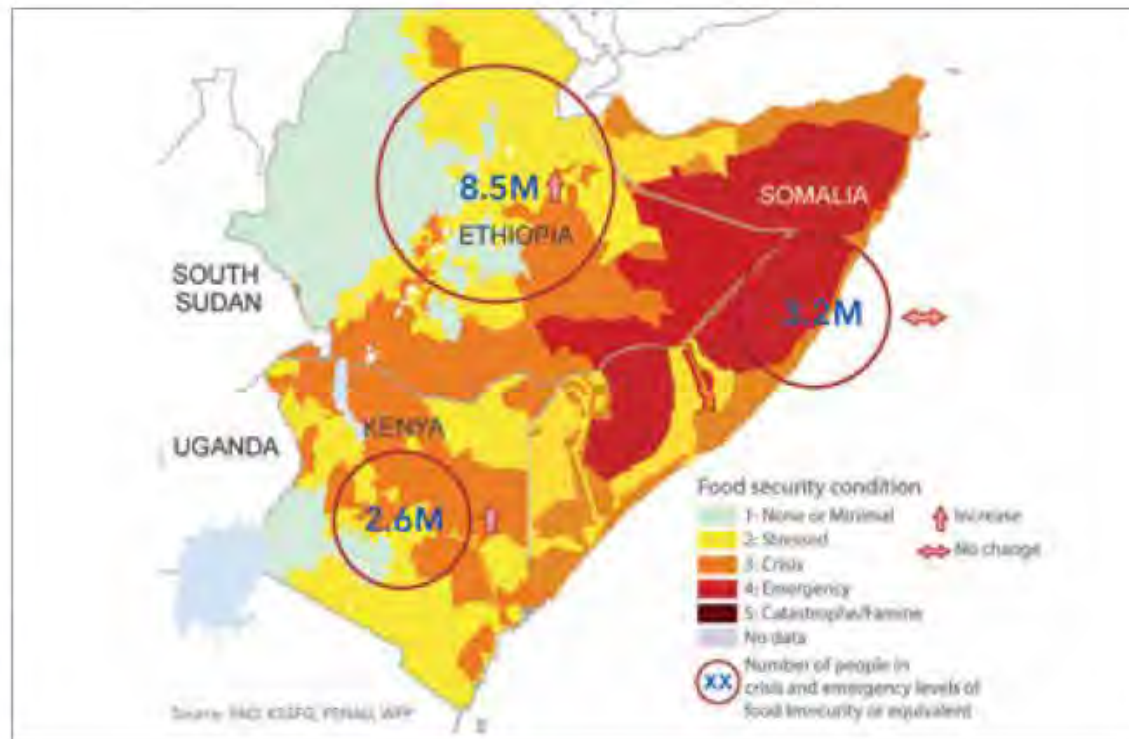


Image source: <https://www.theweathernetwork.com/news/articles/world-record-heat-broken-june-snow-newfoundland-same-day/105590/> June 28, 2018 See the section entitled 'Highest Low Temperature'. The record was broken on June 26, 2018.

**Many parts of Africa are vulnerable to droughts – made more severe by climate change. Somalia, Ethiopia and Kenya were hit hard in 2017.**

The image shows the number of severely food-insecure people in Kenya, Ethiopia and Somalia

Source: Figure 19 in WMO Statement on the State of the Global Climate in 2017 report (WMO source: 'Horn of Africa: Humanitarian Impacts of Drought', Issue 9, August 20, 2017 OCHA)





# Drought in Somalia – the UN reported more than 890,000 people were displaced there between Nov. 2016 and Dec. 2017

Source:

<https://unocha.exposure.co/ten-things-you-need-to-know-about-the-looming-famine-in-somalia> and NOAA State of the Climate 2017



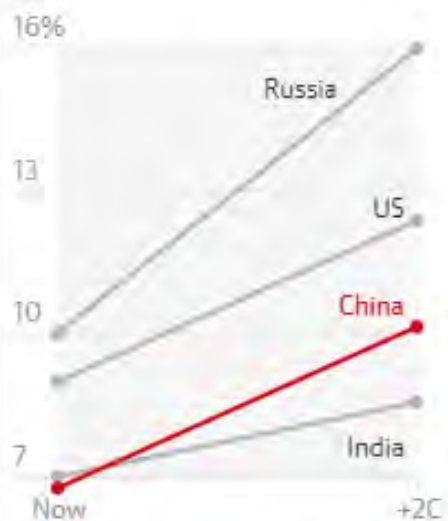
**As global average temperature rises, one of the risks to food security is increased crop damage by pests.**

Sources: "Increase in crop losses to insect pests in a warming climate", *Science*, Curtis A. Deutsch et al., August 31, 2018, and <https://www.theguardian.com/environment/2018/aug/30/crop-losses-to-pests-will-soar-as-climate-warms-study-warns>

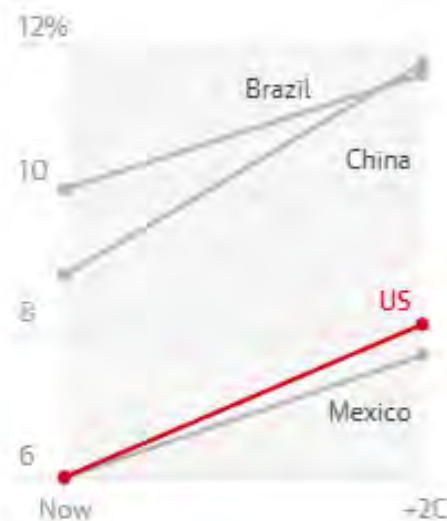
### The world's top four grain producers will lose far more to pests with just 2C of global warming

% of yield lost to field pests - top producer in red

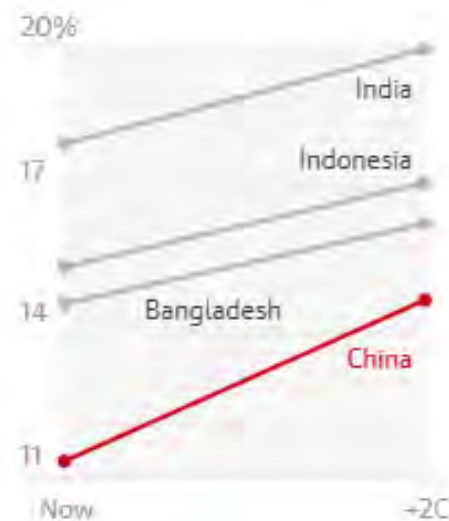
#### Wheat



#### Maize



#### Rice



Guardian graphic. Source: Deutsch et al, Science 2018



**As temperatures rise, the fire season is becoming longer and more dangerous in much of western North America. The tragic Fort McMurray wildfire in May 2016 is one example of the more dangerous forest fire season that is emerging in some parts of Canada. That fire destroyed more than 2,500 homes and forced the evacuation of over 80,000 people. The fire spread into Saskatchewan and ultimately across 590,000 hectares before being brought under control.**



Information sources: <https://business.financialpost.com/feature/in-the-shadow-of-the-beast-two-years-after-the-monster-fire-fort-mcmurray-struggles-for-a-different-future>, May 11, 2018; <https://www.cbc.ca/news/politics/fort-mcmurray-fire-connecticut-ozone-1.4305787>, September 26, 2017

**British Columbia's 2017 and 2018 experience with forest fires is a second example of the change that is occurring.**



A wildfire burns on a mountain in the distance east of Cache Creek behind a house in Boston Flats, B.C., in the early morning hours of Monday July 10, 2017. (THE CANADIAN PRESS/Darryl Dyck)

