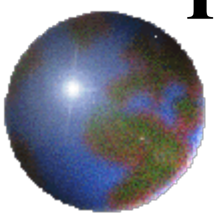
Rapid Climate Change & Impacts: from Global-to-Local (Manitoba)



By: Paul H. Beckwith

Graduate Studies in **Geography**
It starts **here.**

MANITOBA WILDLANDS

Laboratory for Paleoclimatology and Climatology
Department of Geography, University of Ottawa

uOttawa
L'Université canadienne
Canada's university

Laboratory for Paleoclimatology and Climatology

Department of Geography and Environmental Studies (DGES), Carleton University
http://paulbeckwith.net

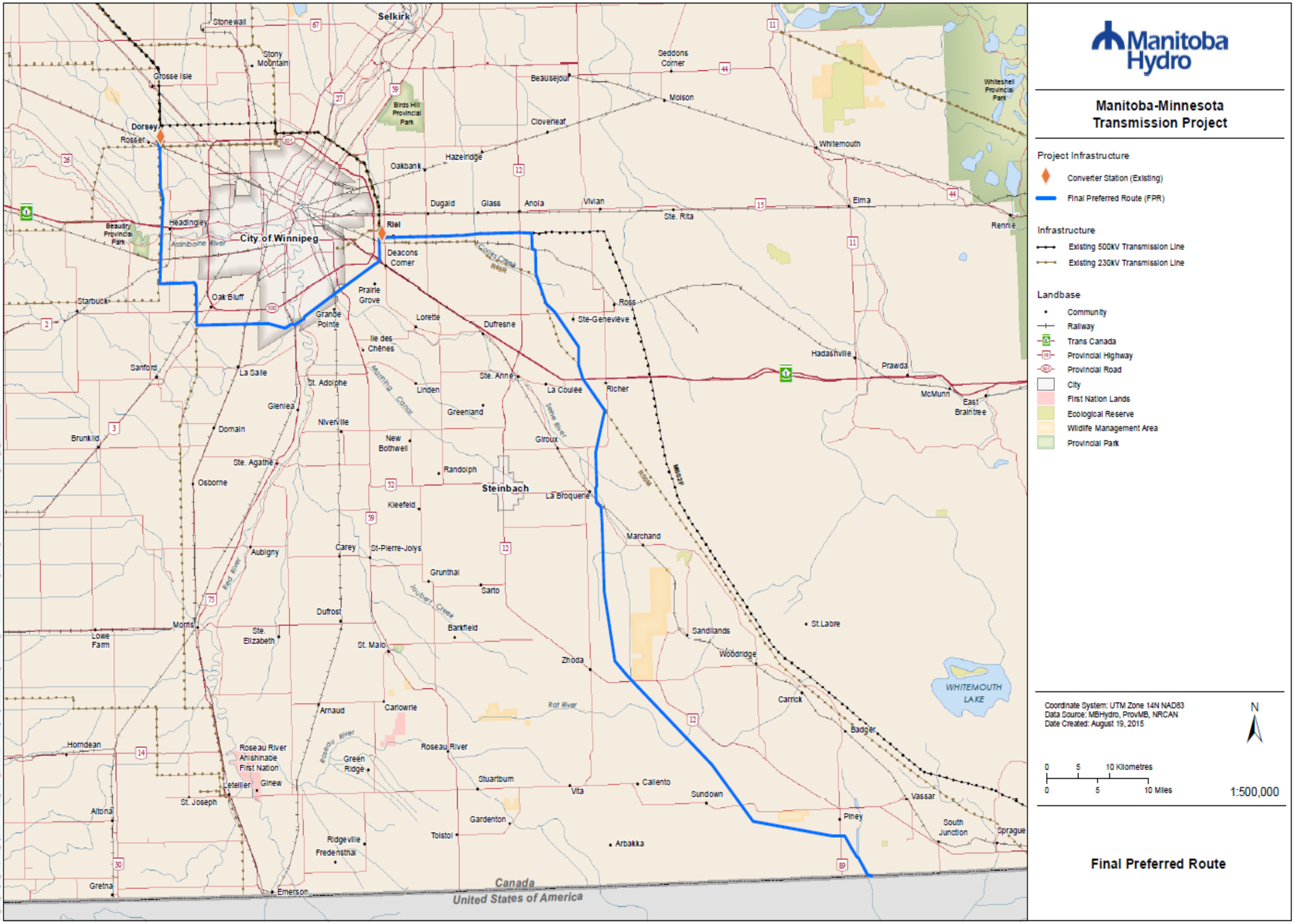
Thursday June 1st, 2017

Carleton UNIVERSITY 75

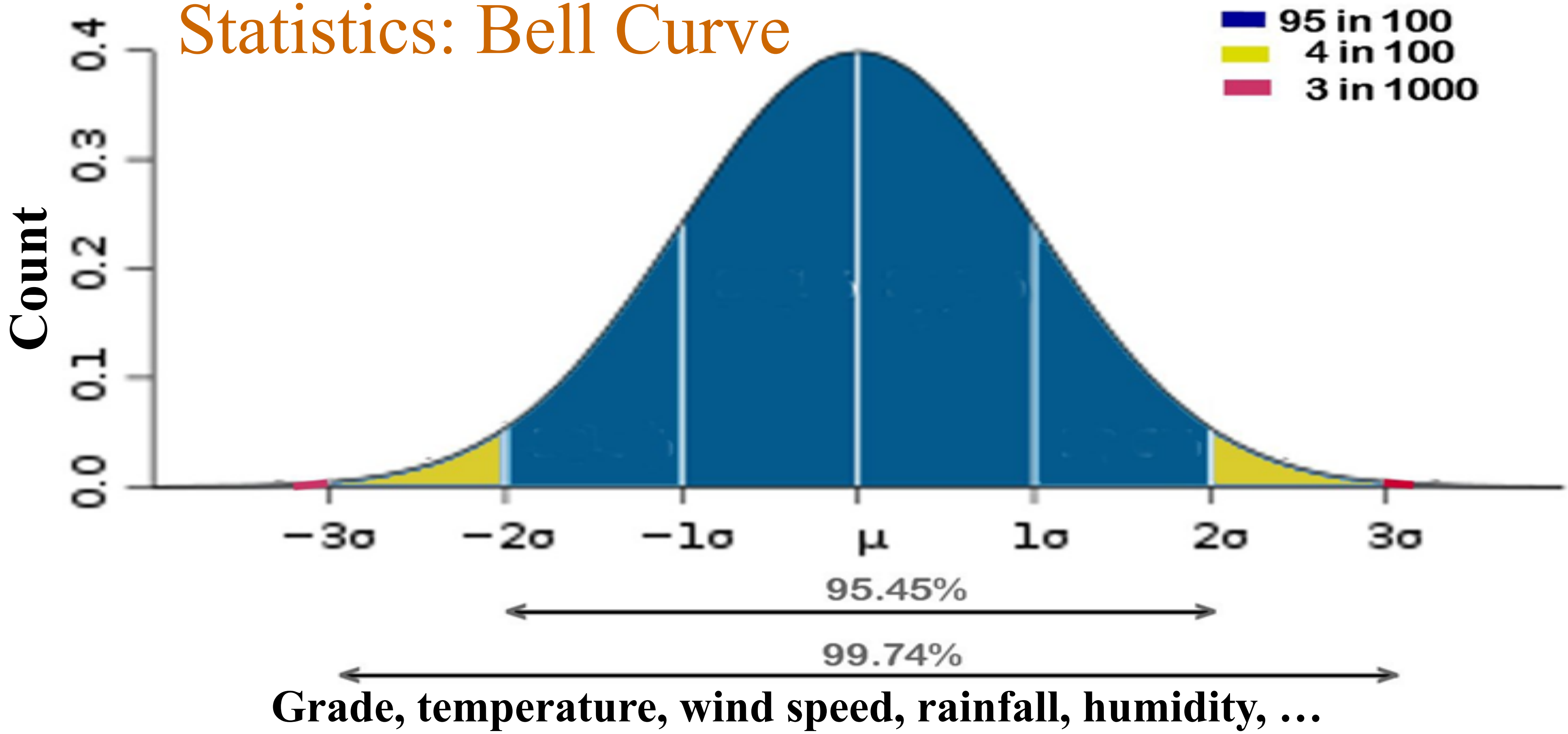
Geography and Environmental Studies

Outline of Evidence: CEC MMTP Hearings 2017

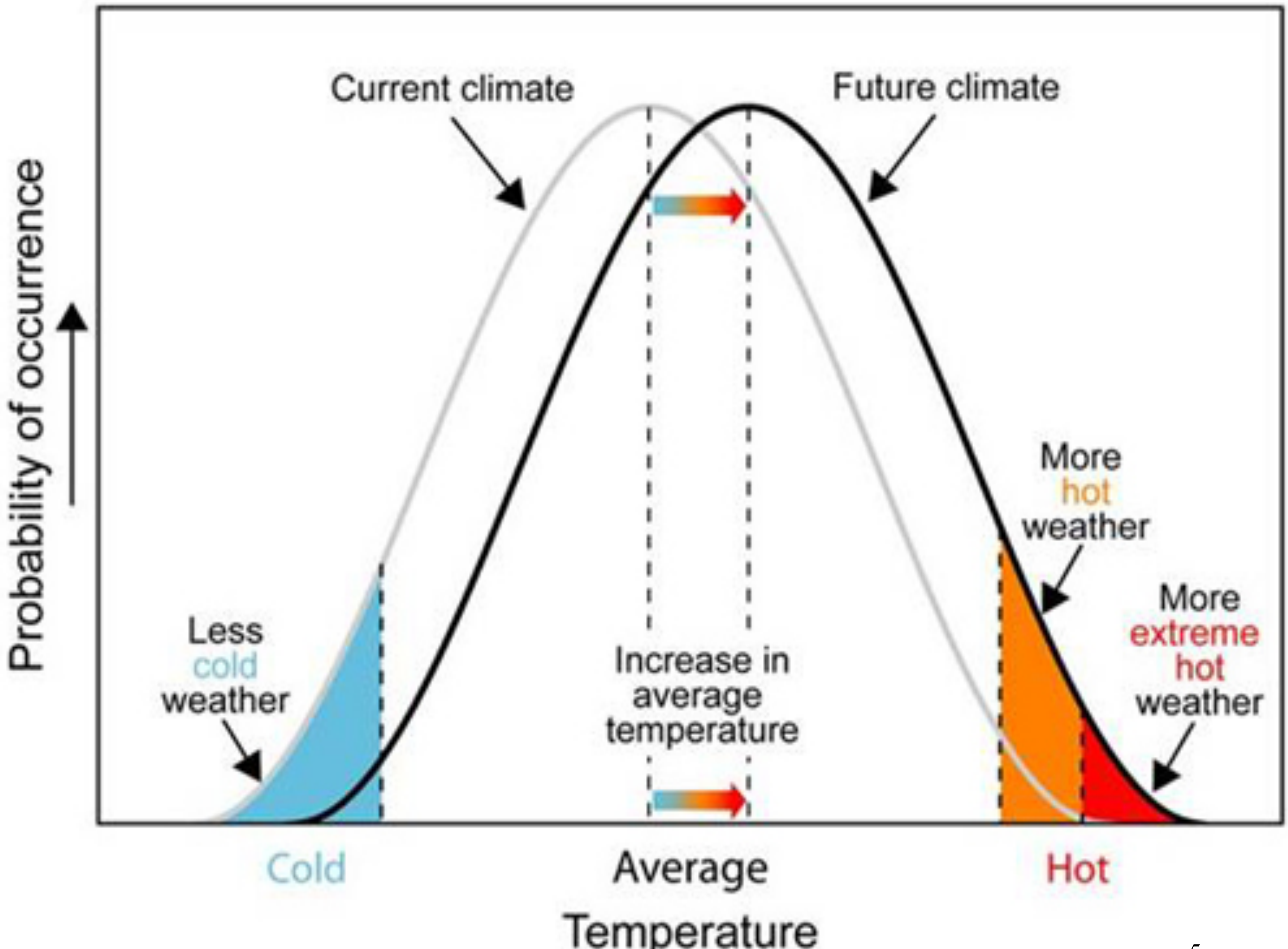
- Update on climate change globally, continentally, & regionally
- A forecast to pay attention to – climate change in Manitoba
- Events globally & in Canada that show that climate change is here
- Investigation of abrupt climate change
- Latest science on global greenhouse gas concentrations, global average temperatures, Arctic climate, jet stream behaviour, methane emissions from terrestrial permafrost & sea-floor sediments, northern hemisphere versus southern hemisphere differences & implications for Manitoba
- Nonlinear changes in climate systems already affecting Canada & Manitoba
- Ways operation of a transmissions system with converter stations, substations, etc. spread throughout a large region could be affected by climate change, including extreme weather events
- Application of all of the above to MMTP, review of the MMTP EIS, and consideration of climate change adaptation for MMTP

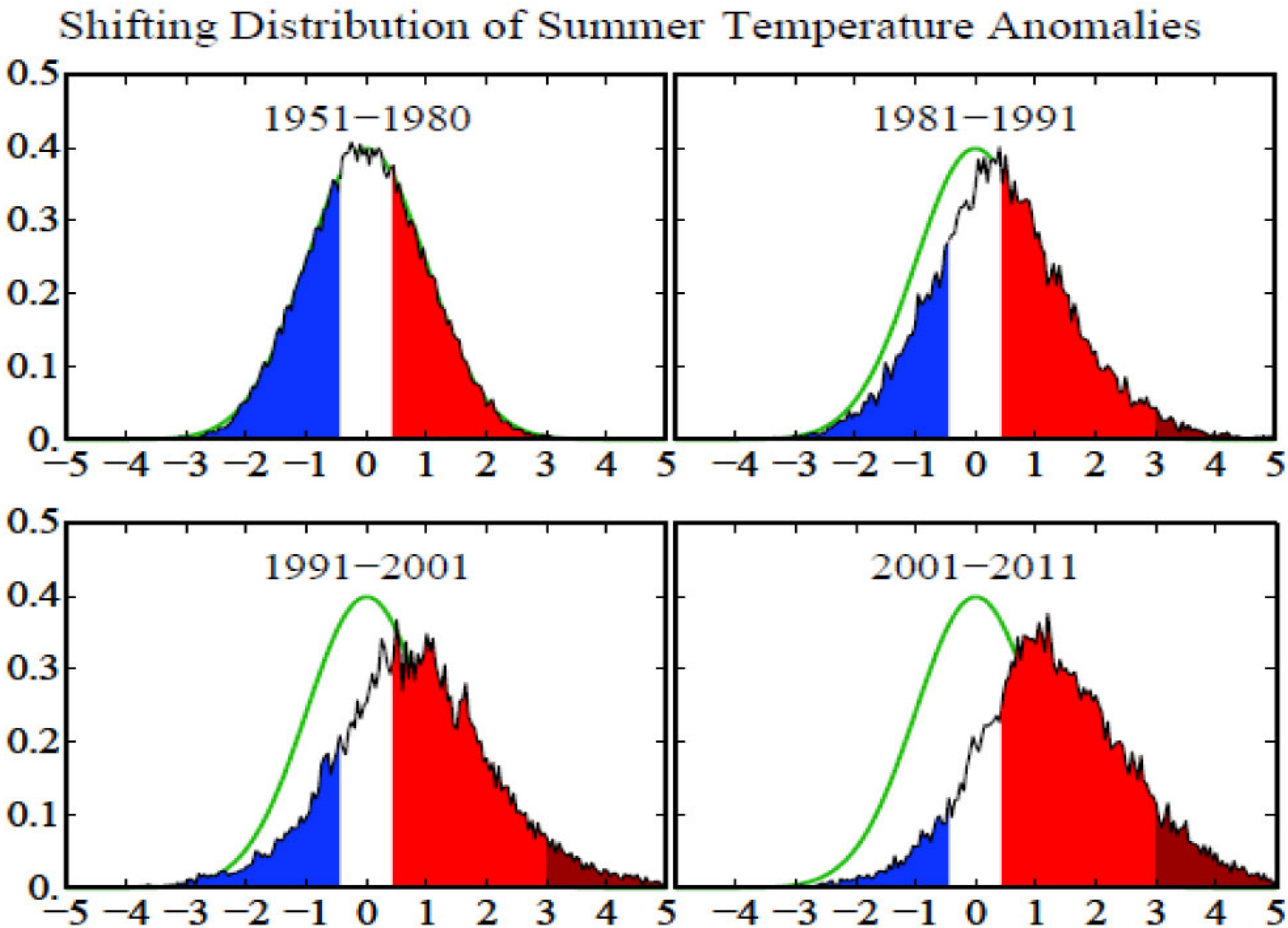

Manitoba Hydro
Manitoba-Minnesota Transmission Project
Project Infrastructure
Converter Station (Existing)
Final Preferred Route (FPR)
Infrastructure
Existing 500kV Transmission Line
Existing 230kV Transmission Line
Landbase
Community
Railway
Trans Canada
Provincial Highway
Provincial Road
City
First Nation Lands
Ecological Reserve
Wildlife Management Area
Provincial Park
Coordinate System: UTM Zone 14N NAD83
Data Source: MBHydro, ProvMB, NRCAN
Date Created: August 19, 2015
N
0 5 10 Kilometres
0 5 10 Miles
1:500,000
Final Preferred Route
Selkirk
Stonewall
Stony Mountain
Grosse Isle
Dorsey
Rosser
Birds Hill Provincial Park
Beausejour
Seddons Corner
Molson
Cloverleaf
Whitemouth
Whiteshell Provincial Park
Oakbank
Hazelridge
Dugald
Glass
Anola
Vivian
Ste. Rita
Elma
Rennie
Headingley
Beaudry Provincial Park
City of Winnipeg
Assiniboine River
Riel
Deacons Corner
Prairie Grove
Oak Bluff
Starbuck
Grande Pointe
Lorette
Dufresne
Ross
Ste-Genevieve
Hadashville
Prawda
McMunn
East Braintree
Sanford
La Salle
Ile des Chênes
St. Adolphe
Linden
Ste. Anne
La Coulee
Richer
Glenlea
Niverville
Greenland
Brunkild
Domain
New Bothwell
Giroux
Ste. Agathe
Osborne
Randolph
Steinbach
La Broquerie
Kleefeld
Marchand
Aubigny
Carey
St-Pierre-Jolys
Grunthal
Sarto
Red River
Dufrost
Barkfield
Morris
Lowe Farm
Ste. Elizabeth
St. Malo
Sandilands
Woodridge
St.Labre
Zhoda
Arnaud
Carlowrie
Rat River
Carrick
WHITEMOUTH LAKE
Badger
Horndean
Roseau River Anishinabe First Nation
Roseau River
Green Ridge
Letellier
Glenw
St. Joseph
Stuartburn
Vita
Callento
Sundown
Vassar
Piney
Altona
Gardenton
Tolstoi
Arbakka
South Junction
Sprague
Ridgeville
Fredensthal
Gretna
Emerson
Canada
United States of America

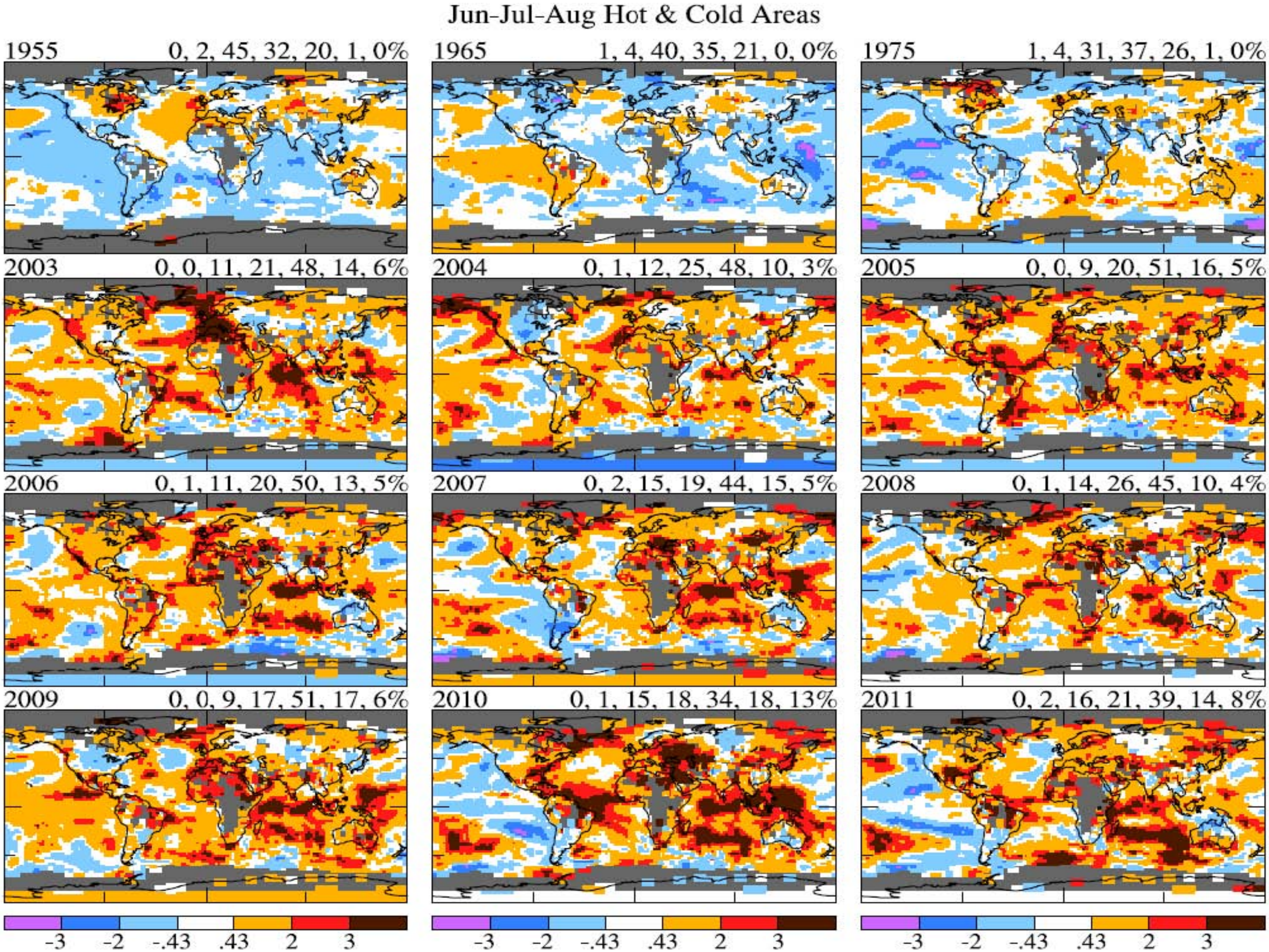
Statistics: Bell Curve

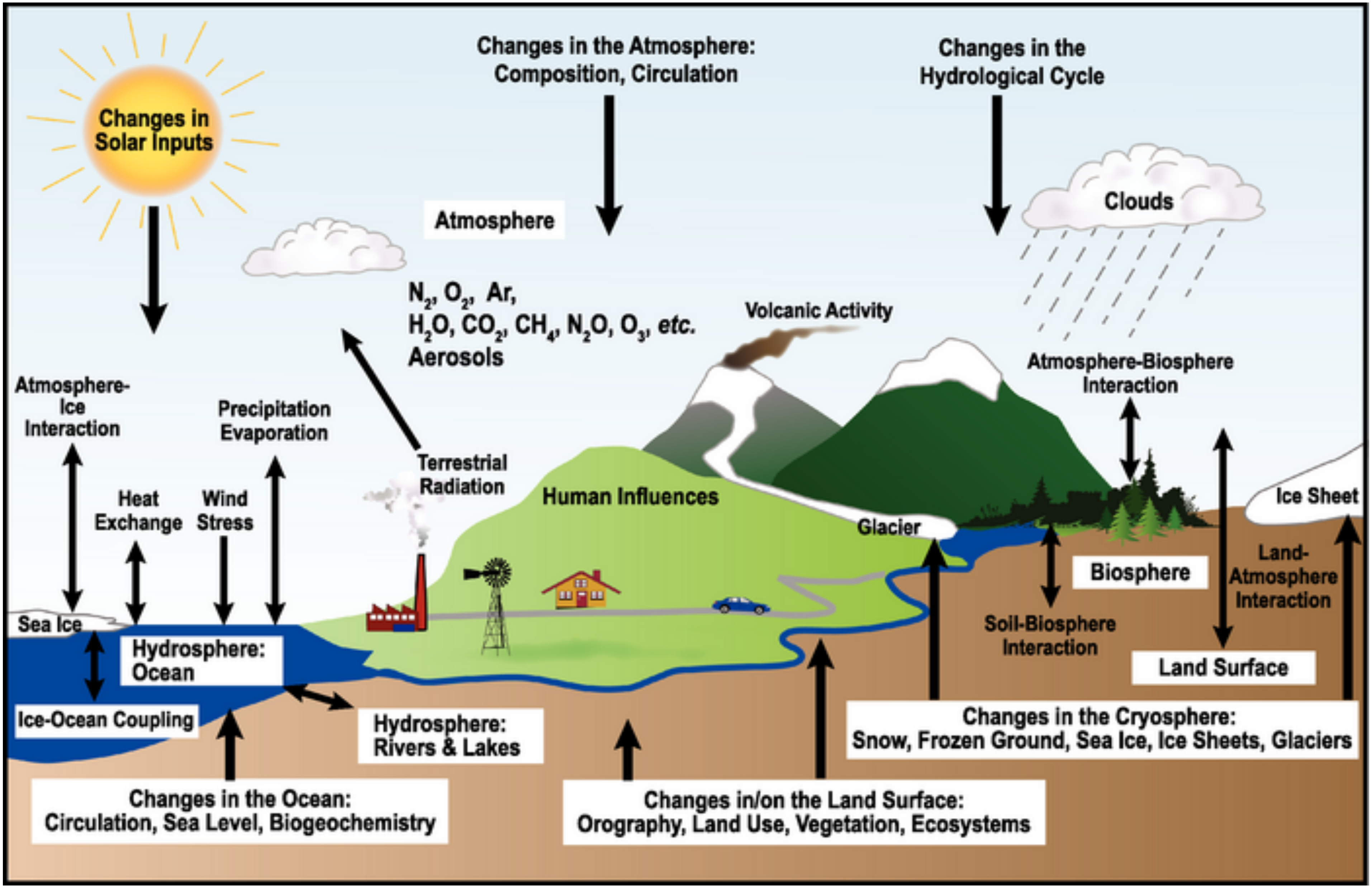


Human emissions have changed the chemistry of atmosphere & oceans → rapid changes in climate (+ faster warming at higher latitudes) → weather statistics have changed → extreme weather events (torrential rains, windstorms, drought, etc.) occur: a) **more often**, b) **are more severe**, c) **last longer**, & d) **happen in new places**.


Current climate
Future climate
Probability of occurrence
More
hot
weather
More
extreme
hot
weather
Less
cold
weather
Increase in
average
temperature
Cold
Average
Hot
Temperature


Shifting Distribution of Summer Temperature Anomalies
1951−1980
1981−1991
1991−2001
2001−2011
0.5
0.4
0.3
0.2
0.1
0.
−5 −4 −3 −2 −1 0 1 2 3 4 5


Jun-Jul-Aug Hot & Cold Areas
1955 0, 2, 45, 32, 20, 1, 0%
1965 1, 4, 40, 35, 21, 0, 0%
1975 1, 4, 31, 37, 26, 1, 0%
2003 0, 0, 11, 21, 48, 14, 6%
2004 0, 1, 12, 25, 48, 10, 3%
2005 0, 0, 9, 20, 51, 16, 5%
2006 0, 1, 11, 20, 50, 13, 5%
2007 0, 2, 15, 19, 44, 15, 5%
2008 0, 1, 14, 26, 45, 10, 4%
2009 0, 0, 9, 17, 51, 17, 6%
2010 0, 1, 15, 18, 34, 18, 13%
2011 0, 2, 16, 21, 39, 14, 8%
-3 -2 -.43 .43 2 3

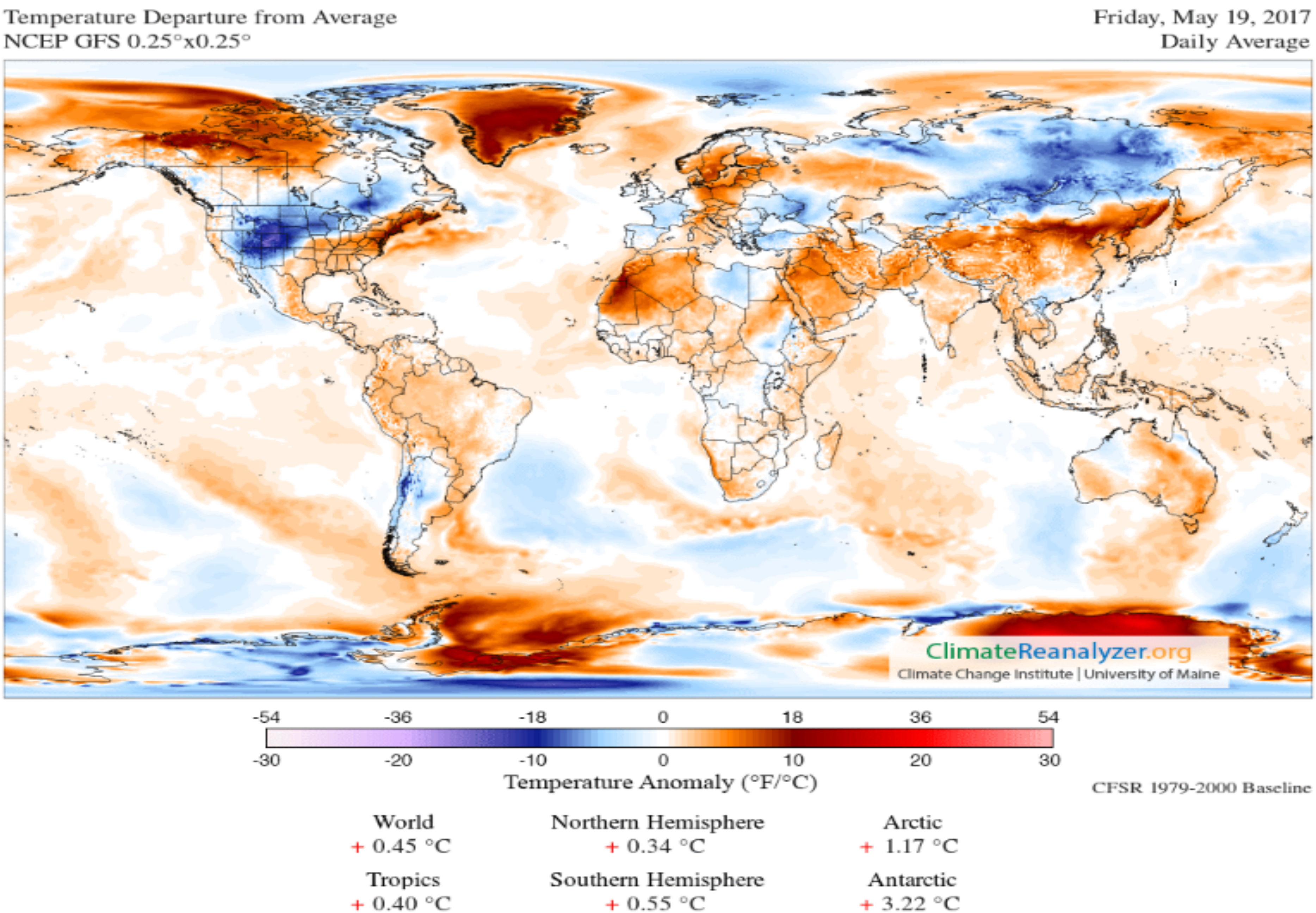


(IPCC:AR4, WG1, Ch. 1, 2007)

Climate system of the Earth (on human timescales)

Global climate system: Joining the dots

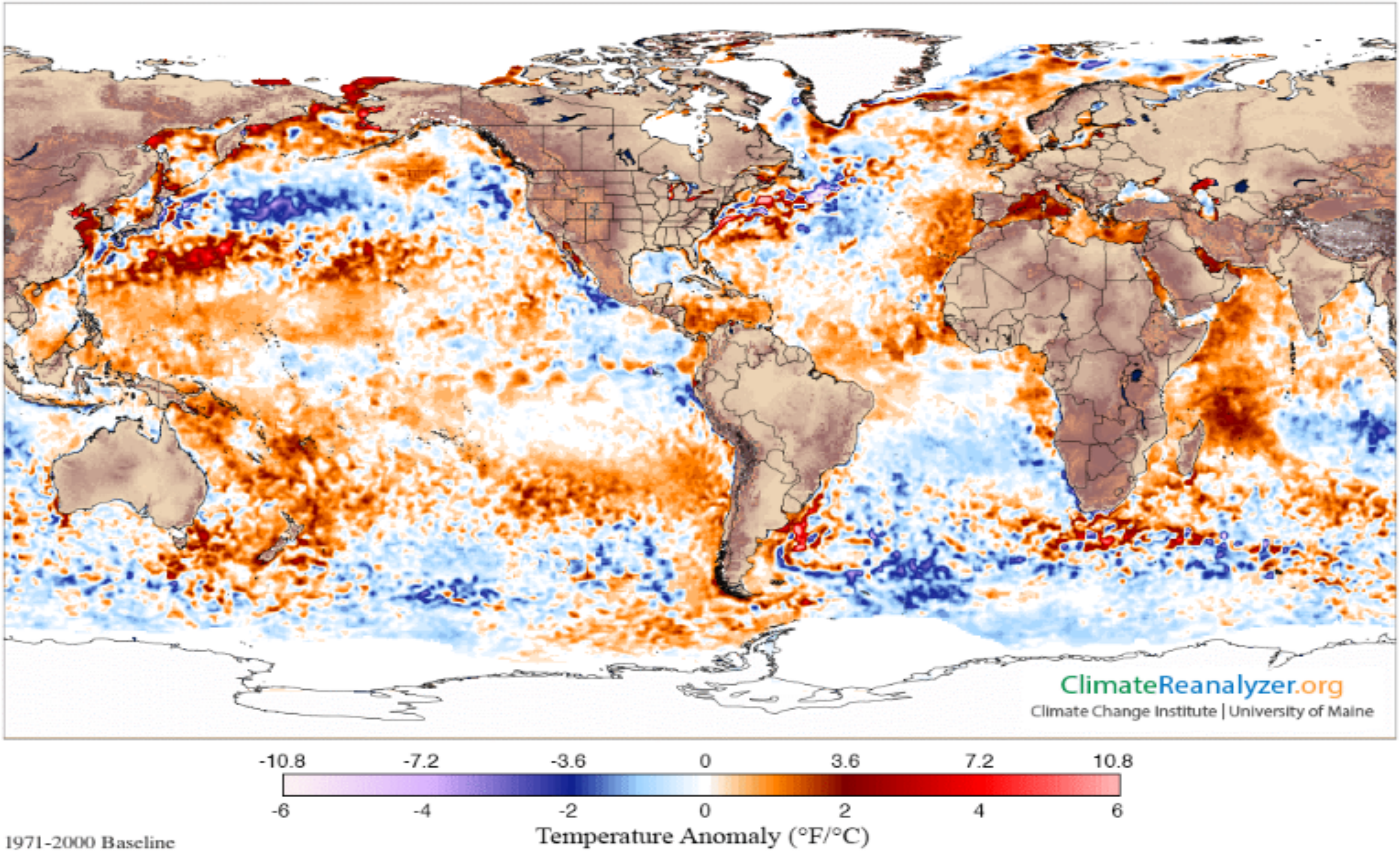
Increased human fossil fuel combustion and land use changes
→ atmospheric greenhouse gas concentrations (CO_2, CH_4 & N_2O) are quickly rising at ever increasing (exponential) rates
→Earth warms → rapid declines in Arctic sea-ice and snow cover → faster Greenland ice sheet melting → surfaces become darker → more sunlight is absorbed → north warms faster by 5x - 8x global average
→ decreases equator-to-Arctic temperature difference → less heat moves from the equator to the pole in the:
a)atmosphere: jet streams slow down, & become wavier & often get "stuck" → extreme weather events are thus more frequent, stronger, they last longer, & occur in new locations
b)oceans: currents such as the Gulf Stream slow down, and contribute to large sea level rise on east coast of North America