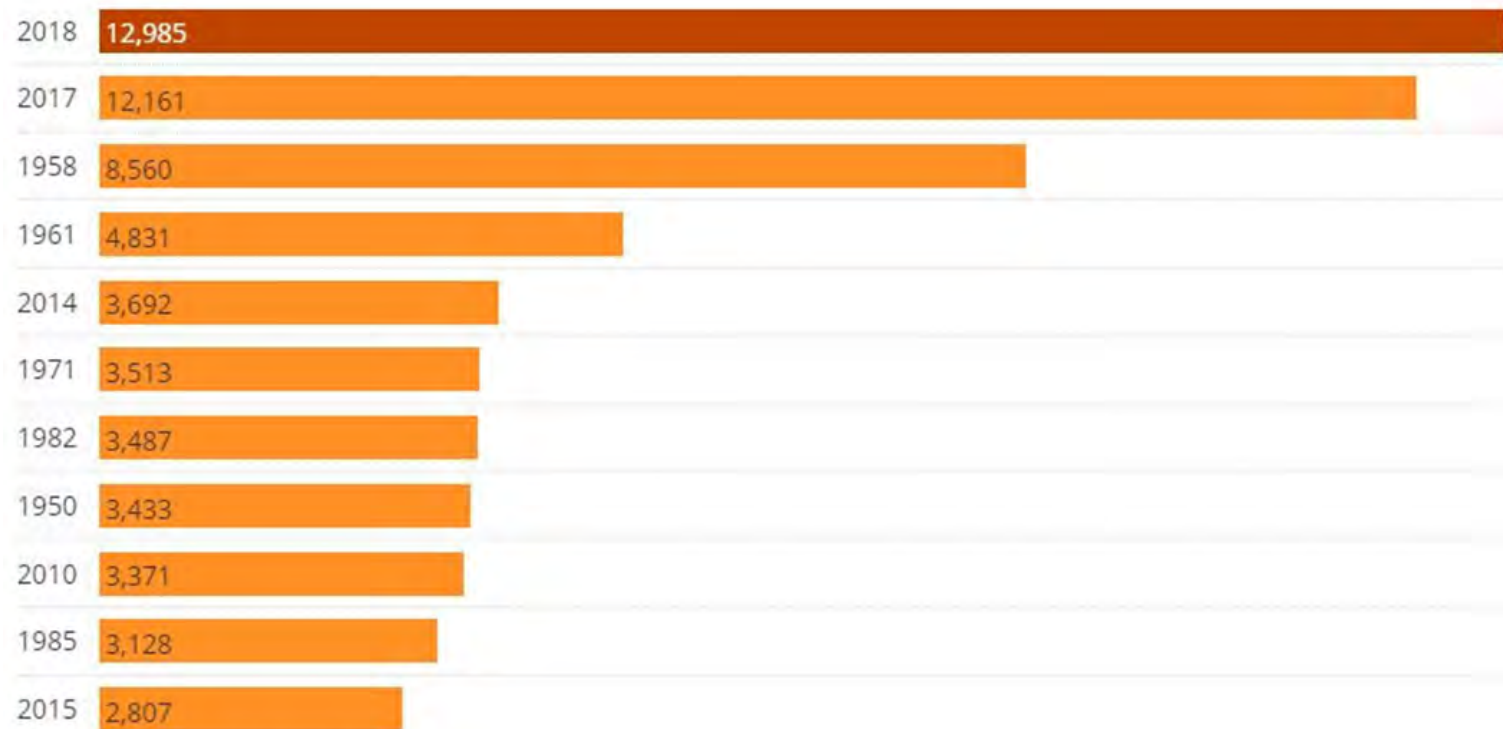


Supplied image via Parks Canada taken on July 30, 2017 of the Verdant Creek Fire in Kootenay National Park/ Assiniboine Provincial Park. PARKS CANADA

Sources: <http://bcfireinfo.for.gov.bc.ca/hprScripts/WildfireNews/Statistics.asp>; <http://www.torontosun.com/2017/07/19/bc-forest-fire-claims-at-least-41-more-homes>  
<http://vancouversun.com/news/local-news/sustained-rain-needed-to-end-devastating-b-c-wildfire-season-officials> ; [http://www.unitedchurch.ca/sites/default/files/resources/prayer\\_for\\_all\\_impacted\\_by\\_wildfires\\_in\\_bc.pdf](http://www.unitedchurch.ca/sites/default/files/resources/prayer_for_all_impacted_by_wildfires_in_bc.pdf)

## Top 10 fire seasons in B.C. since 1950

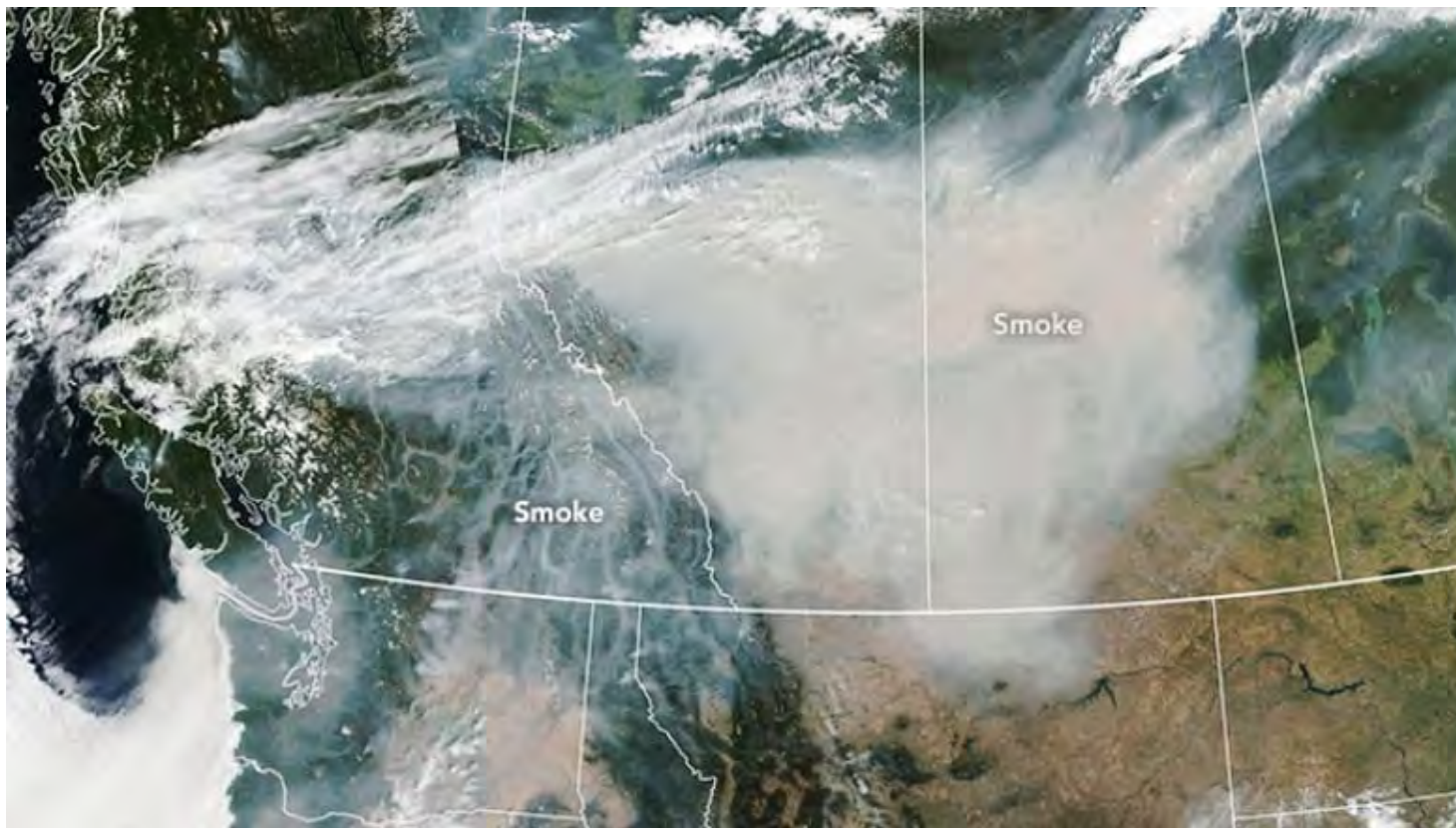
Chart shows number of square kilometres burned in wildfires each season. Does not include false alarms, nuisance fires or training fires.



*2018 data is current as of Aug. 29*

Source of chart: <https://www.theweathernetwork.com/news/articles/2018-wildfire-season-now-worst-on-record-in-british-columbia-provincial-state-of-emergency-extended/110336/>

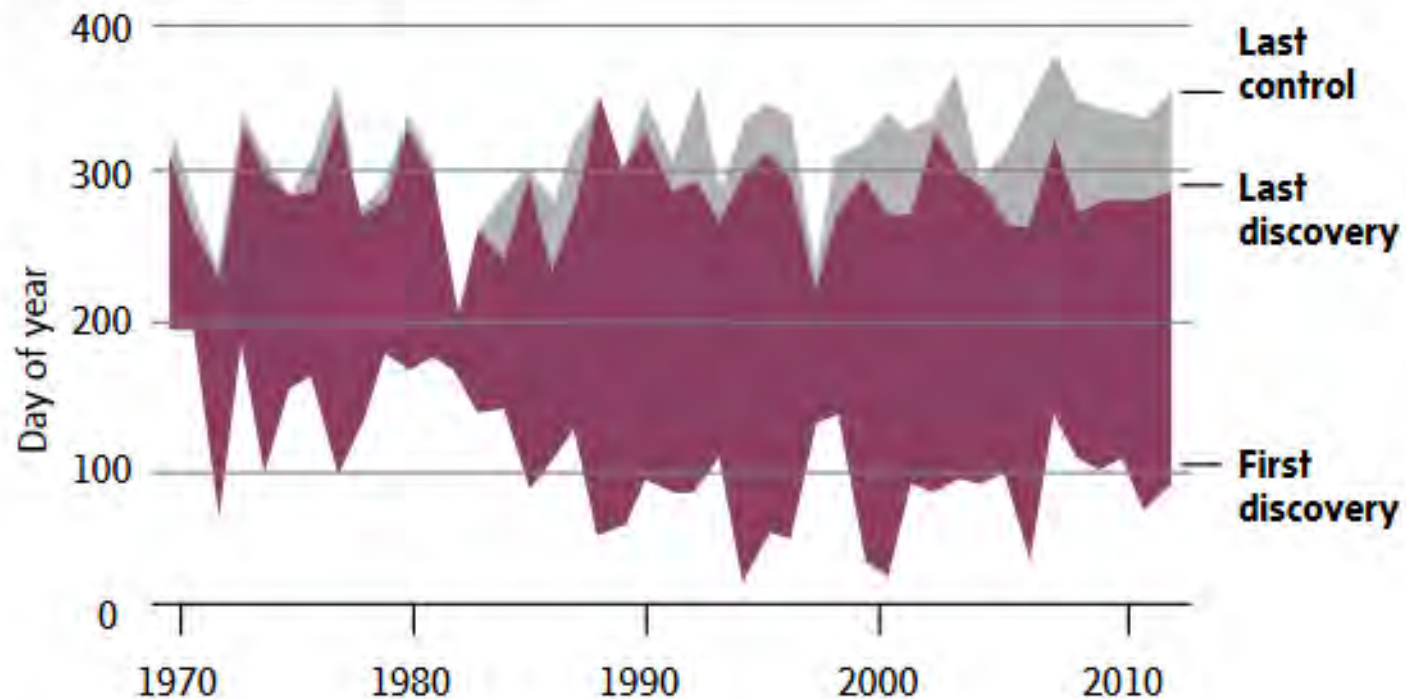
With the fires has come increased health risks associated with forest fire smoke. The satellite image below shows the smoke from fires in British Columbia drifting across Alberta and Saskatchewan on August 15, 2018 (NASA Earth Observatory/NASA GSFC/Lauren Daphin). On August 22, 2018 Calgary set a new record for the number of hours of smoke in a year. The previous record had been set in 2017.