Climate Reanalyzer: University of Maine http://www.cci-reanalyzer.org/

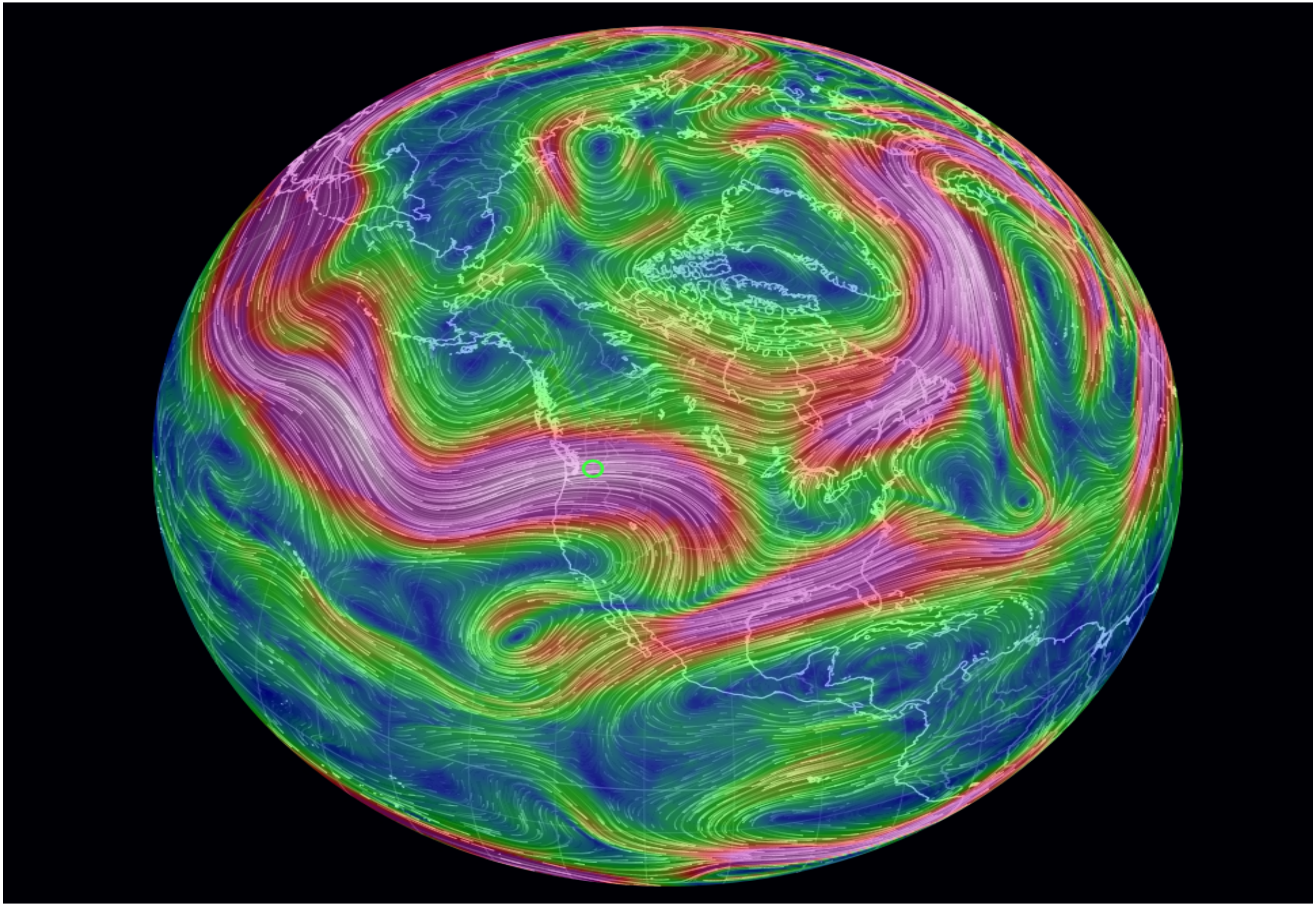
SST Departure from Average
NOAA OISST V2

Friday, May 19, 2017
Daily Average



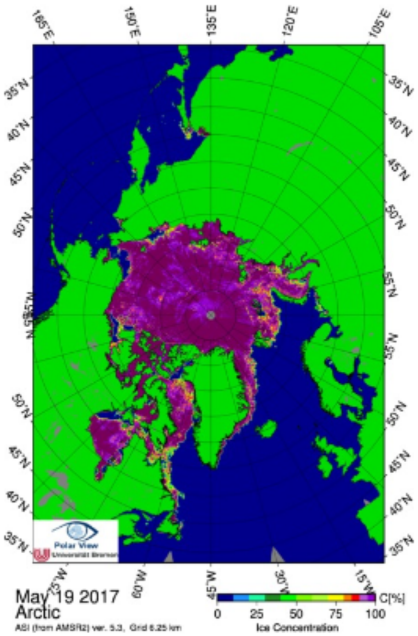
1971-2000 Baseline

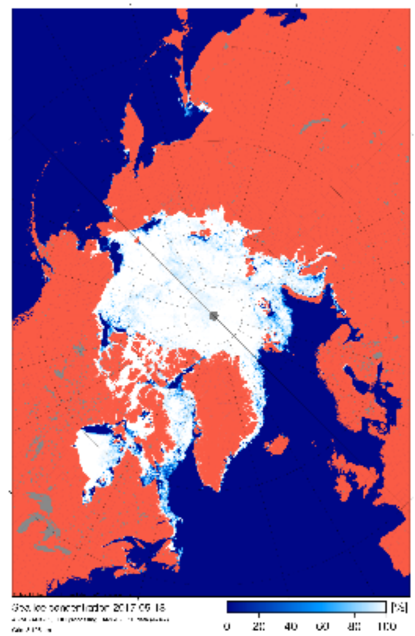
World	Northern Hemisphere	North Atlantic
+ 0.22 °C	+ 0.36 °C	+ 0.34 °C
Equatorial Pacific	Southern Hemisphere	North Pacific
+ 0.25 °C	+ 0.13 °C	+ 0.27 °C

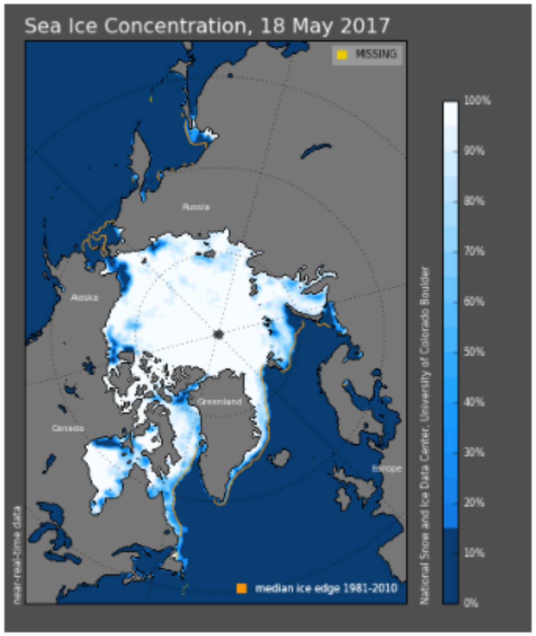


Earth nullschool (global map of weather and ocean conditions); click on text “Earth” for accessing menus https://earth.nullschool.net//

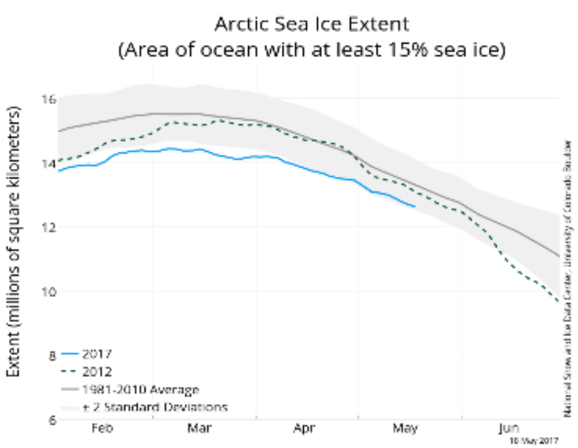
Sea ice concentration

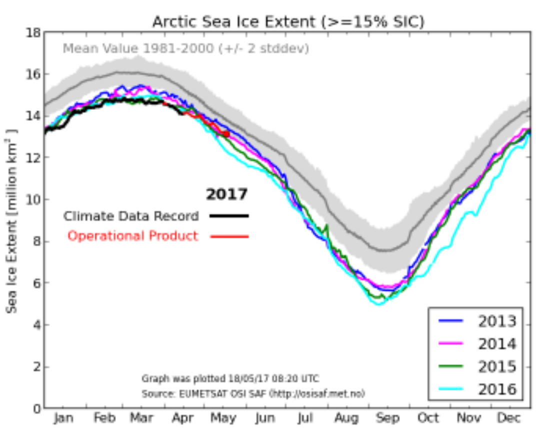


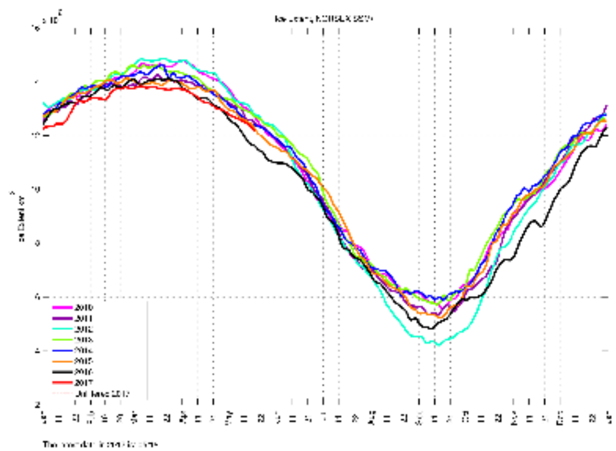




Sea ice extent & area

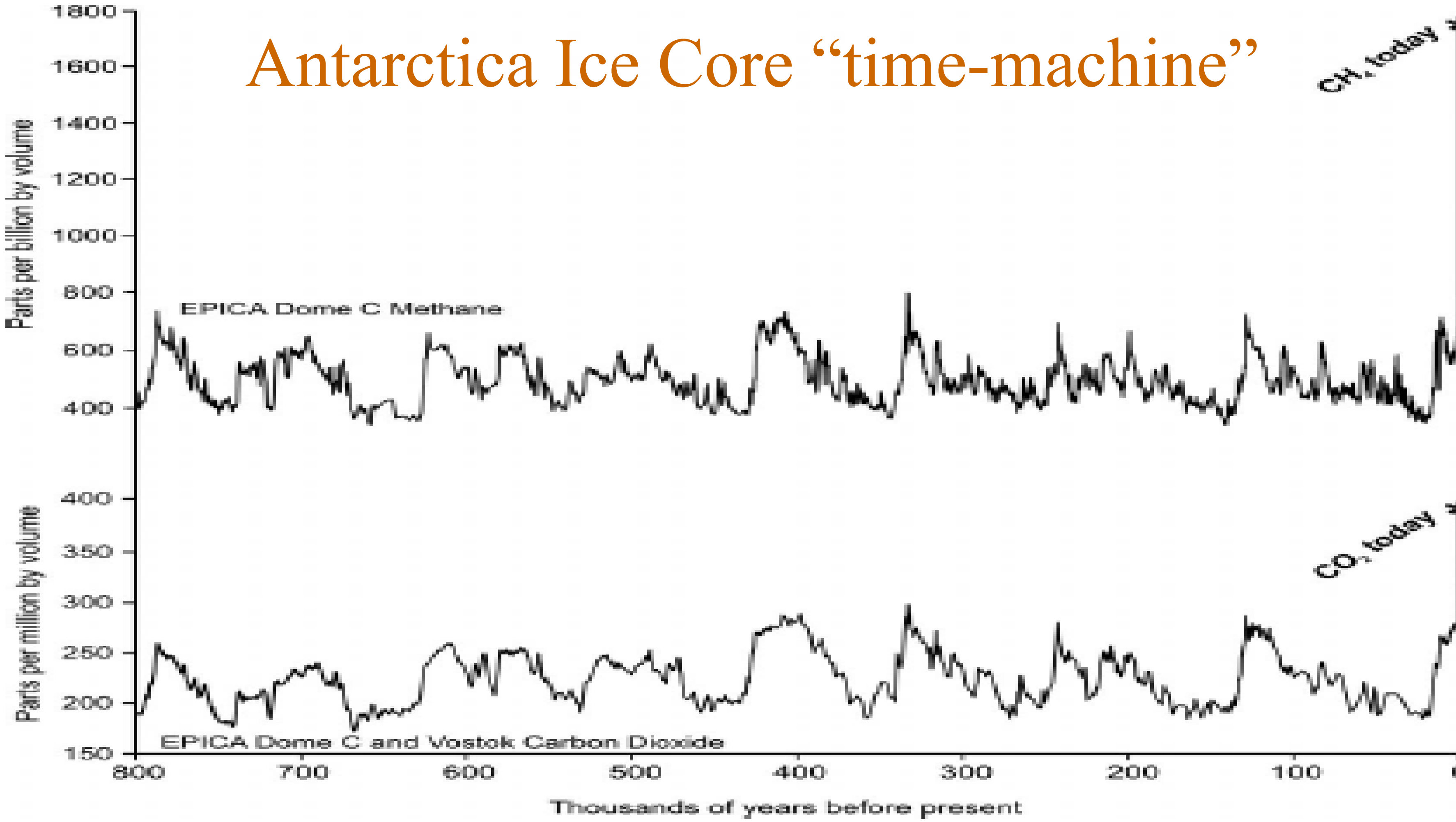






Arctic sea ice graphs https://sites.google.com/site/arcticseaicegraphs/

Antarctica Ice Core “time-machine”



Atmospheric methane & CO_2 concentrations

CH_4 and CO_2 concentrations trapped in ice cores are measured, oxygen isotopes in the frozen water allow us to determine temperature, & layers give dates back 800,000 years in the thickest ice sheets in Antarctica

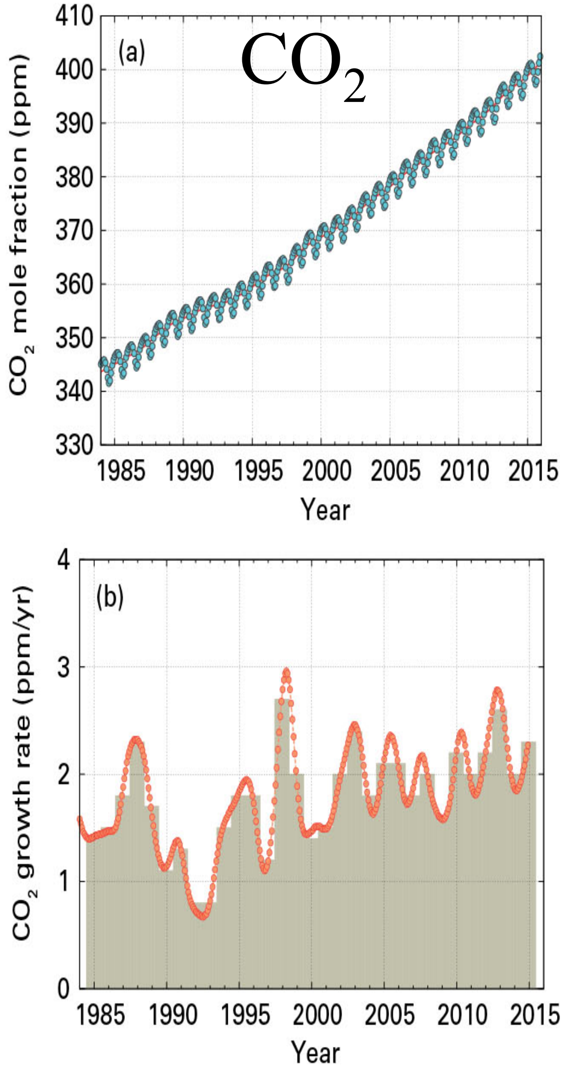


Figure 3. Globally averaged CO_2 mole fraction (a) and its growth rate (b) from 1984 to 2015. Increases in successive annual means are shown as columns in (b).

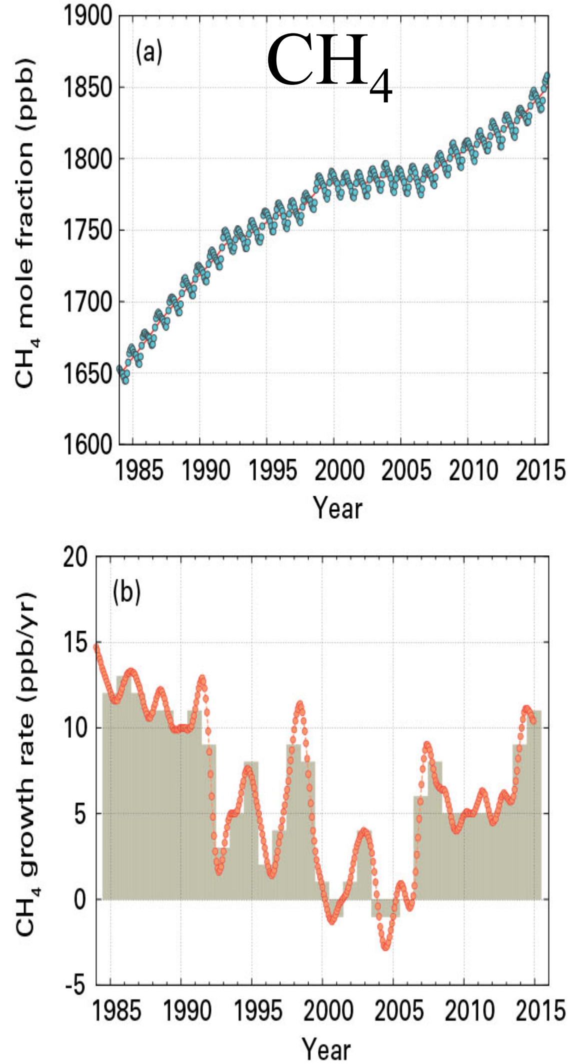


Figure 4. Globally averaged CH_4 mole fraction (a) and its growth rate (b) from 1984 to 2015. Increases in successive annual means are shown as columns in (b).

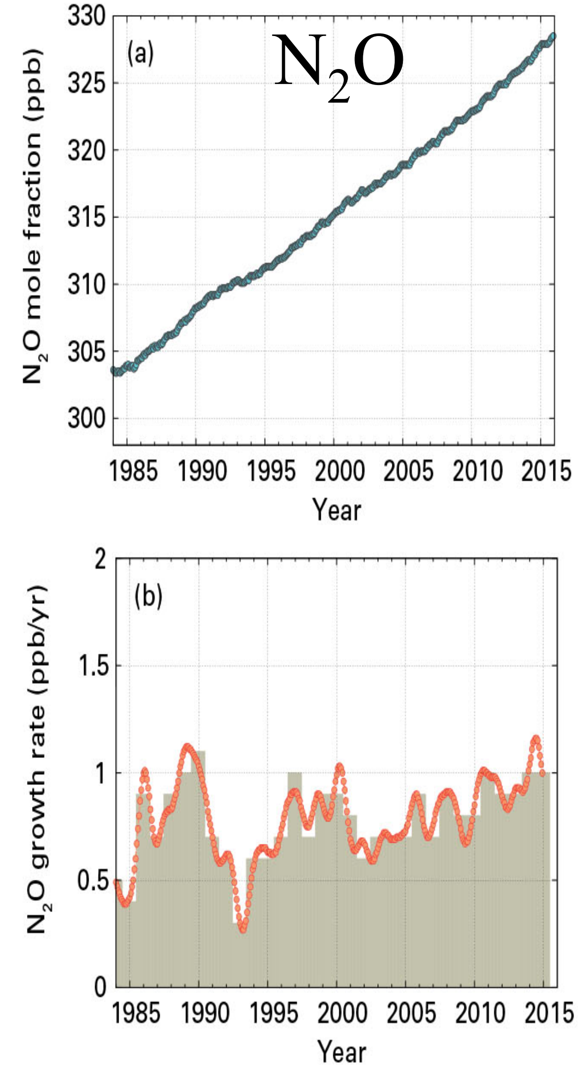
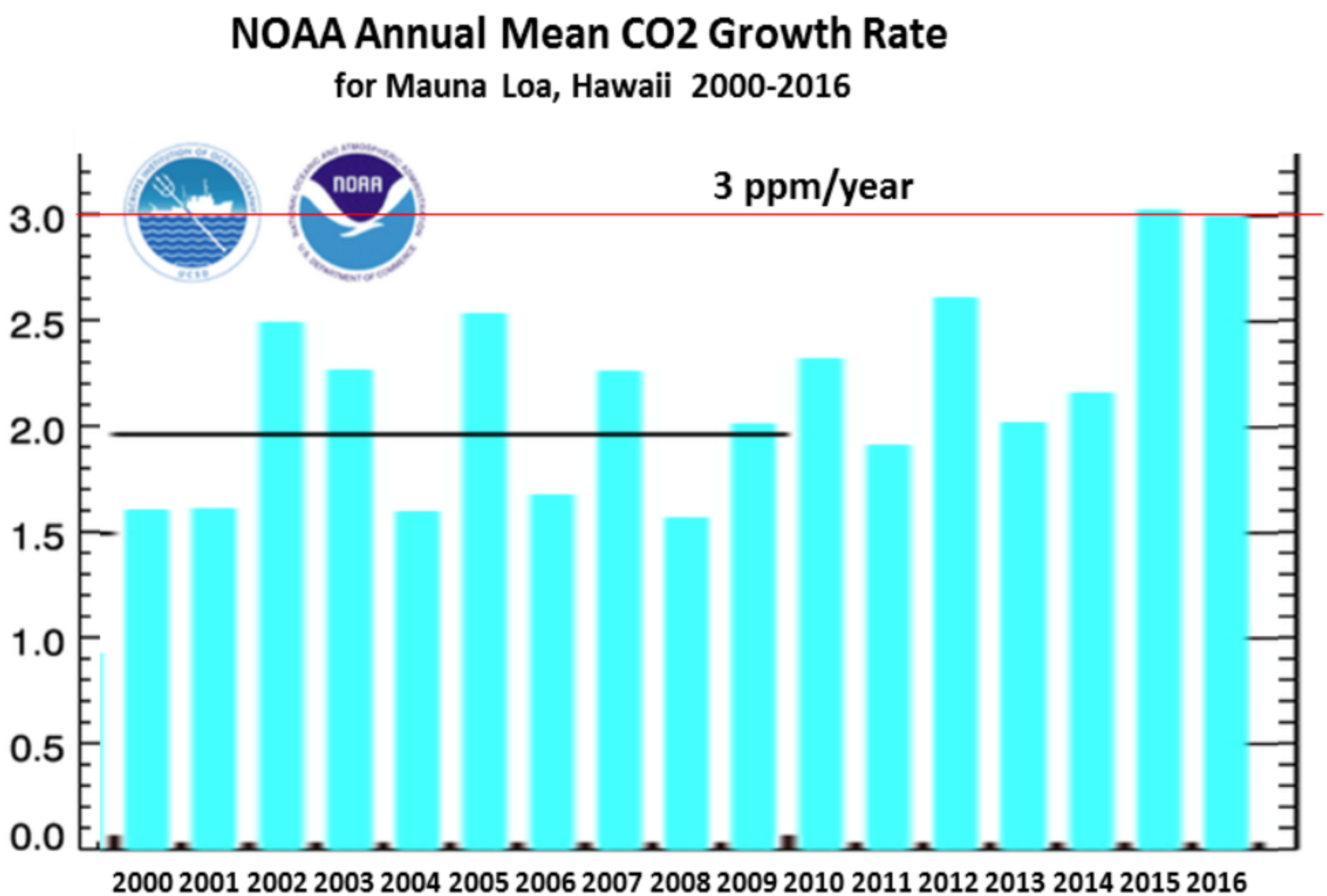


Figure 5. Globally averaged N_2O mole fraction (a) and its growth rate (b) from 1984 to 2015. Increases in successive annual means are shown as columns in (b).

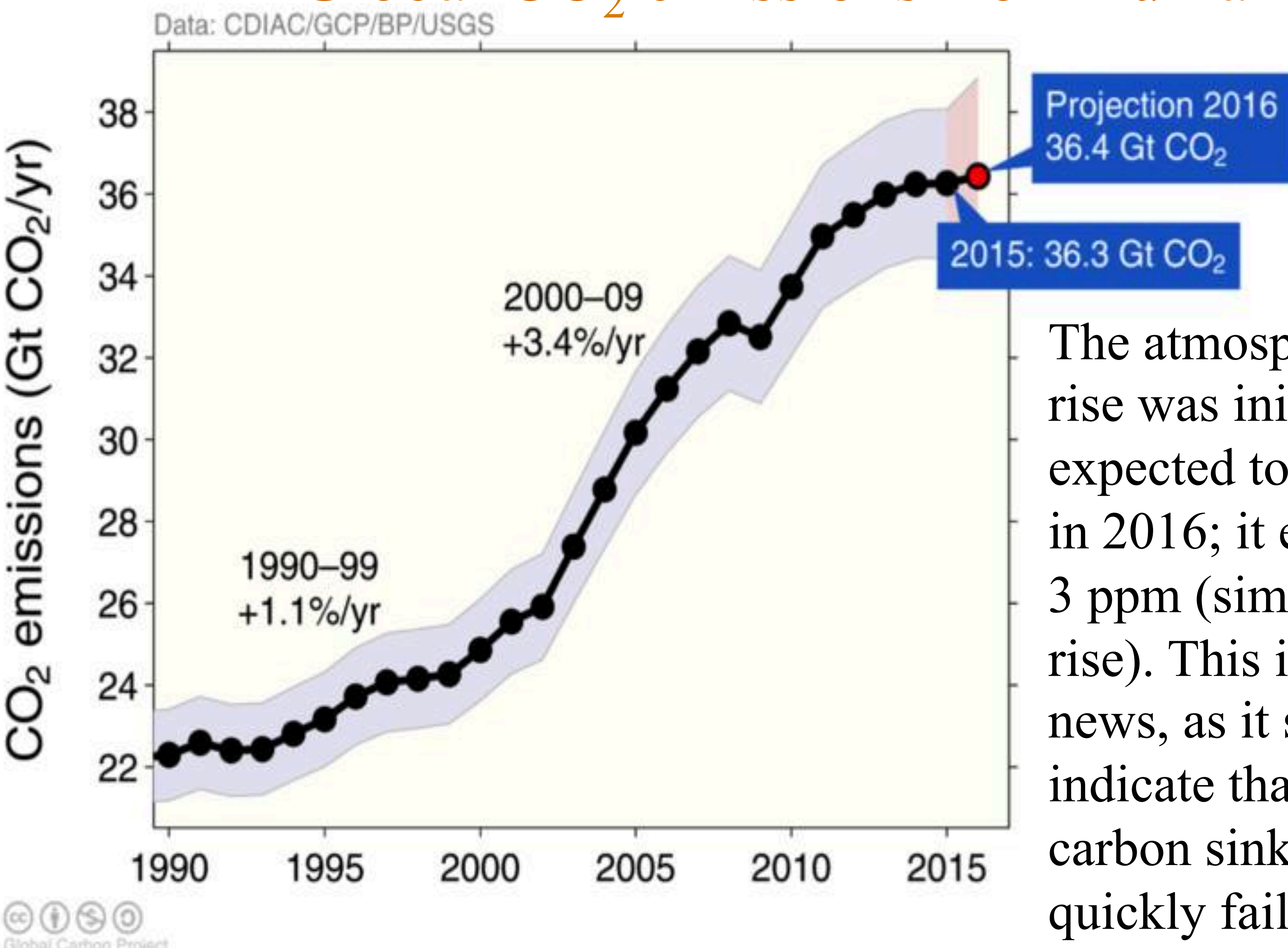
Annual atmospheric CO2 increases 2015 & 2016 unprecedented in Earth history (A. Glikson 2016)

NOAA
Average growth rate for the past 10 years is 2.01 ppm

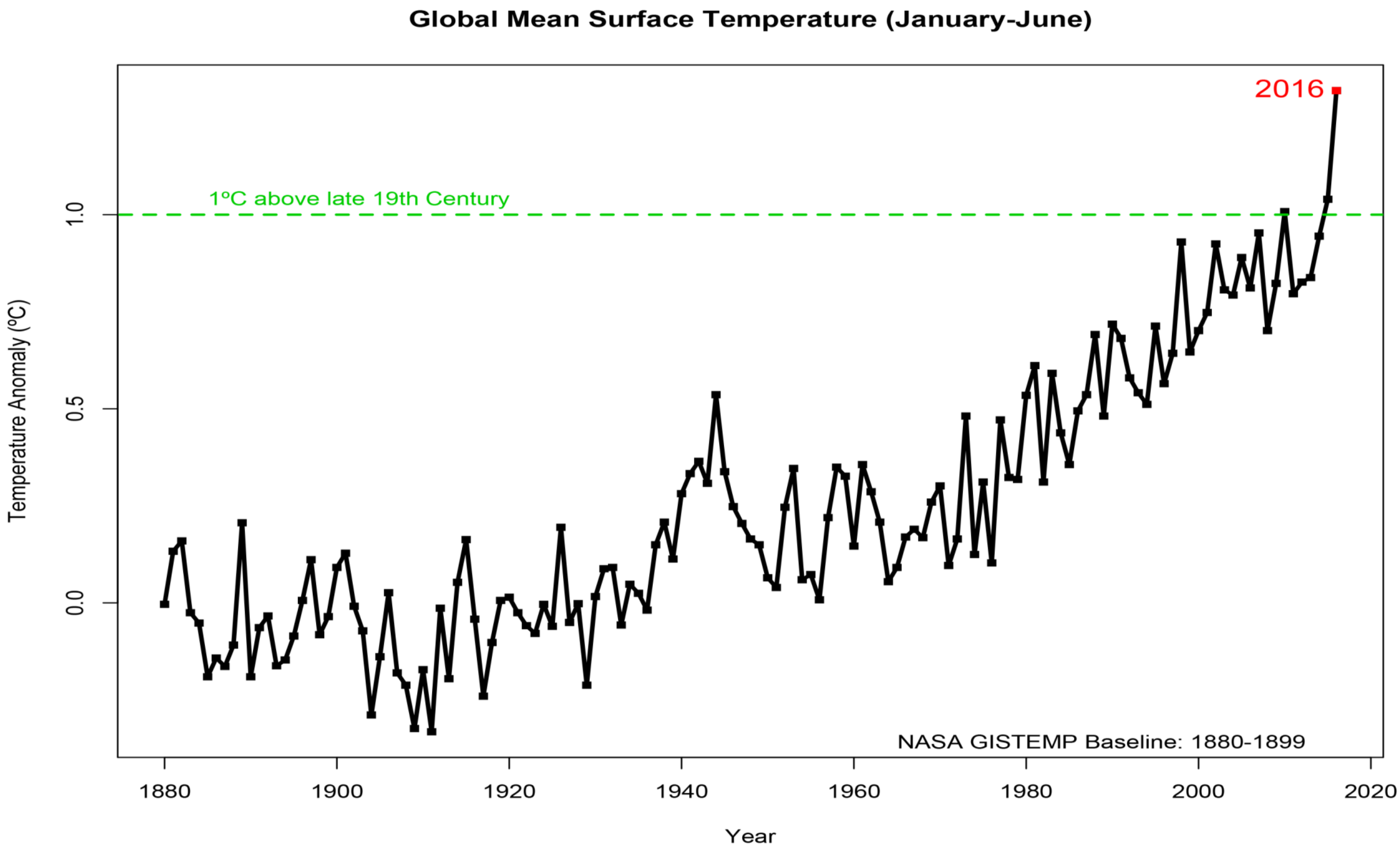
2016 3.00
2015 3.03
2014 2.16
2013 2.02
2012 2.61
2011 1.92
2010 2.32