## Fire season length in Western U.S.

Annual time between first and last large-fire discovery and last fire declared under control



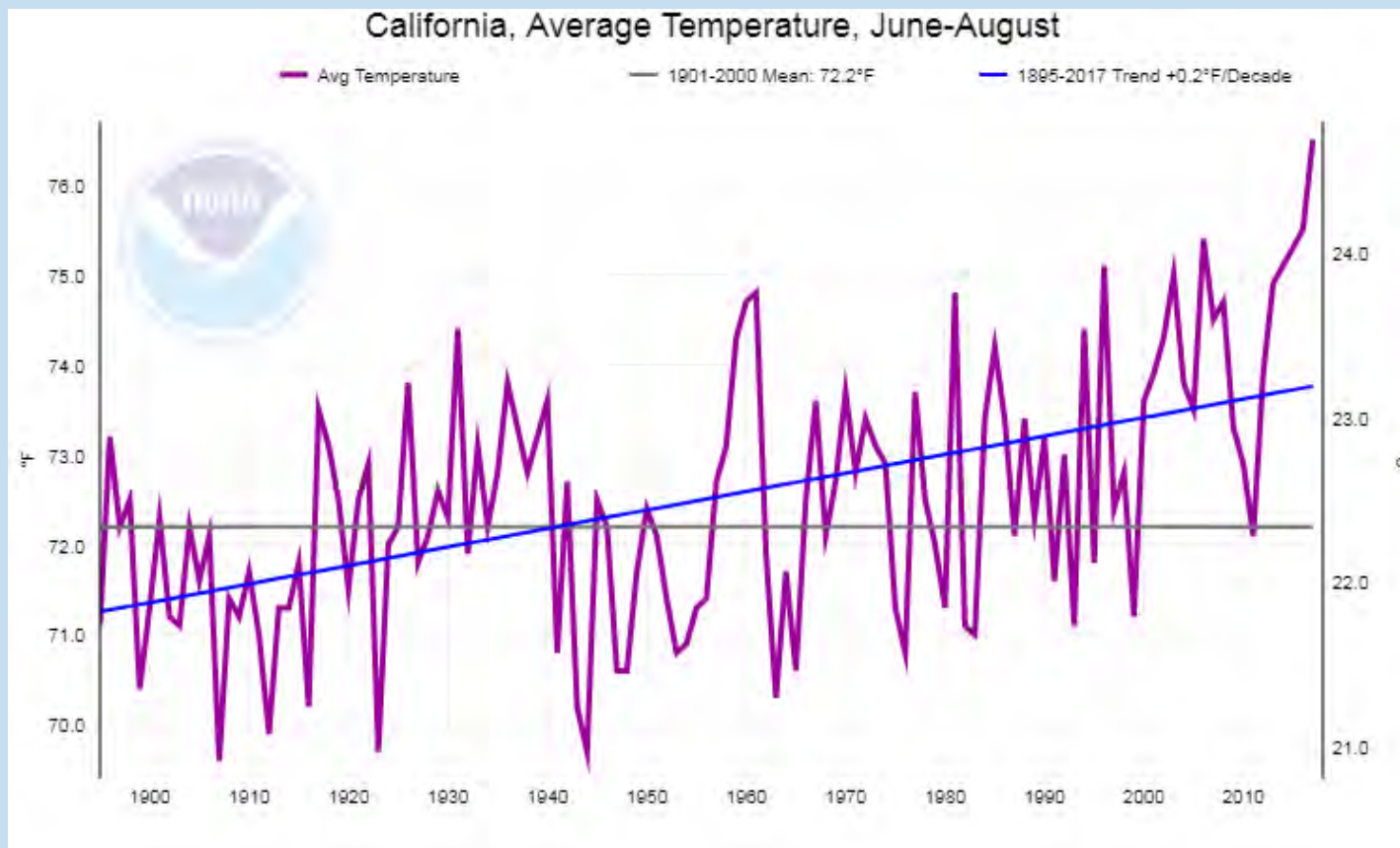
'INCREASING WESTERN U.S. FOREST WILDFIRE ACTIVITY: SENSITIVITY TO CHANGES IN THE TIMING OF SPRING,' ANTHONY LEROY WESTERLING SIERRA NEVADA RESEARCH INSTITUTE, UNIVERSITY OF CALIFORNIA

Source: Globe and Mail, September 4, 2018, Folio page



**Record high summer temperatures in California are increasing fire risk in that state.**

**Graph source:** [https://www.ncdc.noaa.gov/cag/time-series/us/4/0/tavg/3/8/1895-2017?base\\_prd=true&firstbaseyear=1901&lastbaseyear=2000&trend=true&trend\\_base=10&firsttrendyear=1895&lasttrendyear=2017](https://www.ncdc.noaa.gov/cag/time-series/us/4/0/tavg/3/8/1895-2017?base_prd=true&firstbaseyear=1901&lastbaseyear=2000&trend=true&trend_base=10&firsttrendyear=1895&lasttrendyear=2017)



## Top 10 Fires By Size in California – 2017 & 2018 have recorded the largest fires

	FIRE NAME (CAUSE)	DATE	COUNTY	ACRES	STRUCTURES	DEATHS
1	<b>MENDOCINO COMPLEX*</b> (Under Investigation)	July 2018	Colusa County, Lake County, Mendocino County & Glenn County	451,388	280	1
2	<b>THOMAS</b> (Under Investigation)	December 2017	Ventura & Santa Barbara	281,893	1,063	2
3	<b>CEDAR</b> (Human Related)	October 2003	San Diego	273,246	2,820	15
4	<b>RUSH</b> (Lightning)	August 2012	Lassen	271,911 CA / 43,666 NV	0	0
5	<b>RIM</b> (Human Related)	August 2013	Tuolumne	257,314	112	0
6	<b>ZACA</b> (Human Related)	July 2007	Santa Barbara	240,207	1	0
7	<b>CARR*</b> (Human Related)	July 2018	Shasta County, Trinity County	229,651	1,604	7
8	<b>MATILIJA</b> (Undetermined)	September 1932	Ventura	220,000	0	0
9	<b>WITCH</b> (Powerlines)	October 2007	San Diego	197,990	1,650	2
10	<b>KLAMATH THEATER COMPLEX</b> (Lightning)	June 2008	Siskiyou	192,038	0	2

Source: [http://www.fire.ca.gov/communications/downloads/fact\\_sheets/Top20\\_Acres.pdf](http://www.fire.ca.gov/communications/downloads/fact_sheets/Top20_Acres.pdf)

**Another consequence of higher global average temperatures is melting permafrost that releases carbon dioxide or methane into the atmosphere. This is an example of a feedback loop, in which climate warming releases greenhouse gases that will further exacerbate the warming trend.**



In this photo, melting permafrost and ice is visible along the coast of the Mackenzie Delta.

<http://www.cbc.ca/news2/interactives/sh/Tnq3tJHEAz/disappearing-island-arctic-beaufort-sea-tuktoyaktuk/>, October 13, 2017,

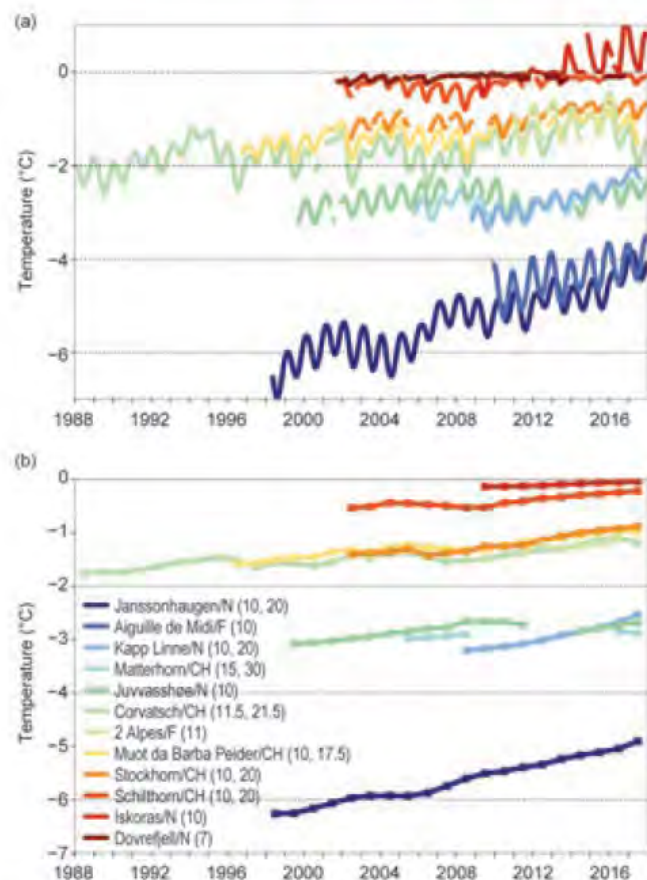
Image credit: Roger MacLeod/Natural Resources Canada



**A recent study published in the National Academy of Sciences found a 70% increase of carbon dioxide release into the atmosphere during early winter at NOAA's Barrow observatory in Alaska (baseline was 1975). Warmer fall temperatures are delaying freezing of the tundra, and increasing the length of time the tundra gives off greenhouse gas emissions.**



Source: <http://www.noaa.gov/stories/as-alaskas-north-slope-warms-greenhouse-gases-have-nowhere-to-go-but-up>, National Oceanic and Atmospheric Administration web site, June 12, 2017.