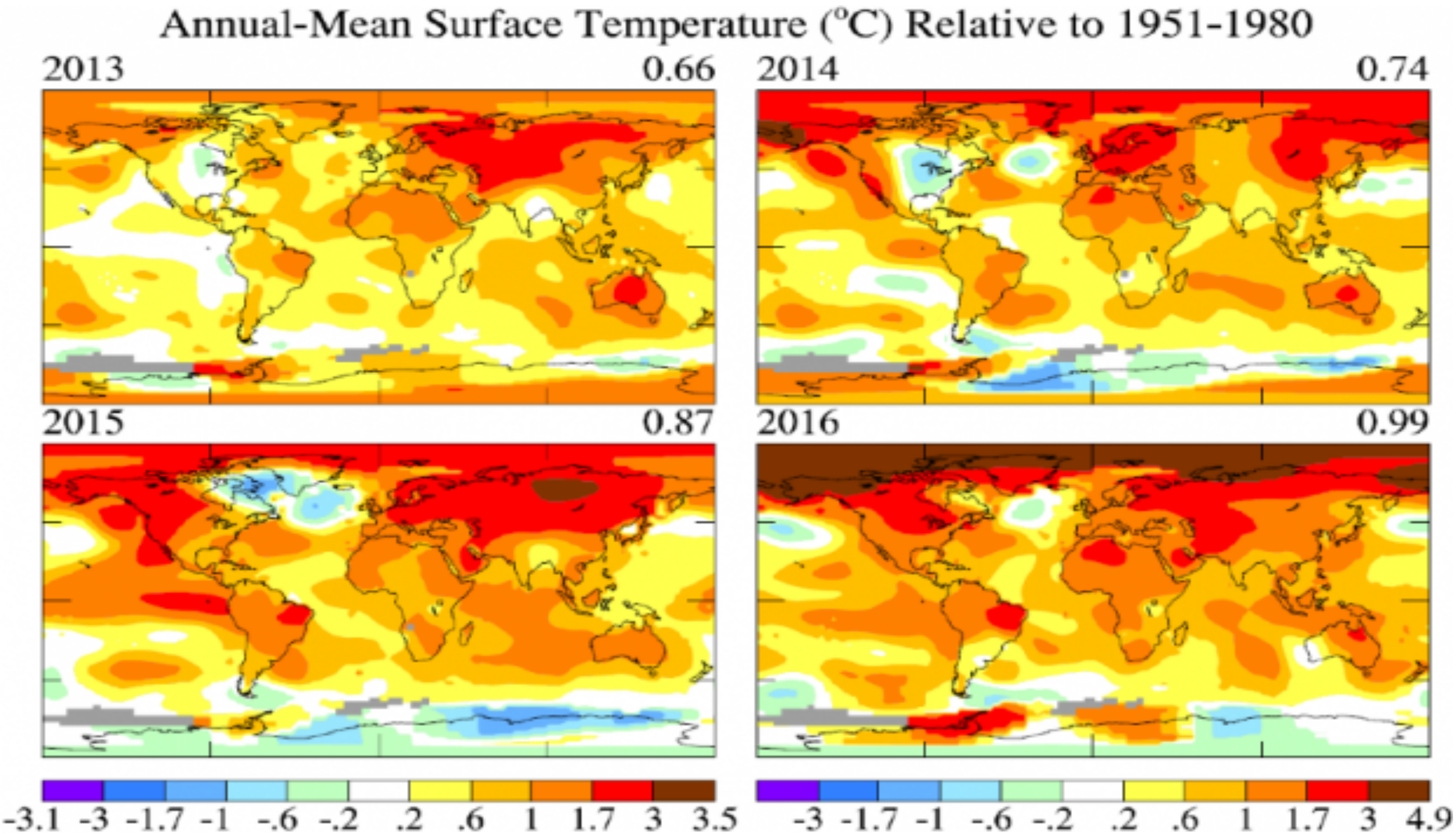
Global CO_2 emissions from humans



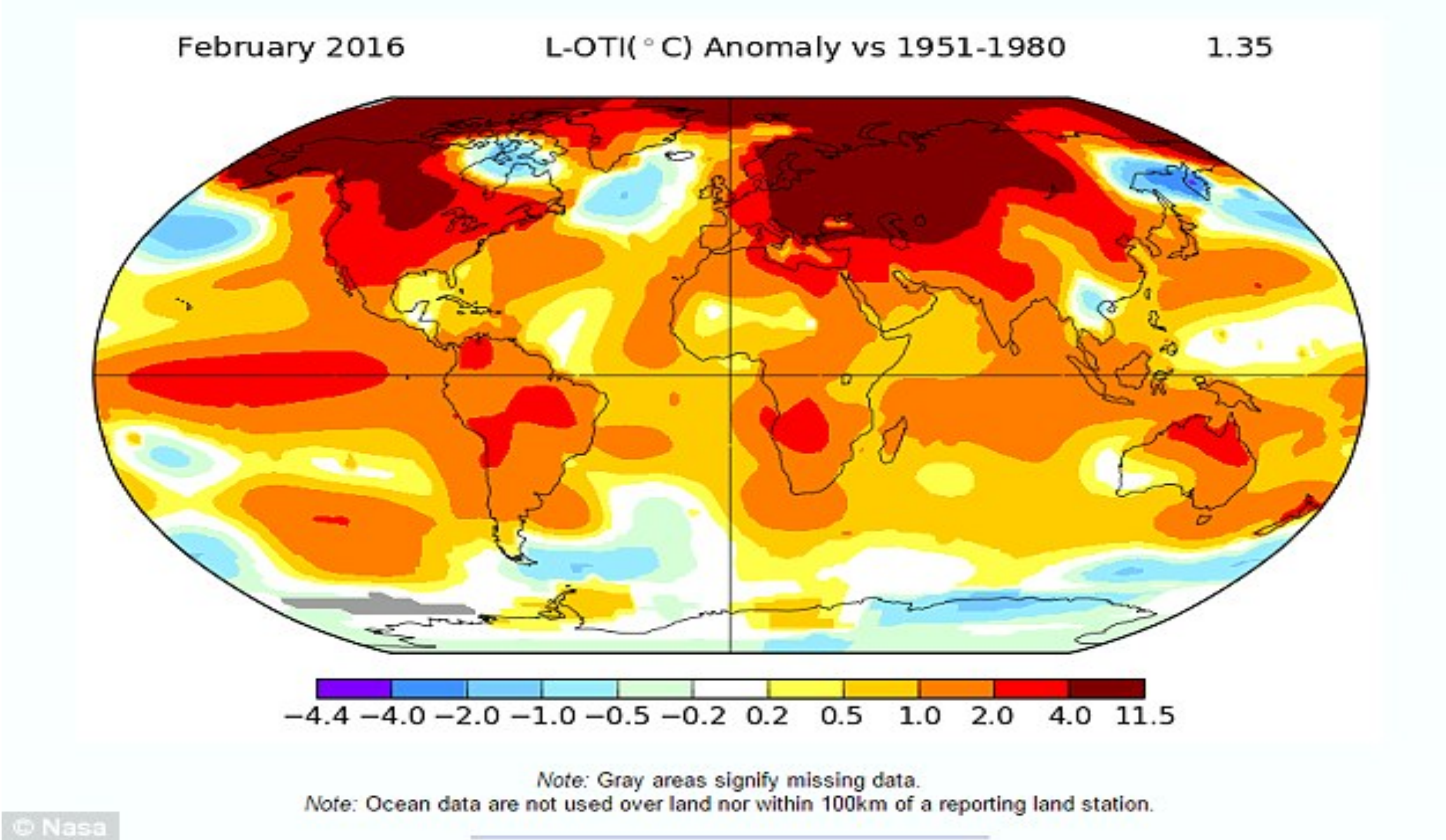
The atmospheric CO_2 rise was initially expected to be 4-5 ppm in 2016; it ended up at 3 ppm (similar to 2015 rise). This is very bad news, as it seems to indicate that global carbon sinks are quickly failing.



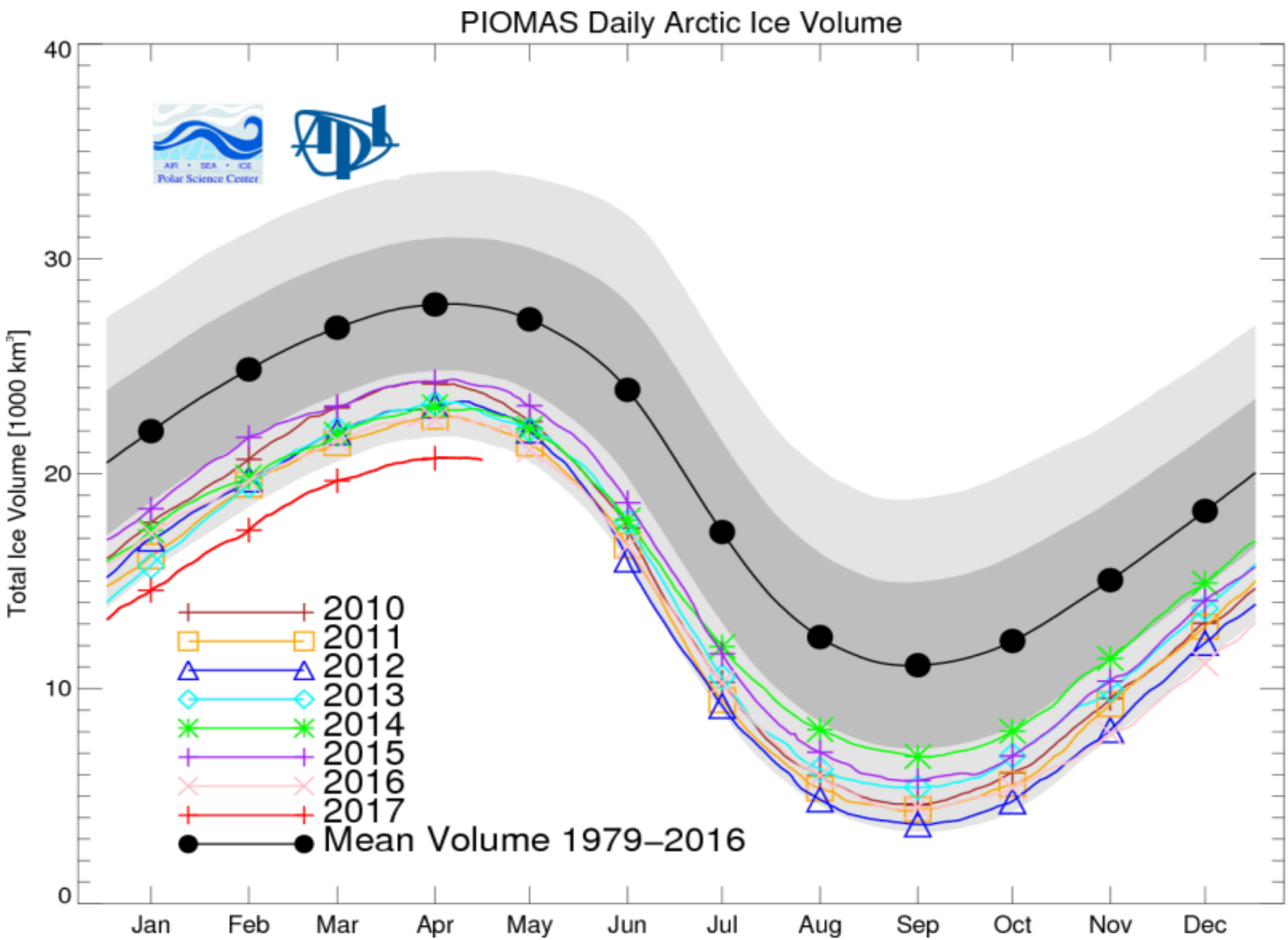
Very Important: Paris climate conference temperature targets are 2°C (1.5°C aspiration) relative to temperatures in 1750 (pre-industrial); thus one must ADD 0.15°C to the late 19th century values to get the temperature rise relative to 1750 .

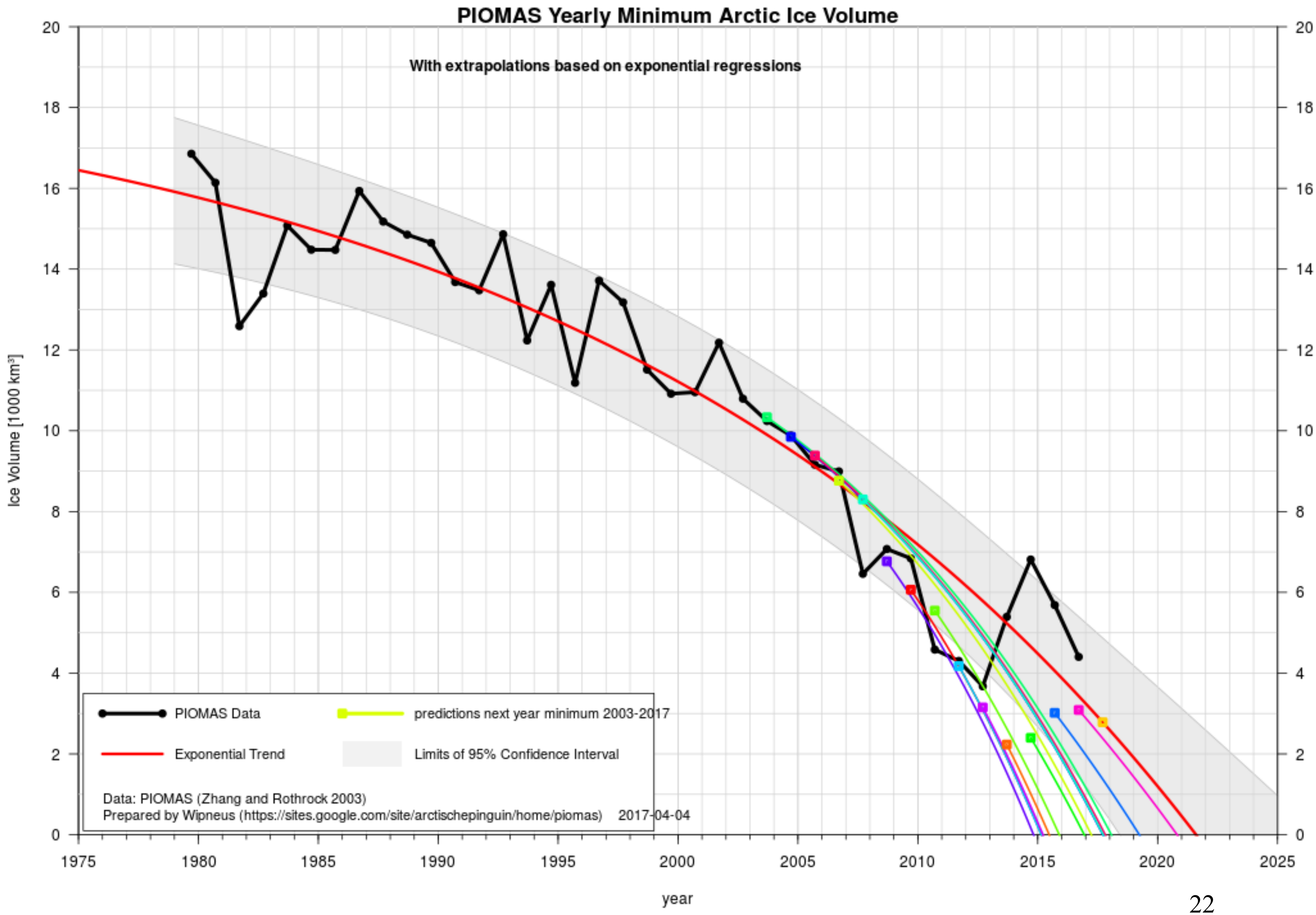


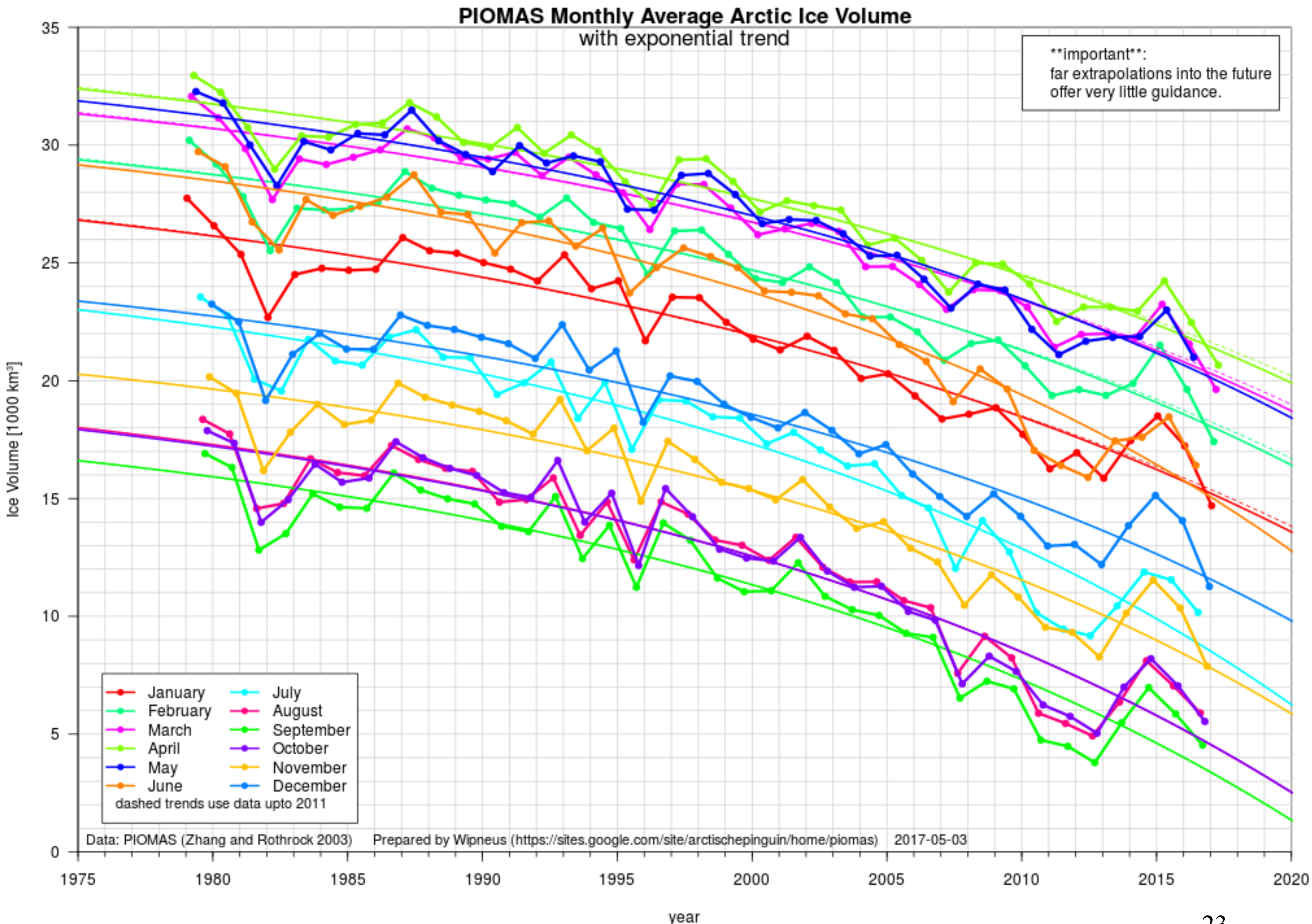
2016 average higher than 1951-1980 average by 0.99°C; 1951-1980 average higher than 1880-1910 average by 0.3°C; 1880-1910 average higher than 1750 by 0.15°C; Conclusion: 2016 is higher than pre-industrial (1750) by **1.44°C**



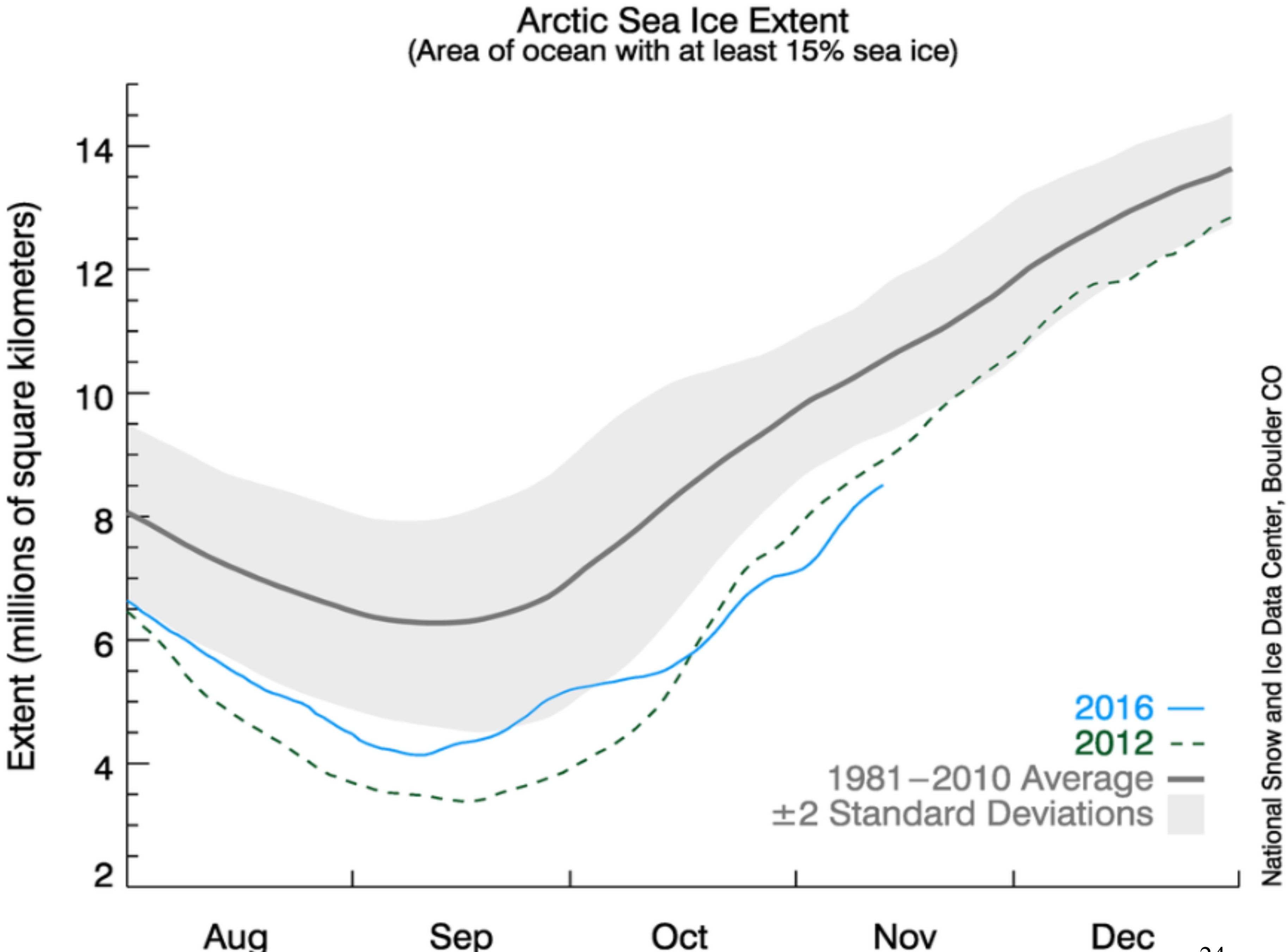
Feb, 2016 average higher than 1951-1980 average by 1.35°C; 1951-1980 average higher than 1880-1910 average by 0.3°C; 1880-1910 average higher than 1750 by 0.15°C; Conclusion: Feb, 2016 was higher than pre-industrial (1750) by **1.8°C**


PIOMAS Daily Arctic Ice Volume
Total Ice Volume [1000 km³]
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2010
2011
2012
2013
2014
2015
2016
2017
Mean Volume 1979–2016
AIR • SEA • ICE
Polar Science Center

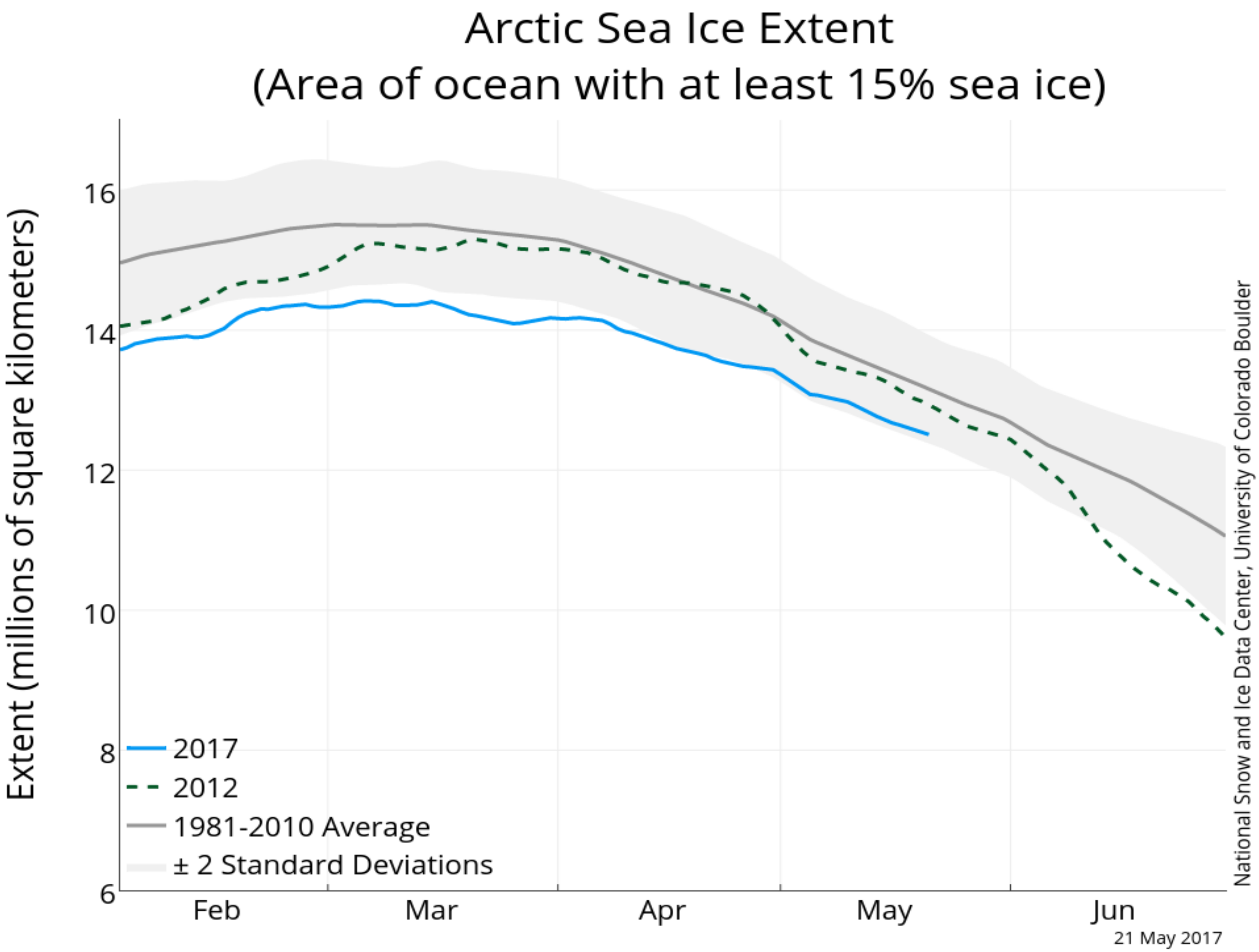

PIOMAS Yearly Minimum Arctic Ice Volume
With extrapolations based on exponential regressions
Ice Volume [1000 km³]
year
PIOMAS Data
predictions next year minimum 2003-2017
Exponential Trend
Limits of 95% Confidence Interval
Data: PIOMAS (Zhang and Rothrock 2003)
Prepared by Wipneus (https://sites.google.com/site/arctischepinguin/home/piomas) 2017-04-04



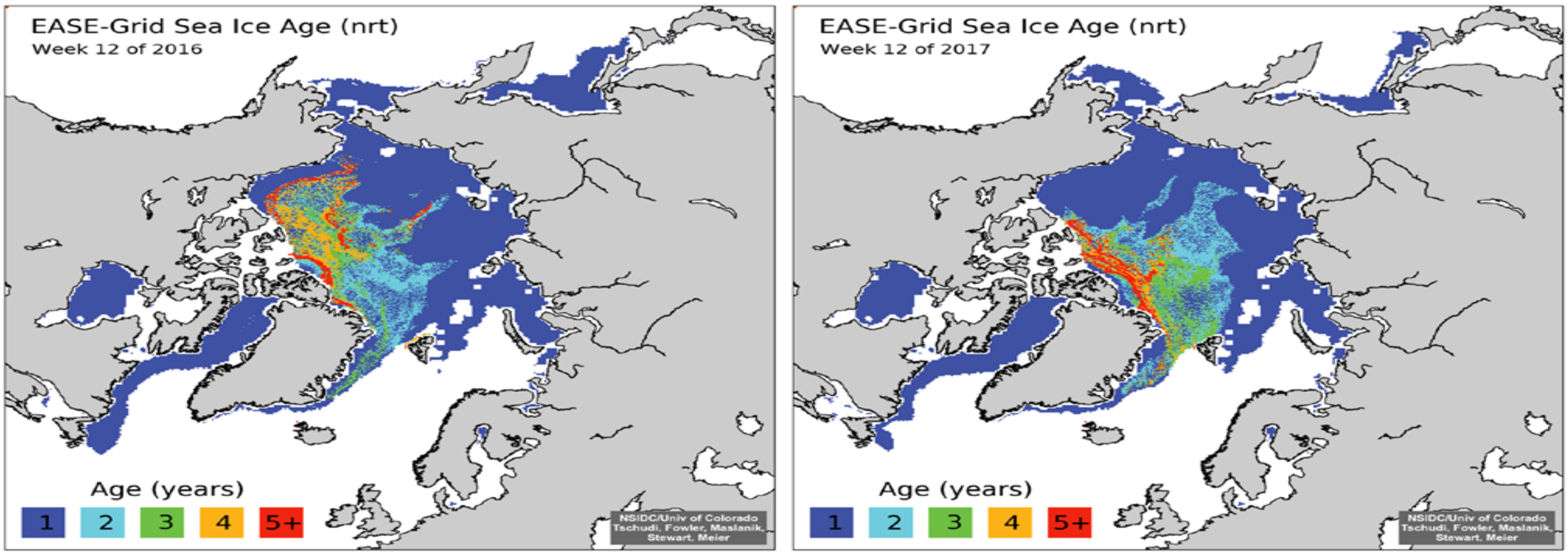
PIOMAS Monthly Average Arctic Ice Volume
with exponential trend
important:
far extrapolations into the future
offer very little guidance.
Ice Volume [1000 km³]
year
January
February
March
April
May
June
July
August
September
October
November
December
dashed trends use data upto 2011
Data: PIOMAS (Zhang and Rothrock 2003) Prepared by Wipneus (https://sites.google.com/site/arctischepinguin/home/piomas) 2017-05-03



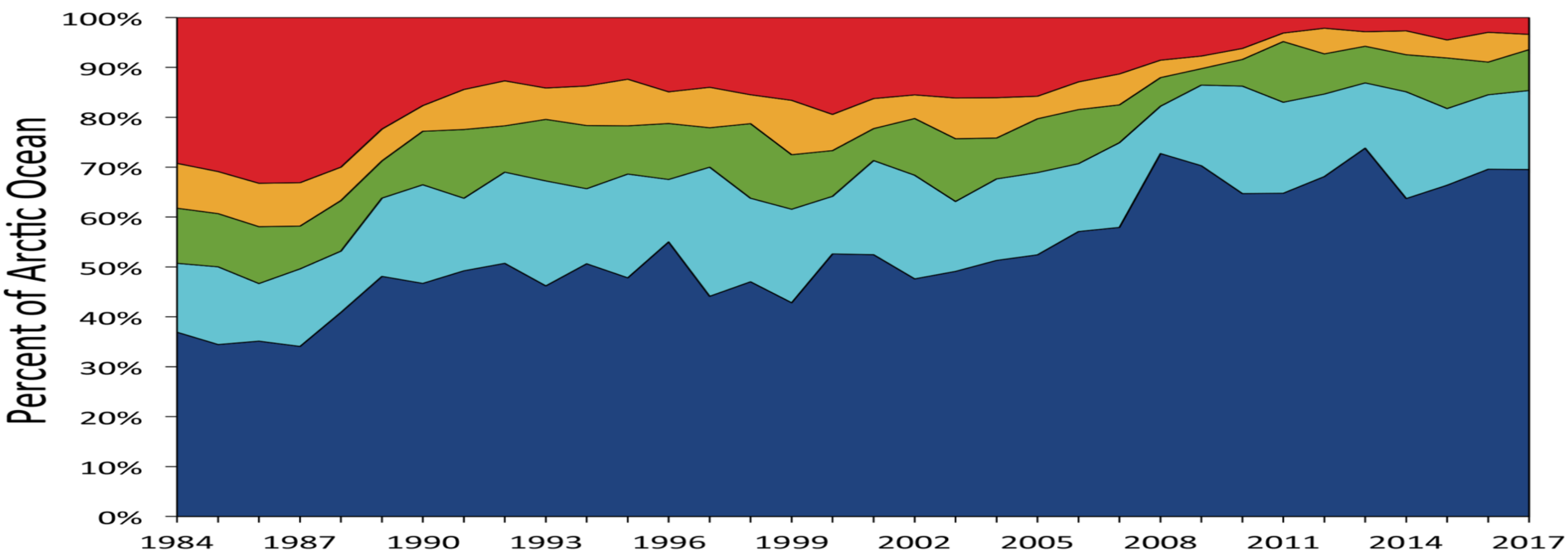
Arctic Sea Ice Extent
(Area of ocean with at least 15% sea ice)
Extent (millions of square kilometers)
14
12
10
8
6
4
2
Aug
Sep
Oct
Nov
Dec
2016
2012
1981–2010 Average
±2 Standard Deviations
National Snow and Ice Data Center, Boulder CO