**FIG. 2.11.** Temperature (°C) measured in permafrost boreholes in the European Alps and Nordic countries at depths of (a) ~10 m (monthly means) and (b) ~20 m (annual means). (Sources: Swiss Permafrost Monitoring Network PERMOS; Norwegian Meteorological Institute and the Norwegian Permafrost Database NORPERM; French Permafrost Monitoring Network PermaFRANCE.)

**Permafrost temperatures are rising close to or above the thawing point at many other locations around the world.**

**Graph Source: Figure 2.11 State of the Climate 2017 page S21 Additional information related to Figure 2.11 is below:**

**“The long term trend of rising permafrost temperatures continued in 2017”. There are significant regional differences.**

**In mountain permafrost in the European Alps most boreholes are located between 2600 and 3000 metres above sea level, with permafrost temperatures typically above minus 3 degrees Celsius.**

**In northern Norway (Iskoras) there is evidence of thawing permafrost with ground temperatures well above zero Celsius at 10 metres depth since 2013-14.**



**Climate change is accelerating the rate of melt on Greenland, and that melt-water is making its way into the oceans and contributing to sea level rise. In the photo, Arctic cotton grows on Greenland's seashore. Illustrating the warming trend in the Arctic, this sedge species is 26 days ahead of its timetable 10 years ago. (March 1, 2017)**



Source: Photograph: Pearl Bucknall/Alamy <https://www.theguardian.com/environment/2017/mar/01/northern-hemisphere-sees-in-early-spring-due-global-warming>

**In May of 2017 the Global Seed Vault, buried in a mountain deep inside the Arctic Circle, was breached by melting waters – another sign of the profound changes occurring in the Arctic. The breach occurred despite the vault having been especially built to protect millions of food crops from climate change, war and natural disasters.**



Source: <https://www.theguardian.com/environment/2017/may/19/arctic-stronghold-of-worlds-seeds-flooded-after-permafrost-melts#img-1> Photograph: John Mcconnico/AP

**The extent of Arctic sea ice continues to decline. In 2017 the winter maximum of Arctic sea ice was the lowest winter maximum in the satellite record. In 2018 it was the second lowest. The 4 lowest maximums have occurred in the last 4 years.**



Sources: [nsidc.org/arcticseaicenews/2018/03/arctic-sea-ice-maximum-second-lowest/](https://nsidc.org/arcticseaicenews/2018/03/arctic-sea-ice-maximum-second-lowest/)  
<https://www.theguardian.com/environment/2017/mar/22/arctic-ice-falls-record-winter-low-polar-heatwaves>

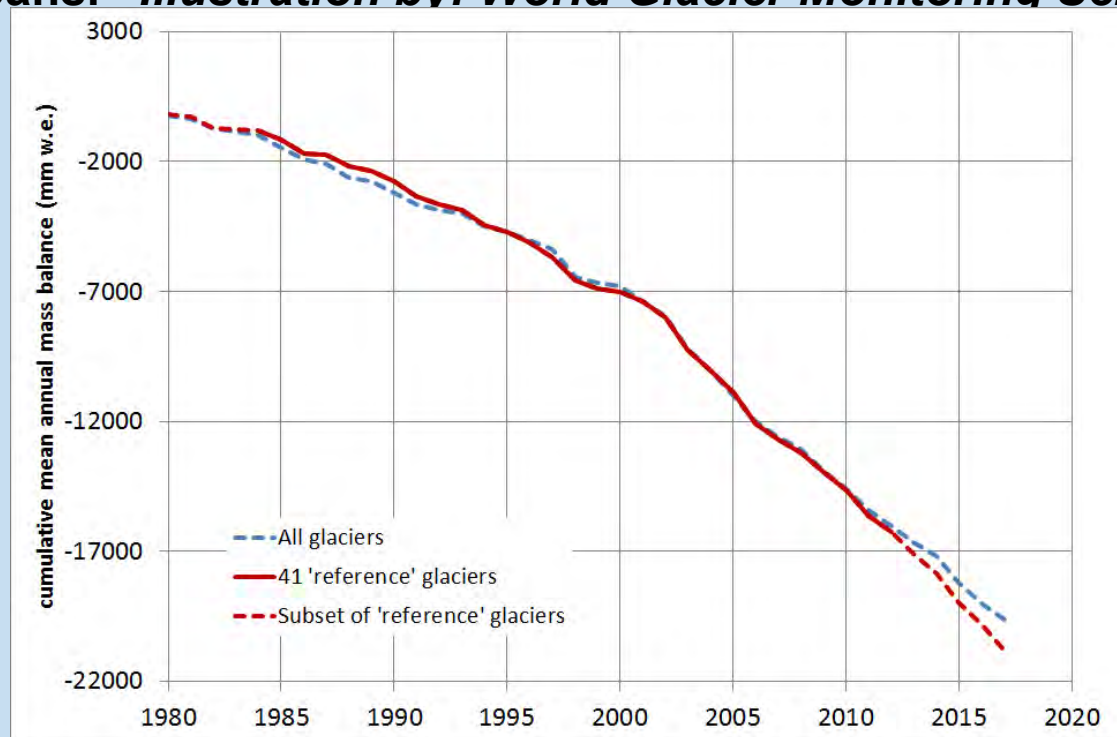


**Mount Kilimanjaro in Tanzania is one example of a natural wonder at risk from climate change, as its glaciers shrink.**



<https://www.theguardian.com/environment/2017/nov/13/from-the-everglades-to-kilimanjaro-climate-change-is-destroying-world-wonders>, November 13, 2017.

The graph below provides another window into the pace of glacial ice melt. It illustrates changes to the mass of 41 reference glaciers around the world measured in millimeters of equivalent water. As the Earth warms, glaciers melt faster and faster, particularly at the bottom. The runoff ultimately makes its way to the oceans. *Illustration by: World Glacier Monitoring Service*



Source: <https://wgms.ch/latest-glacier-mass-balance-data/> (accessed Sept. 2018) Figure 2: 'Mean cumulative mass balance of all reported glaciers (blue line) and the reference glaciers (red line)



**Climate change can sometimes lead to abrupt changes. For example, for hundreds of years, the Slims River carried meltwater northwards from the vast Kaskawulsh glacier in Canada's Yukon territory into the Kluane river and Kluane Lake, and then into the Yukon river that flows towards the Bering Sea. But in the spring of 2016, glacial melting changed the drainage gradient completely, diverting the flow of the glacier melt into a different water course, and leading to the sudden disappearance of the Slims River.**



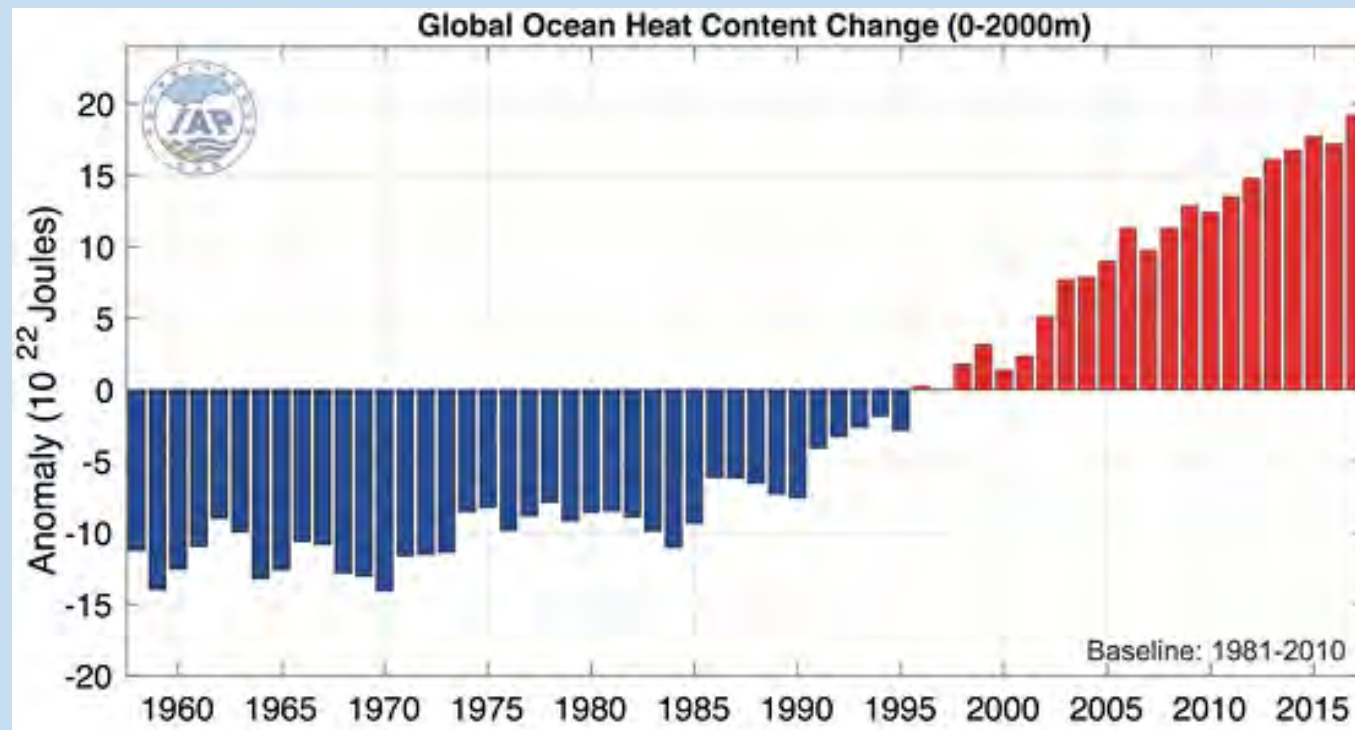
Image reference: 'Looking up the Slims River Valley, from the south end of Kluane Lake. The river used to flow down the valley from the Kaskawulsh glacier.' (Photo: Sue Thomas, CBC) <https://www.cbc.ca/news/canada/north/slims-river-dries-yukon-kluane-glacier-1.3639472>, June 17, 2016  
Information reference: 'Retreating glacier causes immense Canadian river to vanish in four days', *The Guardian*, April 17, 2017

**Over the past 50 years, the Antarctic Peninsula has warmed about half a degree per decade. As an illustration of the warming trend, in some islands off the Peninsula, the rate of moss growth is 4 times higher than in 1950.**



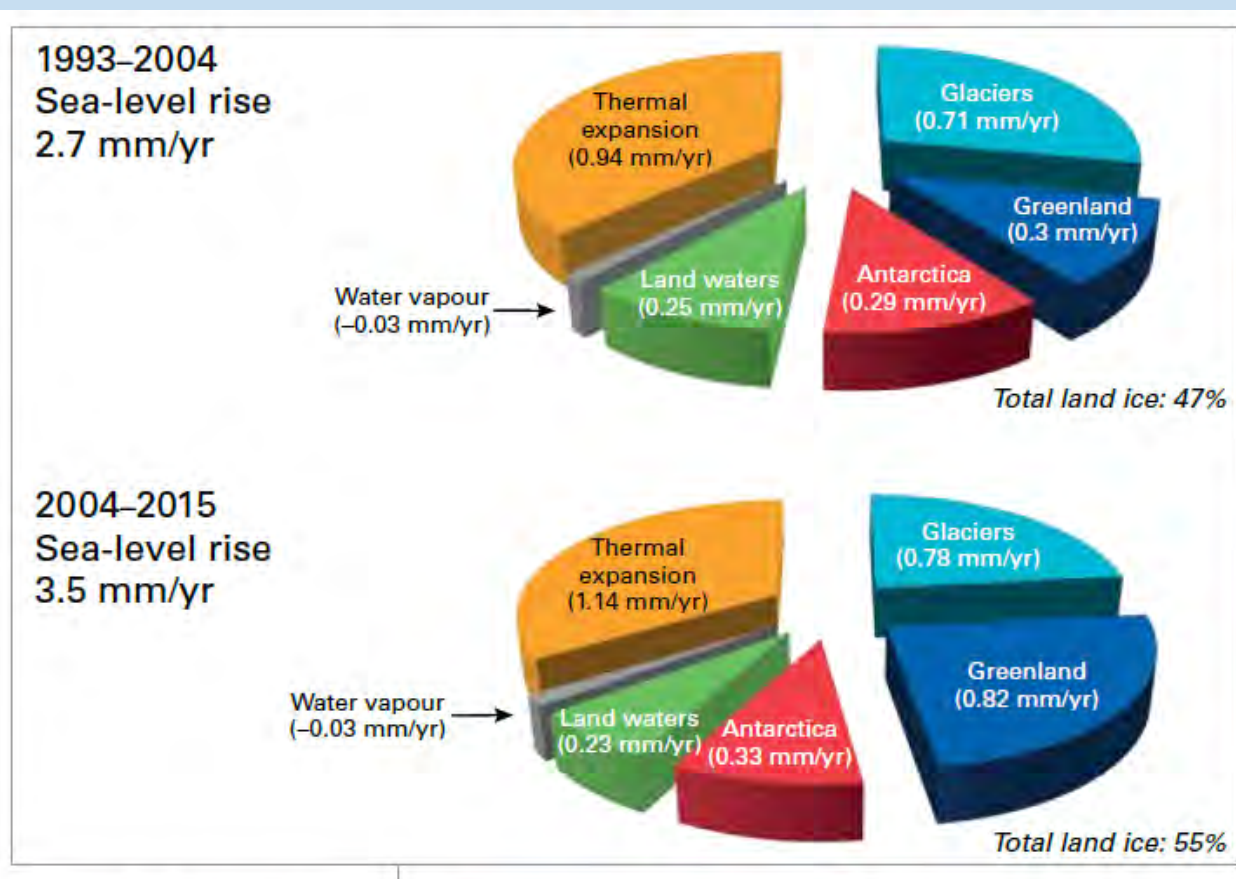
A moss bank on Green Island. Source: Photograph: Matt Amesbury, *The Guardian*, May 18, 2017.

As rising greenhouse gas concentrations in the atmosphere trap more heat, over 90% of that heat is being absorbed by the oceans. As illustrated by the chart below, the upper 2,000 metres of the world's oceans reached record high heat content in 2017.



Sources: "2017 was the warmest year on record for the global ocean" *Advances in Atmospheric Science*, Lijing Cheng and Ziang Zhu, Volume 34, March 2018, <https://link.springer.com/content/pdf/10.1007%2Fs00376-018-8011-z.pdf> and *The Guardian*, Fri 26 Jan 2018, <https://www.theguardian.com/environment/climate-consensus-97-per-cent/2018/jan/26/in-2017-the-oceans-were-by-far-the-hottest-ever-recorded>

Sea levels are rising – both because warmer ocean waters result in thermal expansion, and because of glacial melt. The figure below shows the source contributions to global mean sea level rise during both 1993-2004 and 2004-2015. Note that sea level rise is accelerating. Source: Figure 8 World Meteorological Organization Statement on the State of the Global Climate in 2017 [https://library.wmo.int/doc\\_num.php?explnum\\_id=4453](https://library.wmo.int/doc_num.php?explnum_id=4453)





**On Kiribati, an island nation (pictured below) with a population of approximately 100,000, sea level rise threatens to displace many of its people. The average height above sea level there is 2 metres. The country spans 33 islands. Sea level rise now threatens many island nations. It is one of the key reasons that the 18 nations of the Pacific Islands Forum have declared climate change their greatest security threat.**



Sources: Image (left): <http://www.visit-kiribati.com/> Information: "Australia joins Pacific to declare climate single greatest security threat", Climate Home News, 15/09/2018, <http://www.climatechangenews.com/2018/09/05/australia-joins-pacific-declare-climate-single-greatest-security-threat/>, <https://www.theguardian.com/world/2017/may/14/our-country-will-vanish-pacific-islanders-bring-desperate-message-to-australia> and "Waiting for the Tide to Turn: Kiribati's Fight for Survival" by Mike Bowers, The Guardian, October 23, 2017.

**One of the consequences of sea level rise is seawater incursions into plant growing areas - rendering them a wasteland and polluting once-reliable drinking water sources. King tides are already invading some dwelling areas, as the photo (to the right) taken on Kiribati illustrates.**



Source: <https://www.theguardian.com/world/2017/oct/23/waiting-for-the-tide-to-turn-kiribatis-fight-for-survival> Photo: Mike Bowers  
Tebunginako village on the island of Abaiang, Kiribati.



Source: <https://www.theguardian.com/world/2017/oct/31/new-zealand-considers-creating-climate-change-refugee-visas>



**The combination of sea level rise and powerful storms is causing serious coastal erosion in many locations around the world. In this photo cliffs in Pacifica, California have been eroded. Southern California beaches face the prospect of large scale erosion by mid century, causing billions in property damage.**



Information sources:

<https://www.theguardian.com/environment/2018/aug/27/california-climate-change-report-wildfires-jerry-brown>

Image source: Erosion undermines coastal homes in Pacifica, Calif., in 2016. (Josh Edelson/AFP/Getty Images)

[https://www.washingtonpost.com/news/speaking-of-science/wp/2018/07/11/california-will-have-a-terrible-choice-save-cliff-side-homes-or-public-beaches-from-rising-seas/?noredirect=on&utm\\_term=.886670d32b69](https://www.washingtonpost.com/news/speaking-of-science/wp/2018/07/11/california-will-have-a-terrible-choice-save-cliff-side-homes-or-public-beaches-from-rising-seas/?noredirect=on&utm_term=.886670d32b69)

**Hurricanes feed off warmer ocean waters – above 26 degrees Celsius. At these temperatures there is rapid evaporation, providing energy to power a storm. Heat is pulled out of the ocean up to at least 160 metres in depth. As the water vapour condenses, it falls out of the storm as rain. Warmer ocean waters and higher sea levels, both outcomes of climate change, are making hurricanes more dangerous.**