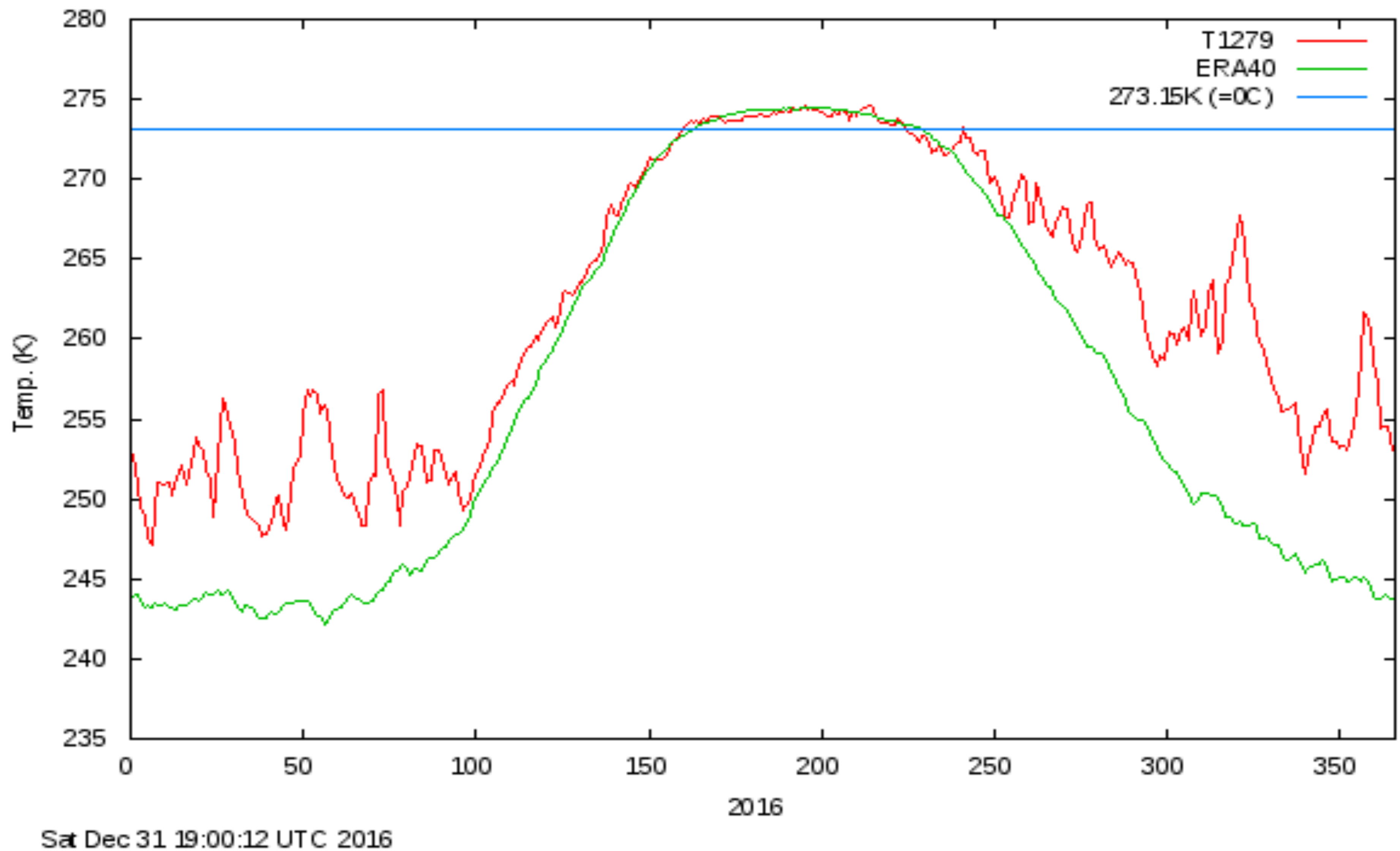


Arctic Sea Ice Extent
(Area of ocean with at least 15% sea ice)
Extent (millions of square kilometers)
16
14
12
10
8
6
2017
2012
1981-2010 Average
± 2 Standard Deviations
Feb
Mar
Apr
May
Jun
21 May 2017
National Snow and Ice Data Center, University of Colorado Boulder

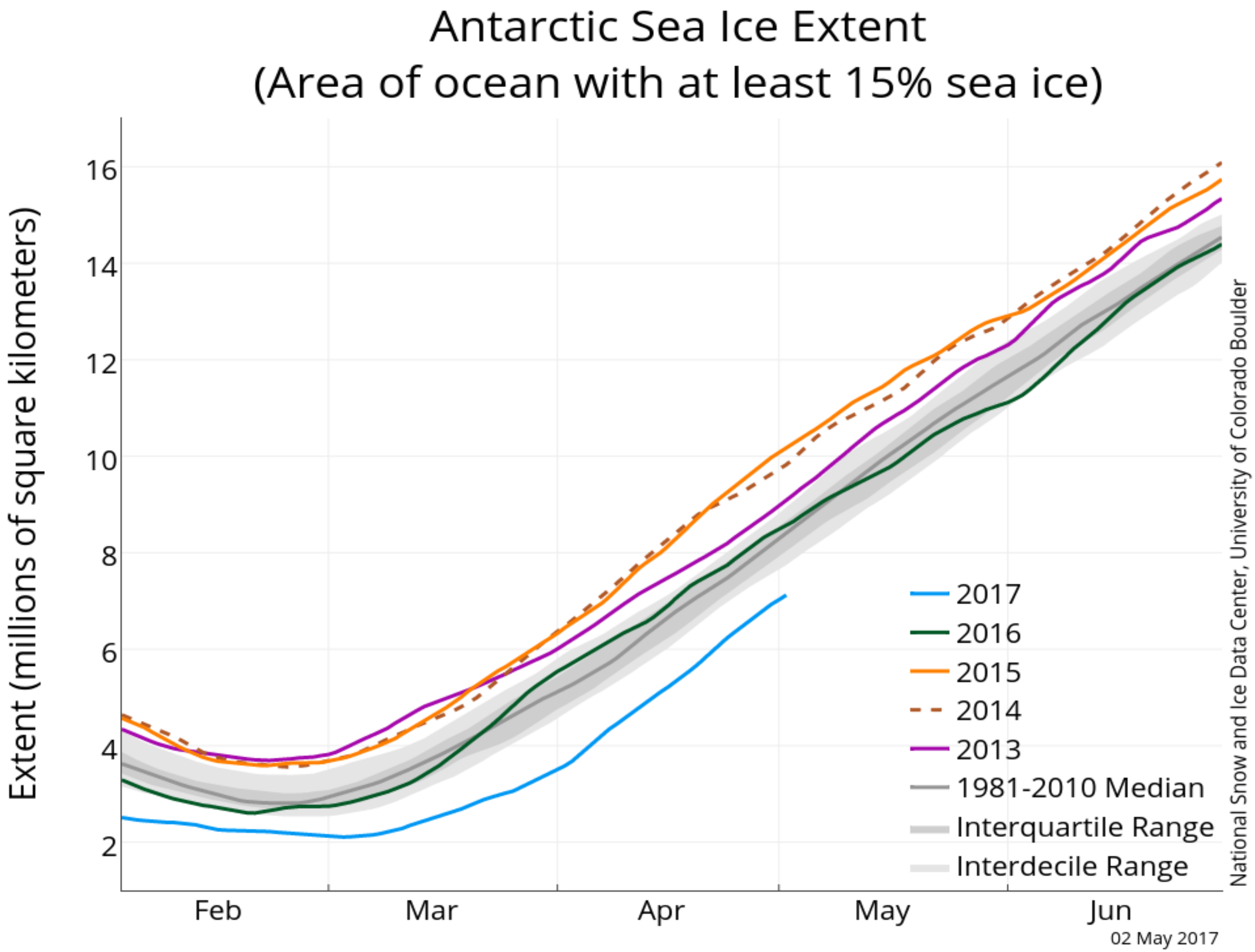


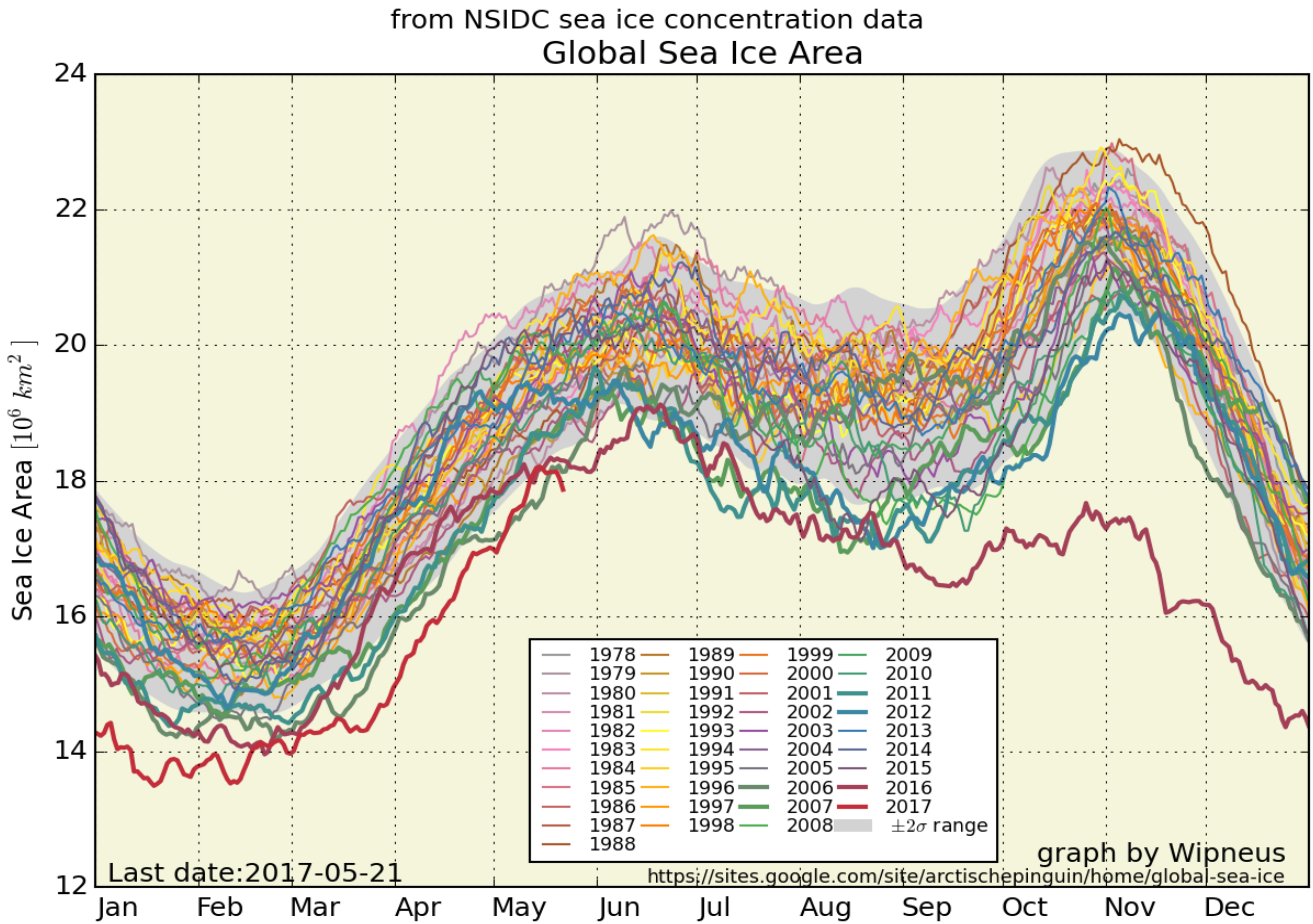
Sea Ice Age, End of March



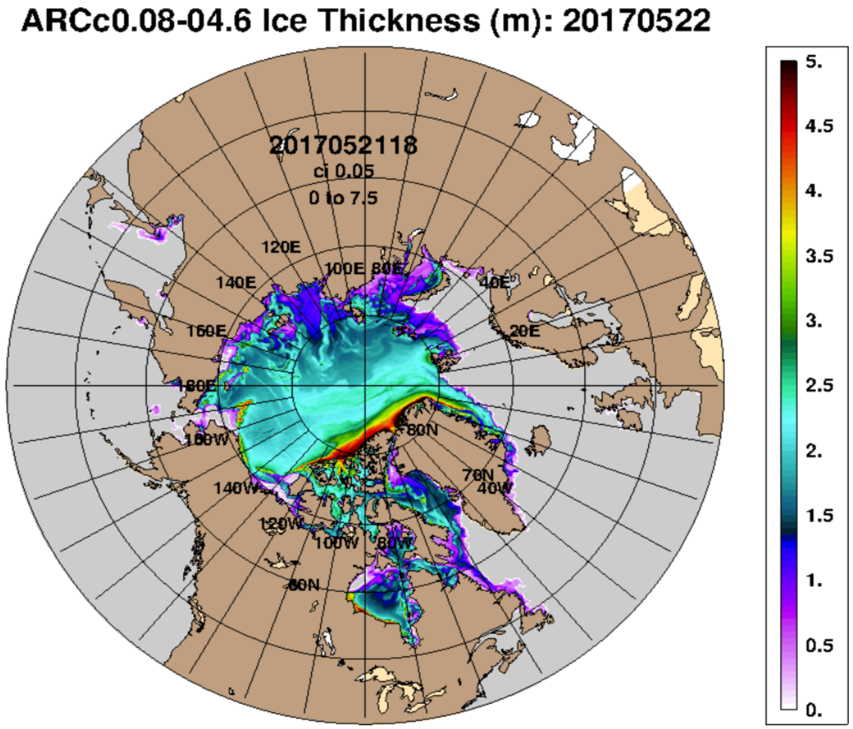


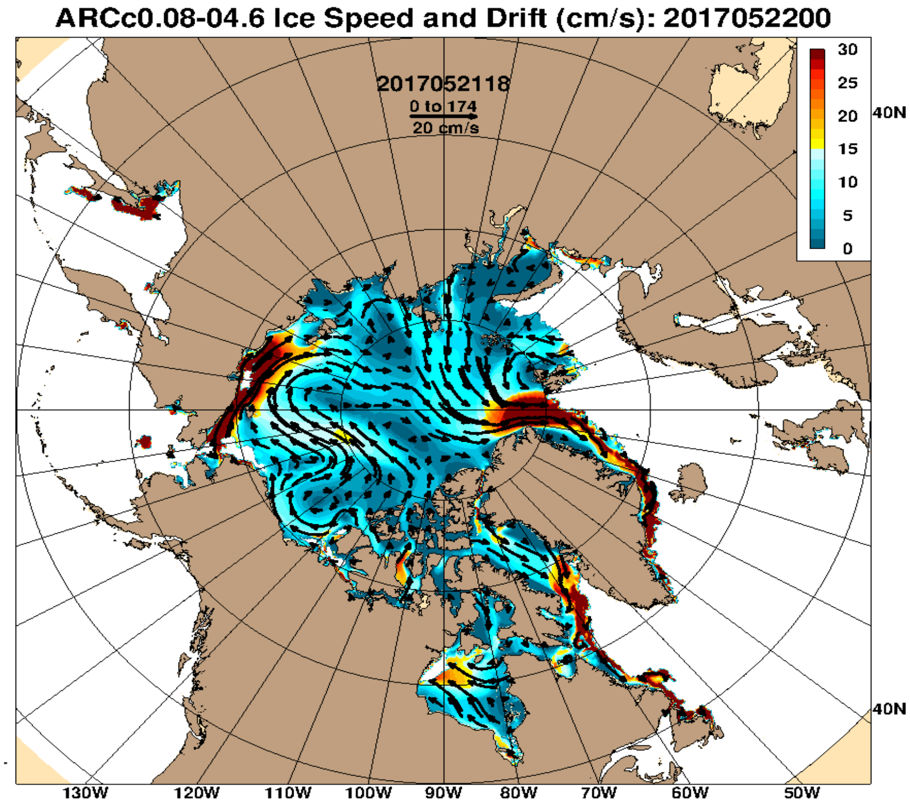
RED line: Arctic region temperature above latitude 80°N for 2016, compared to long-term average (green line). Red curve end in November, 2016 spiked to temperatures about 17°C above average, meaning it was still "summer" in the Arctic last Nov/Dec.

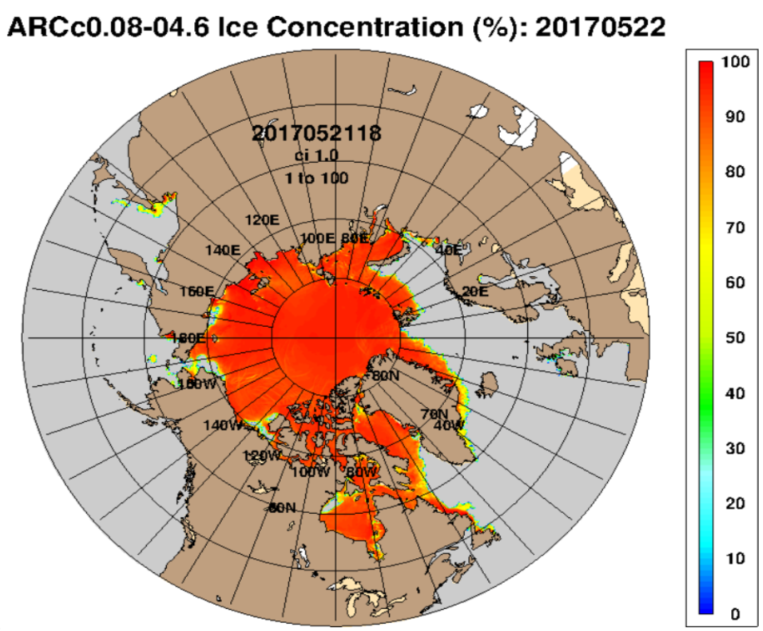

Antarctic Sea Ice Extent
(Area of ocean with at least 15% sea ice)
Extent (millions of square kilometers)
16
14
12
10
8
6
4
2
Feb
Mar
Apr
May
Jun
2017
2016
2015
2014
2013
1981-2010 Median
Interquartile Range
Interdecile Range
National Snow and Ice Data Center, University of Colorado Boulder
02 May 2017



from NSIDC sea ice concentration data
Global Sea Ice Area
Sea Ice Area $[10^6\ km^2]$
24
22
20
18
16
14
12
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
$\pm 2\sigma$ range
Last date:2017-05-21
graph by Wipneus
https://sites.google.com/site/arctischepinguin/home/global-sea-ice







Up-to-date daily information on Arctic sea ice concentration, thickness & ice motion from U.S. Navy (also available: sea-surface height (SSH), sea-surface temperature (SST), sea-surface salinity (SSS), etc.