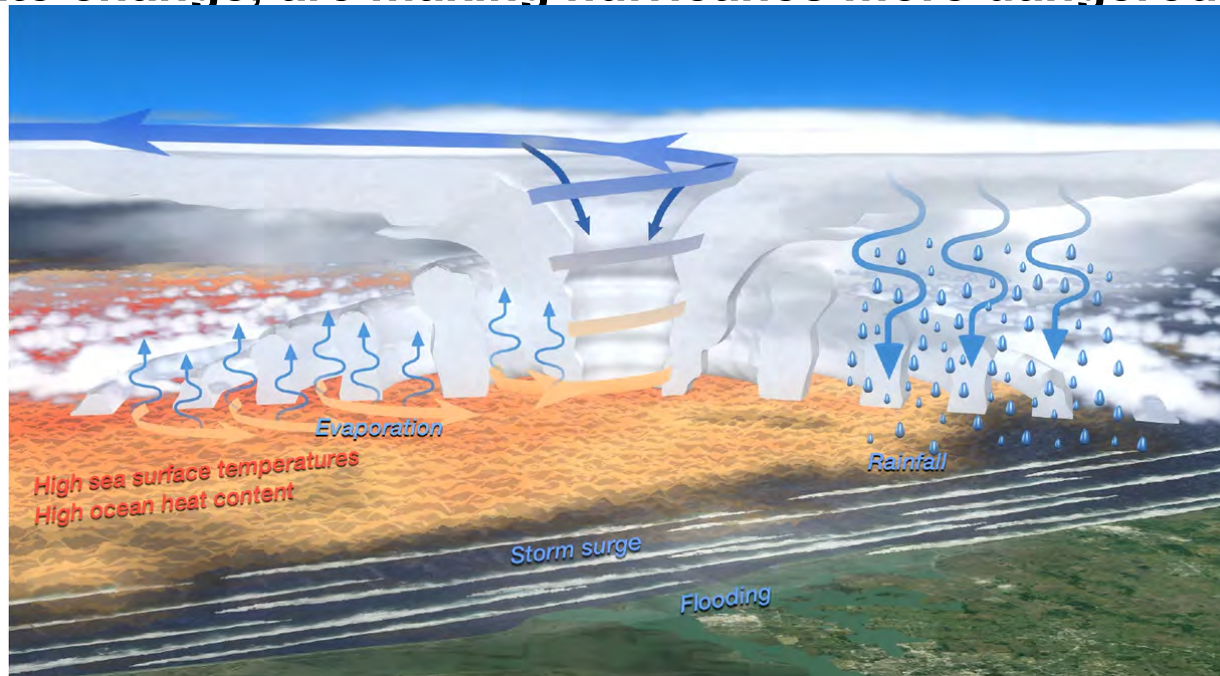


Diagram of evaporation and rainfall within a hurricane. Illustration: Trenberth et al. (2018), *Earth's Future* Replicated in:

<https://www.theguardian.com/environment/climate-consensus-97-per-cent/2018/may/23/global-warming-made-hurricane-harvey-more-destructive#img-2>

For further information, also refer to: "Hurricane Harvey Links to Ocean Heat Content and Climate Change Adaptation" (Figure 6), published in *Advancing Earth and Space Science*, May 22, 2018.



**In August and September of 2017 we saw the consequences of more powerful hurricanes in the Americas, as Hurricane Harvey struck Houston (wind speed of 209km/hr) and Hurricane Irma struck the Caribbean (wind speed of up to 295km/hr) and Florida (215km/hr). Climate change is not making hurricanes more frequent, but it is making them more dangerous. The warmer atmosphere increased the rainfall rates associated with these hurricanes, and sea level rise made their coastal surges more damaging. High ocean heat content helped make the hurricanes more powerful.**



Tidwell Road in northeast Houston, August 28, 2017 – after Hurricane Harvey.



The French Island of St. Martin after Hurricane Irma, September 8, 2017

Sources: WMO expert team statement on Hurricane Harvey, <https://public.wmo.int/en/media/news/wmo-expert-team-statement-hurricane-harvey> Published 1 September 2017; 'Hurricane Harvey Links to Ocean Heat Content and Climate Change Adaptation', Kevin Trenberth et al, <https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2018EF000825>

**In September 2017 no sooner did people in the Caribbean begin to assess the damage from Hurricane Irma, when Hurricane Maria struck. This photo shows the capital of the island of Dominica – on September 20, 2017 – after being struck by Hurricane Maria, a Category 5 Hurricane. Winds up to 260km/hr hit Dominica. The capital was devastated.**



Source: <https://www.theguardian.com/world/2017/sep/21/dominica-daze-hurricane-maria-island-caribbean-rescue#img-1>



**The US National Oceanic & Atmospheric Administration puts estimated losses from Hurricanes Harvey, Irma and Maria at \$265 billion U.S. dollars**

**(Source: <https://www.ncdc.noaa.gov/sotc/tropical-cyclones/201713/>)**



**Roosevelt Skerrit, Prime Minister of the Commonwealth of Dominica, said at the United Nations General Assembly on September 22, 2017: “To deny climate change is to deny a truth we have just lived.”**

**He pleaded with all countries to come together to save our planet. Photo Source: UN Photo/Cia Pak United Nations News Centre**

**Climate change is already having major negative ecological impacts, and these will grow rapidly if fossil fuels are not phased out in the coming decades. For example, in a period spanning 36 months over 2014-17, mass bleaching-level heat stress took place at more than 75% of the Earth's coral reefs; nearly 30% suffered mortality-level stress.**



Illustration of bleached coral

**Source:** “Unprecedented 3 years of global coral bleaching, 2014–2017” by Michon Scott and Rebecca Lindsey, August 1, 2018,

<https://www.climate.gov/news-features/understanding-climate/unprecedented-3-years-global-coral-bleaching-2014%E2%80%932017>

Image: The Guardian, Photo by Bette Willis, Provided by the ARC Centre of Excellence for Coral Reef Studies,

<https://www.theguardian.com/environment/gallery/2017/apr/10/this-mortal-coral-new-bleaching-at-the-great-barrier-reef-in-pictures#img-4>



**In November 2017 the International Union for Conservation of Nature reported that the number of natural world heritage sites being damaged and at risk from climate change had almost doubled (to 62) in just 3 years, including a rising number of wildfires that threaten Monarch butterfly reserves in Mexico.**



Photograph: Alianza-WWF-Telcel / HANDOUT/EPA

Sourced at: <https://www.theguardian.com/environment/2017/nov/13/from-the-everglades-to-kilimanjaro-climate-change-is-destroying-world-wonders#img-2>

**In March of 2018 the World Wildlife Fund warned of a catastrophic loss of animals by the end of the century if the global average temperature increase is not kept to 1.5 degrees Celsius. One example: tiger habitat in the Sundarbans could become completely flooded.**



Image source: Photograph: WWF India. <https://www.theguardian.com/environment/2018/mar/14/worlds-great-forests-could-lose-half-of-all-wildlife-as-planet-warms-report#img-3>



**In the western Antarctic Peninsula – krill populations – a vital source of food for penguins, seals, albatross and whales – are declining due to a combination of climate change and industrial-scale krill fishing. Ocean warming is causing the ice - that is home to the algae and the plankton krill feed on – to retreat. The loss of krill biomass in Antarctic waters in turn has potential for very negative impacts on larger predators.**



Source: [Decline in krill threatens Antarctic wildlife, from whales to penguins](https://www.theguardian.com/environment/2018/feb/14/decline-in-krill-threatens-antarctic-wildlife-from-whales-to-penguins#img-3)

<https://www.theguardian.com/environment/2018/feb/14/decline-in-krill-threatens-antarctic-wildlife-from-whales-to-penguins#img-3>

**Pictured: a melt pond on Arctic sea ice. Changes in the Arctic due to manmade greenhouse gas emissions have enormous implications for our future. They provide another illustration of positive feedback loops that accelerate climate change (example: open Arctic waters absorb more heat energy). They have the potential to disrupt the Jet Stream and cause more extreme weather at mid-latitudes. And there is evidence they may be contributing to a slowing of the important current known as the Atlantic Meridional Overturning Circulation (AMOC). See next 2 slides for more details.**

Image Source:

Photograph: Stefan Hendricks/  
Alfred-Wegener-/PA

[https://www.theguardian.com/  
environment/climate-  
consensus-97-per-cent/2018/  
aug/15/humans-are-pushing-  
the-earth-closer-to-a-climate-  
cliff#img-1](https://www.theguardian.com/environment/climate-consensus-97-per-cent/2018/aug/15/humans-are-pushing-the-earth-closer-to-a-climate-cliff#img-1)





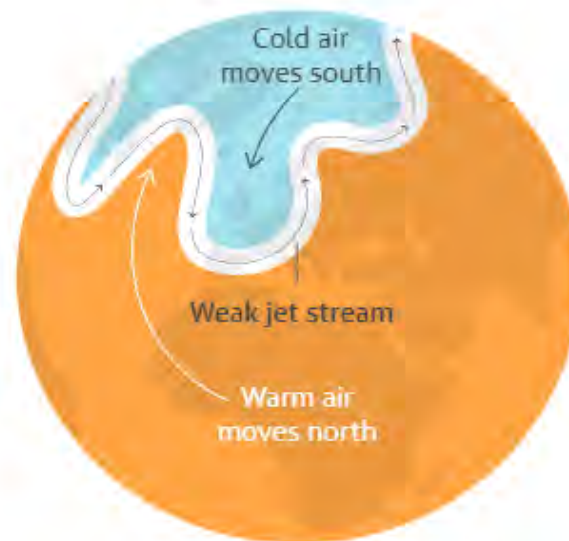
## How Arctic meltdown can lead to extreme weather

### Normal polar jet stream



The jet stream forms a boundary between the cold north and warmer south. The temperature difference between these two areas powers the jet stream to speeds up to 250mph at about 8km above the surface

### Weak polar jet stream



Arctic warming narrows the temperature difference, resulting in a slower jet stream that meanders more. The loops bring extreme weather to lower latitudes

Guardian graphic

Source: NASA

Image source:

<https://www.theguardian.com/environment/2017/mar/27/climate-change-human-fingerprint-found-on-global-extreme-weather>

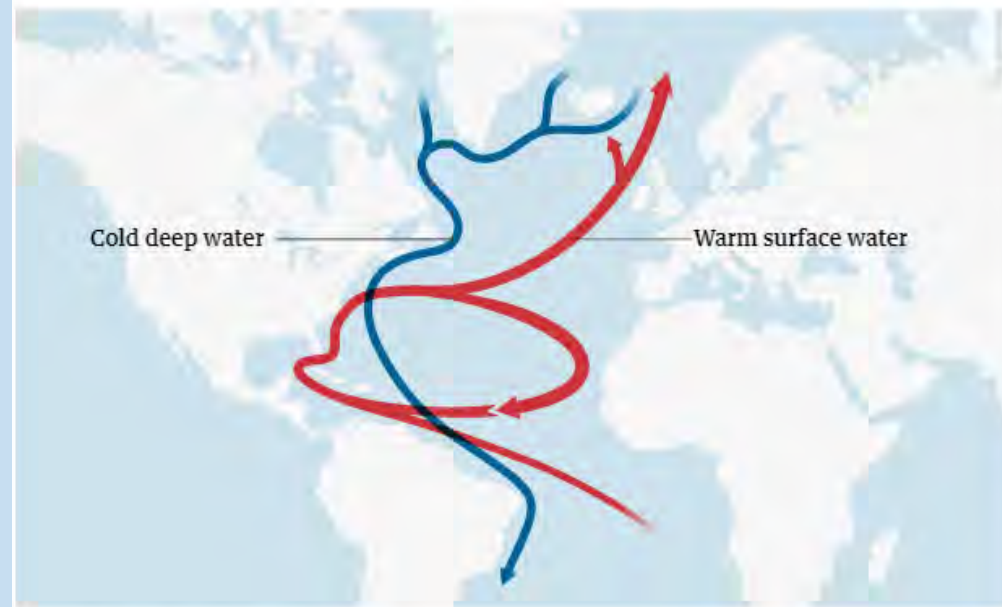
Guardian Graphic: How Arctic Meltdown can lead to extreme weather

**The warm Atlantic current - linked to severe and abrupt changes in Earth's climate in the past - is now at its weakest in at least 1,600 years: 15% weaker than in 400AD. Two published studies in *Nature* in 2018 both reached this conclusion. One example of the risks should this trend continue: a future collapse of the Gulf Stream could result in Western Europe suffering far more extreme winters.**

Melting ice in the Arctic floods the area with less dense fresh water, a factor in weakening the AMOC current.

Source:  
<https://www.theguardian.com/environment/2018/apr/11/critical-gulf-stream-current-weakest-for-1600-years-research-finds>

**Ocean circulation in the Atlantic is driven by warm surface currents and cold deep-water return flows**



Guardian graphic. Source: Nature

For further details refer to the two *Nature* articles:  
“North Atlantic circulation slows down”  
and “Observed fingerprint of a weakening Atlantic Ocean overturning circulation”  
In *Nature*, Vol 556,  
April 12, 2018.

# **Perspectives on Climate Change Action in Canada—A Collaborative Report from Auditors General March of 2018**

## **Climate change impacts in Canada (Quotes from the report)**

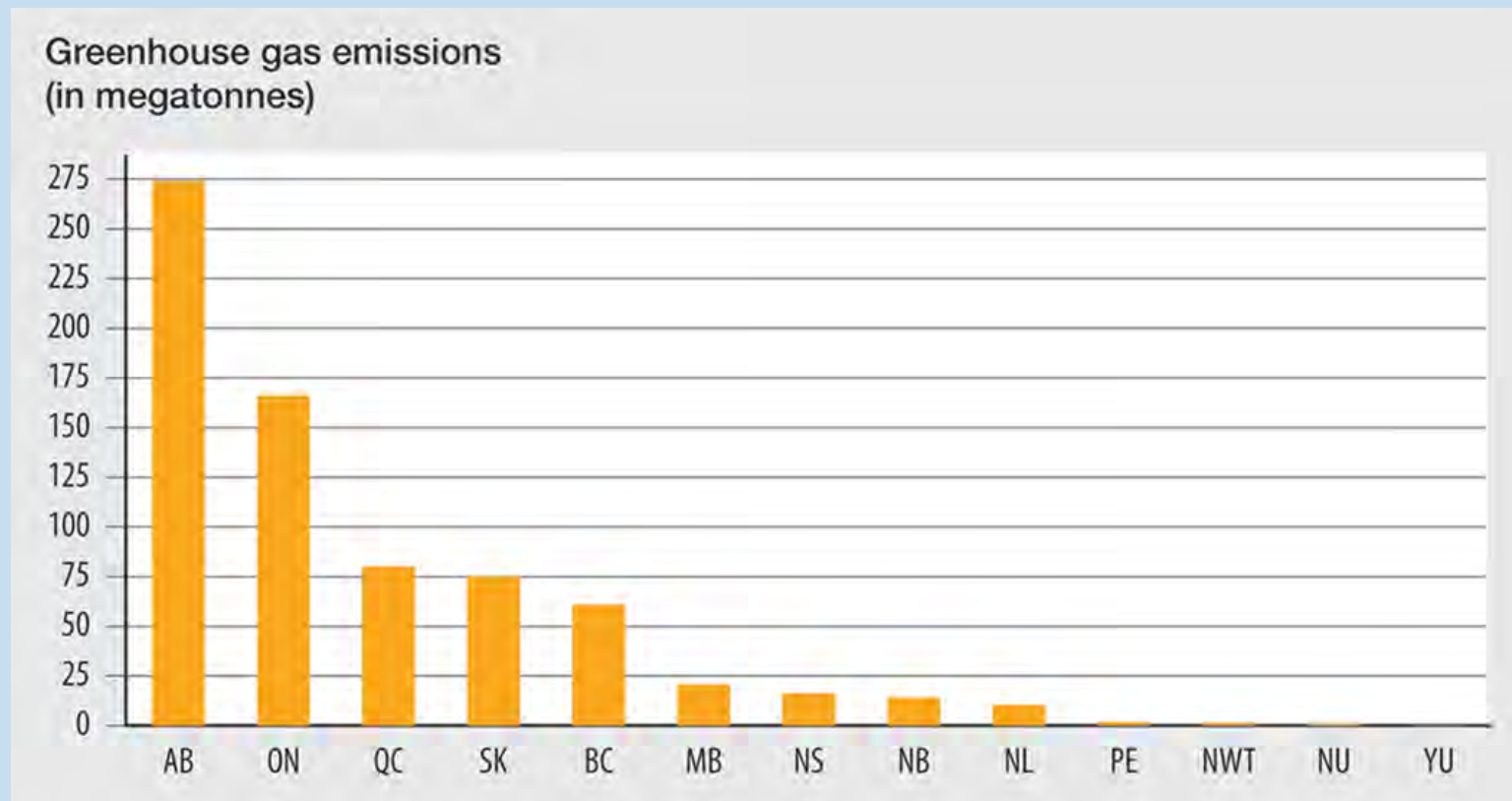
- “The 2013 Alberta floods cost \$1.7 billion. The frequency of similar floods is expected to increase as extreme precipitation events become more frequent.”
- “The extent of summer Arctic sea ice has decreased by nearly a third since 1980. This reduction means less protection from waves and storm surges, which increases the risk of coastal erosion and flooding.”
- “In some areas of Canada’s 243,000-kilometre-long coastline, sea levels could further rise by over 75 centimetres by 2100. By 2050, these changes could cost Canada billions of dollars a year.”

# **Perspectives on Climate Change Action in Canada—A Collaborative Report from Auditors General—March 2018 (continued)**

- “Canada could experience twice the number of (forest) fires by 2100.”
- “More than half of Canada is underlain by varying types of permafrost, much of which is degrading, causing land deformations and landslides that in turn have affected roads, buildings, and other infrastructure. In the Northwest Territories, roads have shifted and slumped, and sinkholes have developed.”
- “Canadians are expected to experience heat waves more often. By 2100, the number of days above 30 degrees Celsius in Canadian cities is expected to double and a 1-in-20-year hottest day may become a 1-in-2-year event.”

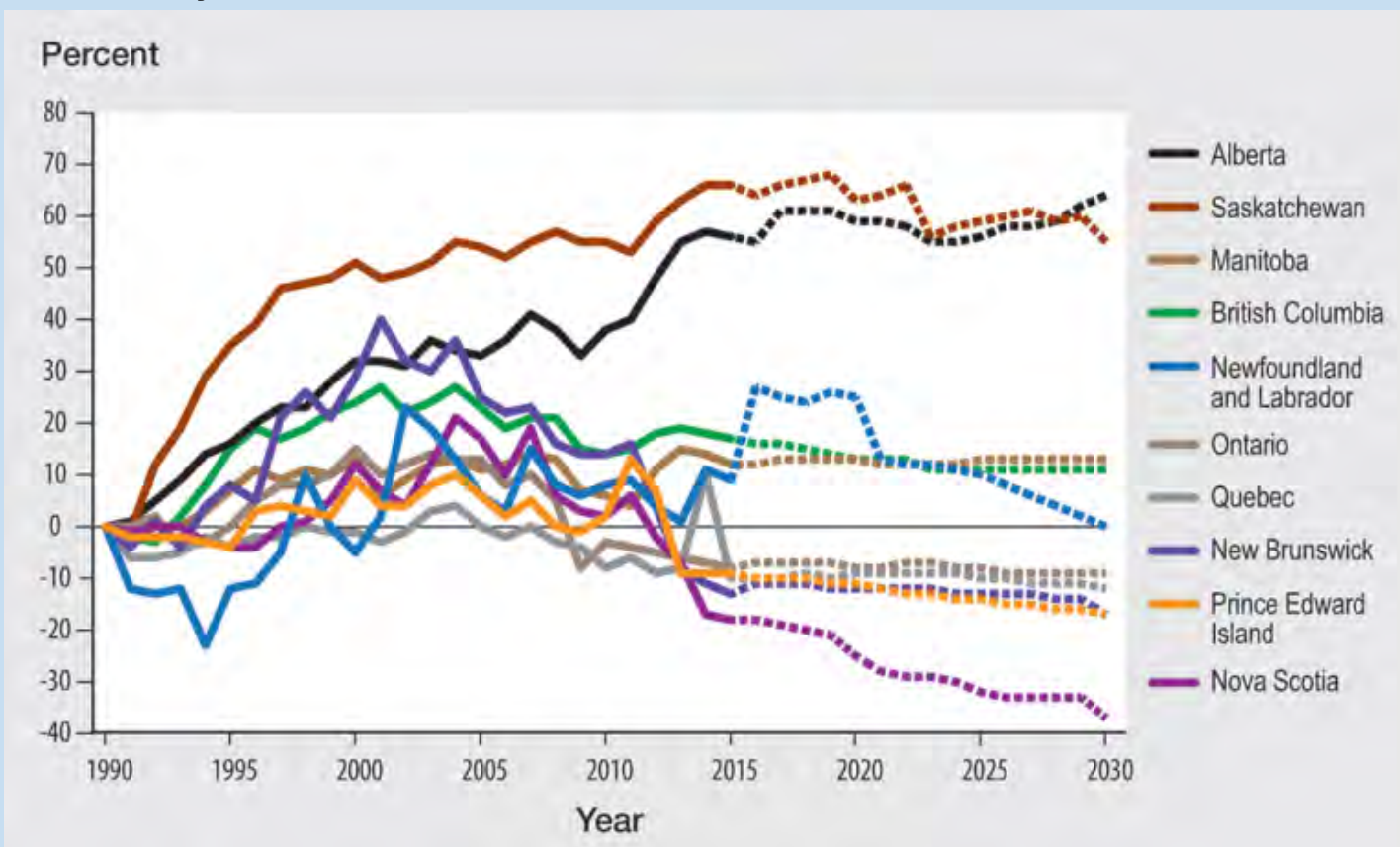


# Total greenhouse gas emissions by province and territory in Canada in 2015



Source: Perspectives on Climate Change Action in Canada—A Collaborative Report from Auditors General—March 2018 Exhibit # 13

## GHG Emissions by Province from 1990 to 2015 - Office of the Auditor General of Canada



A graph showing the provinces and their increases or decreases in greenhouse gas emissions relative to their emissions in 1990. Emissions are shown through to 2015. The dotted lines are predictions.

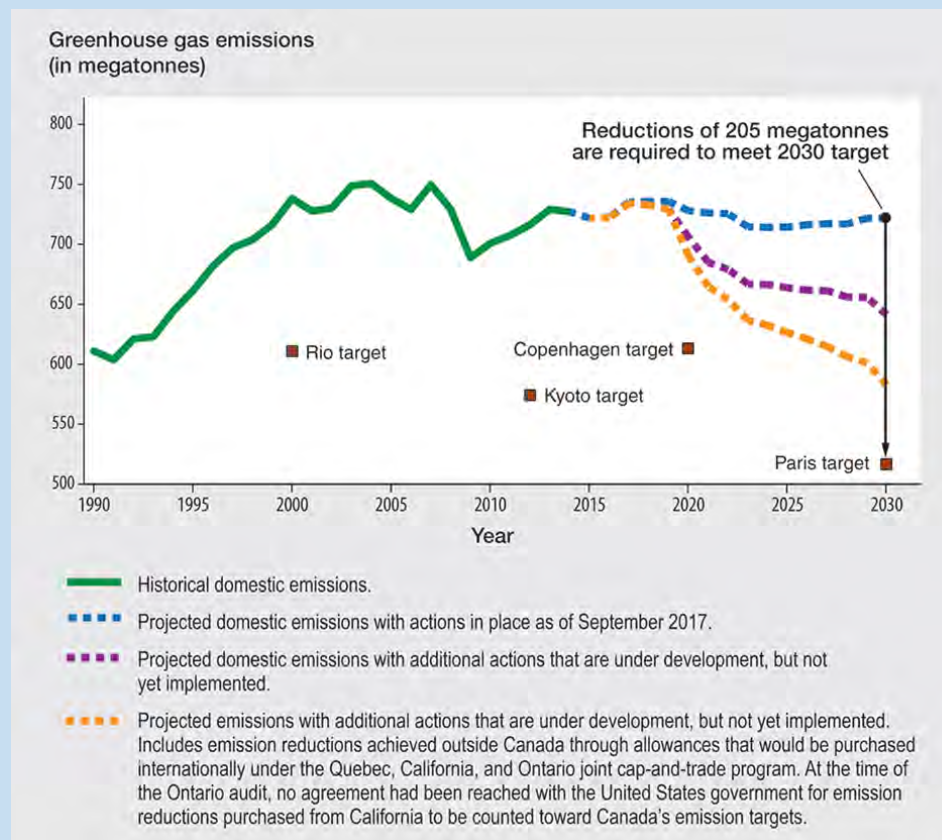
Source: Perspectives on Climate Change Action in Canada—A Collaborative Report from Auditors General—March 2018

# Canada's actual and projected greenhouse gas emissions and emission reduction targets (in megatonnes of carbon dioxide equivalent)

**Under the Paris Agreement, Canada has pledged to cut GHG emissions 30% below 2005 emission levels by 2030. Saskatchewan's proportional share of this is approximately 28 million tonnes carbon dioxide equivalent. (Saskatchewan is currently well above its 2005 GHG emission levels.)**

Graph source:

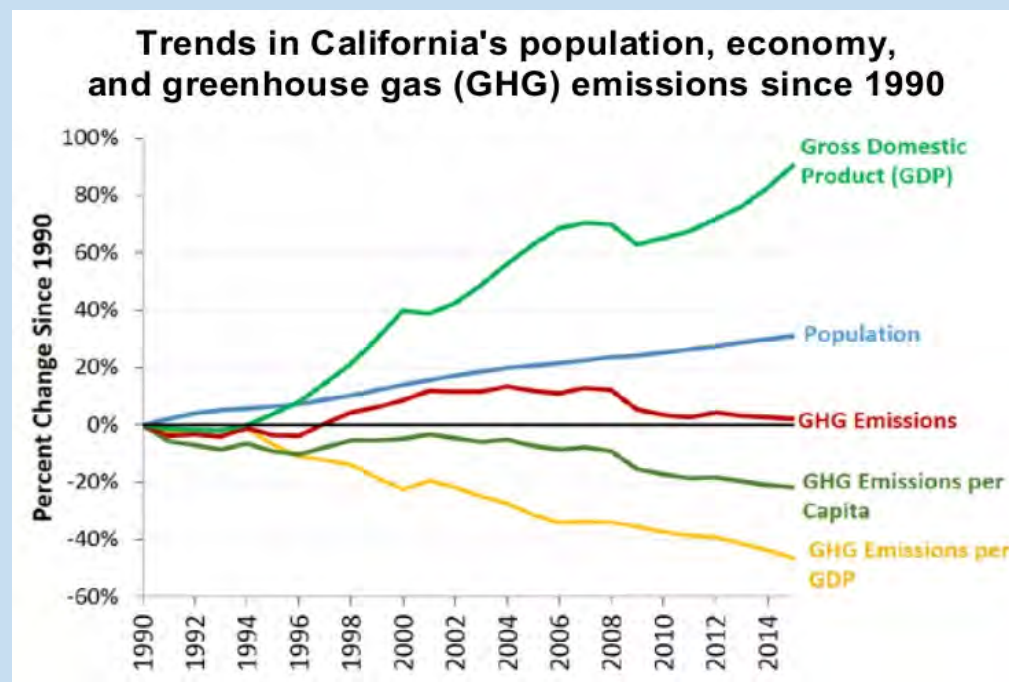
Perspectives on Climate Change Action in Canada—A Collaborative Report from Auditors General—March 2018 Exhibit # 11





### Four Inspiring Examples for Saskatchewan to follow:

**#1 California provides an example of what can be accomplished through good public policy to limit greenhouse gas pollution, despite major population growth. While Saskatchewan's GHG emissions have risen more than 60% since 1990, California's emissions are very close to 1990 levels. The challenge now will be to drive total emissions down and move toward carbon-neutrality.**



Source: California greenhouse gas emissions, population, and GDP. Illustration: California Office of Environmental Health Hazard Assessment

**#2 Several cities in the United States now meet all their electricity needs from renewables. Burlington, Vermont was the first to do so using: a woodchip processor and furnace; a hydro plant situated next to an old wool factory that has its turbines spun by the Winooski River; a small array of wind turbines perched on nearby Georgia Mountain; and a bank of solar panels at Burlington airport.**



**Bernie Sanders, as Mayor of Burlington for many years, provided important leadership in the move to renewables.**

Source: <https://www.theguardian.com/cities/2018/jul/24/the-us-government-has-checked-out-on-renewables-can-cities-fill-the-gap>



**#3 Emissions reductions in agriculture are often challenging to achieve, but critically important. In New Zealand, one example of innovation: scientists are breeding a low-methane breed of sheep, which is leaner and grows more wool.**



Source: <http://www.cbc.ca/news/technology/livestock-ghg-emissions-science-1.4753165>



**#4 The European Union is on track to achieve its goals of a 20% GHG emissions cut below 1990 levels by 2020, and a 20% renewable energy share of electricity by 2020. It's progress stands in sharp contrast to that in Canada and Saskatchewan.**



Sources: “Tracking Europe’s progress on meeting 2020 climate and energy targets”, December 15, 2017, <https://www.eea.europa.eu/articles/tracking-europe2019s-progress-on-meeting>;  
Photograph: Pablo Blazquez Dominguez/Getty Images: Photo of a solar plant in el Bonillo, Spain.