https://www7320.nrlssc.navy.mil/hycomARC/arctic.html

Arctic sea-ice monthly average volume

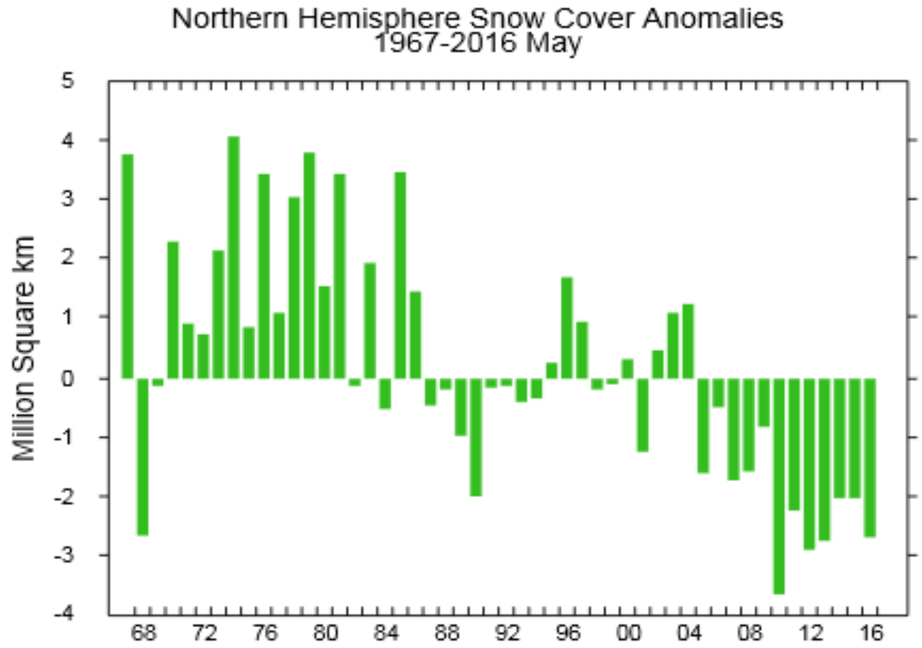
Scenario: overall trend continues; high probability that the first “blue ocean” event occurs by 2020 (ice-free duration would likely be less than 1 month in September for the first “blue ocean” event)

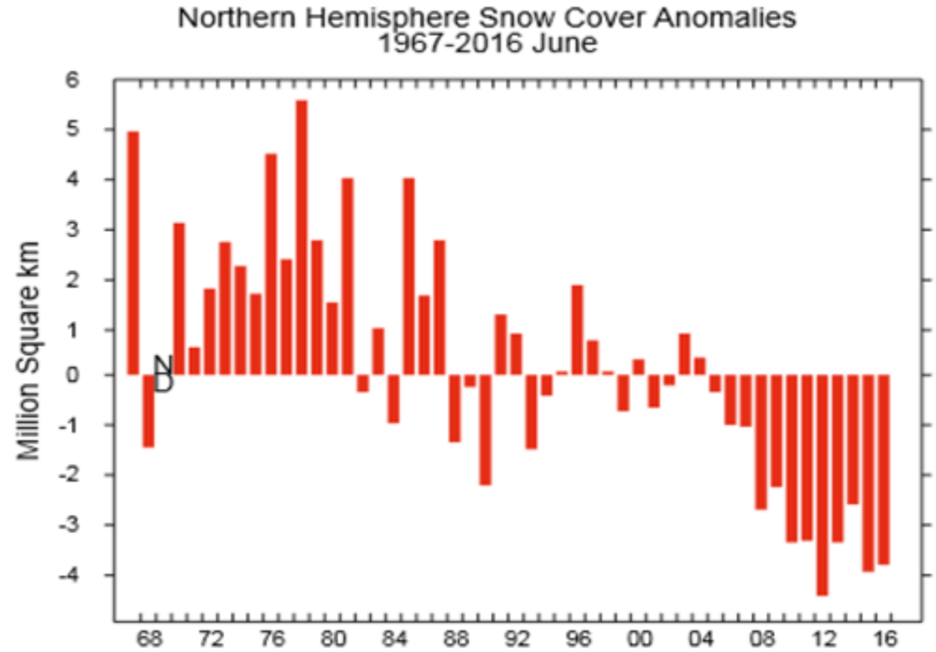
Ice-free duration would be extended to 3 months by t + 1 or 2 years (2021 to 2022)

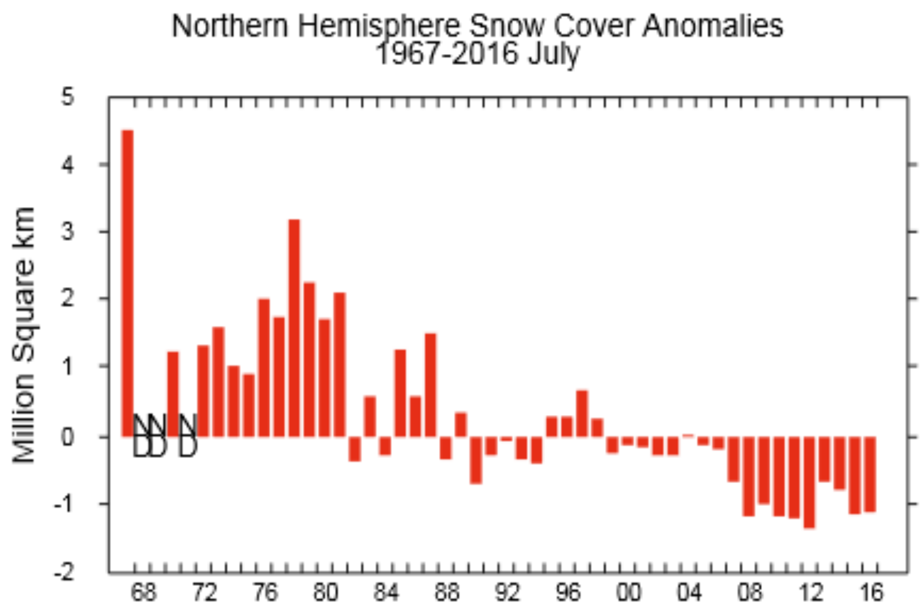
Ice-free duration would be extended to 5 months by t + 3 years (2023)

Ice-free duration all year by roughly t + 10 years (2030 or so)

Huge feedback: The quantity of heat (latent heat) that is sufficient to melt 1 kg of ice at just below freezing to 1 kg of water at just above freezing would raise the temperature (sensible heat) of that 1 kg of water to 80^{o}C.

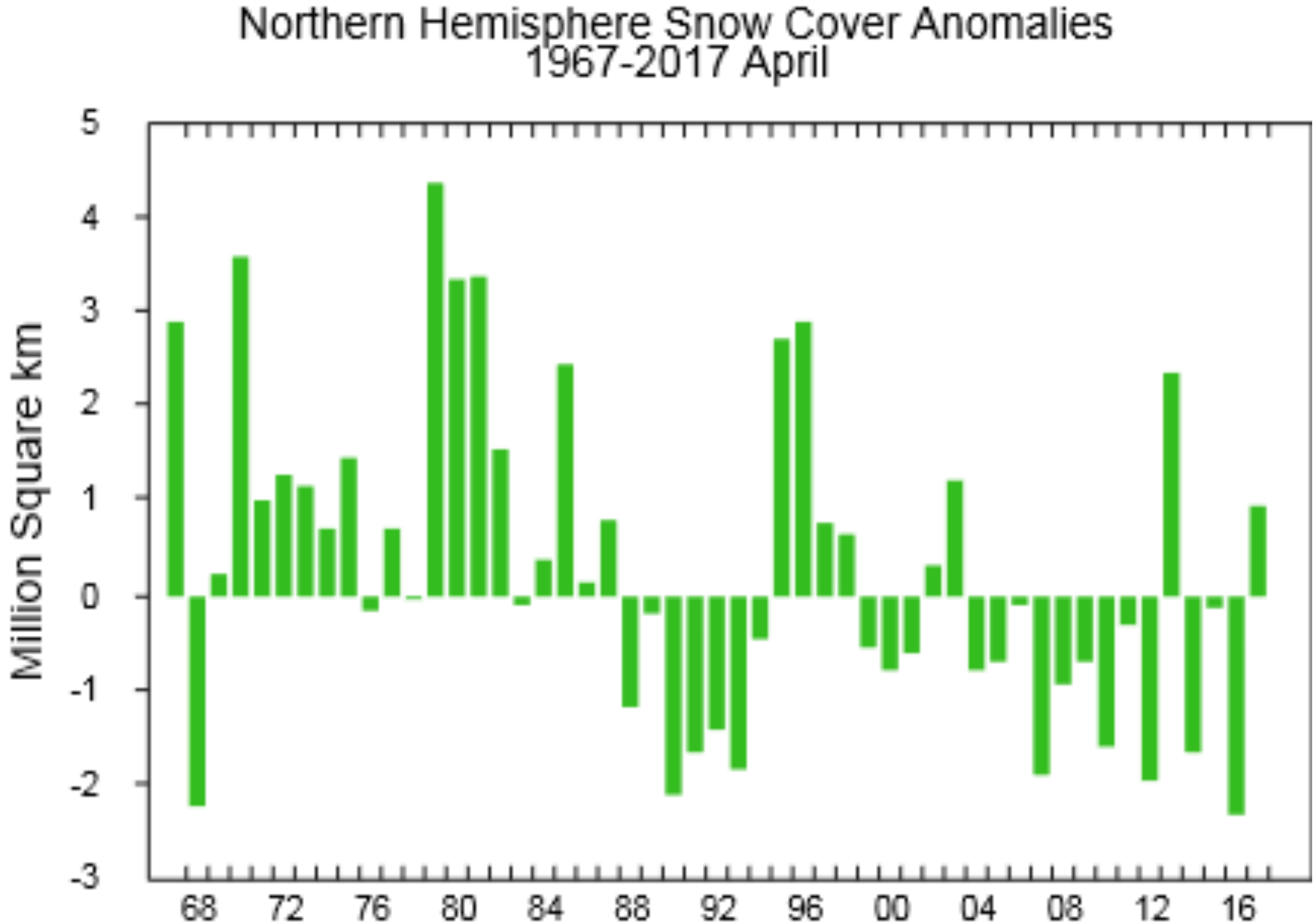


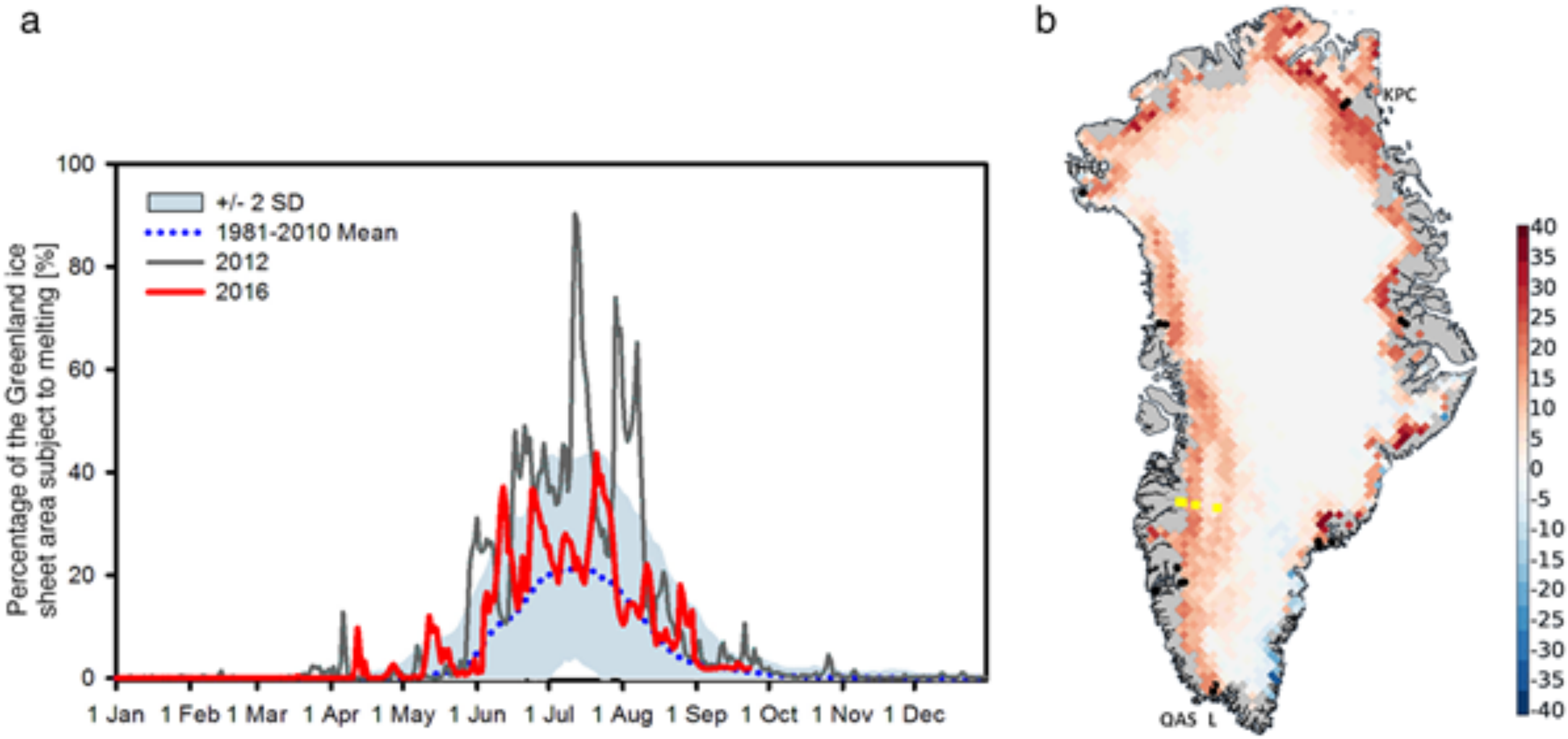




Less snow cover over the northern land regions → dark tundra exposed → more solar radiation absorption → more heating of the Arctic → even less snow cover.

http://climate.rutgers.edu/snowcover/chart_anom.php?ui_set=1&ui_region=nhland&ui_month=4


Northern Hemisphere Snow Cover Anomalies
1967-2017 April
Million Square km
5
4
3
2
1
0
-1
-2
-3
68
72
76
80
84
88
92
96
00
04
08
12
16

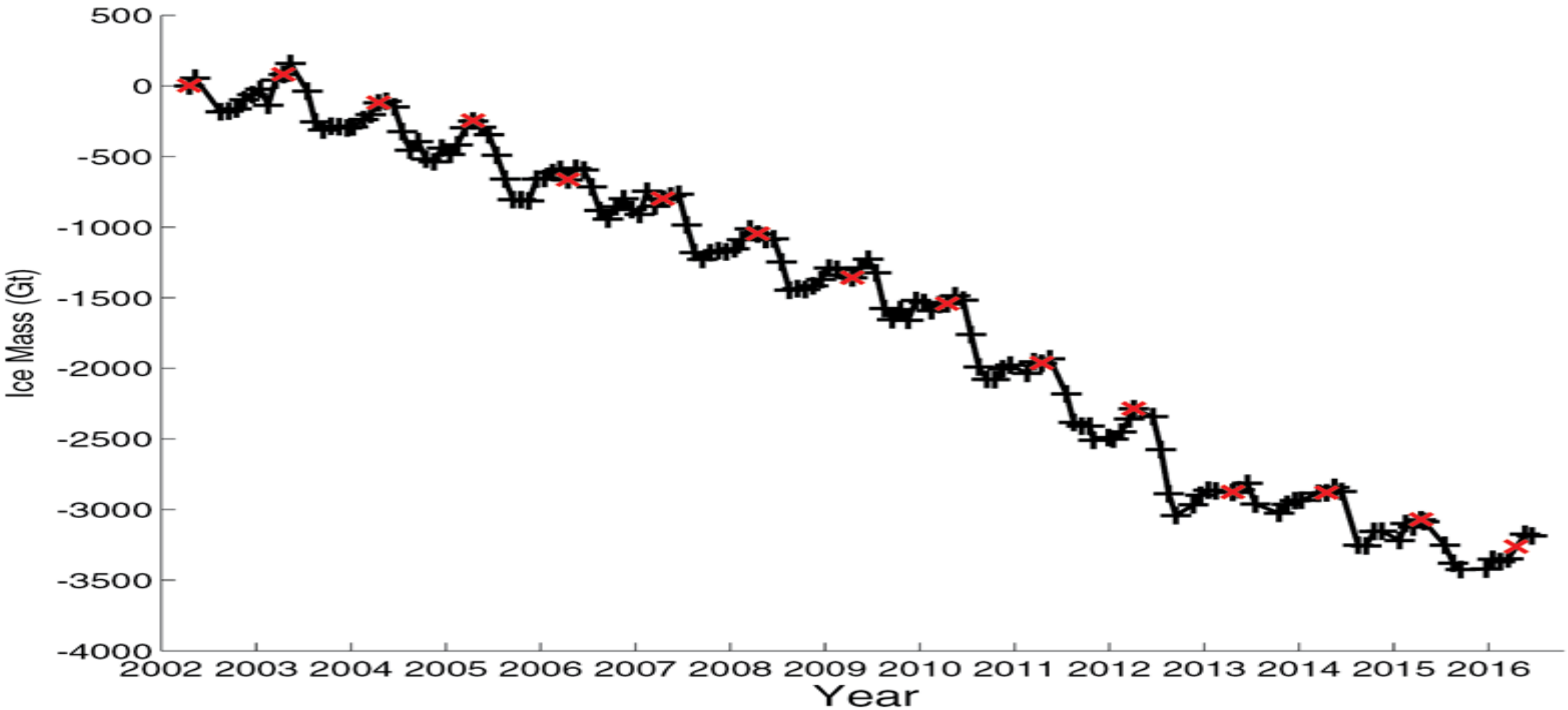


Rapid Increases in Greenland Surface Melting & Darkening

a) Percentage of Greenland ice sheet with surface melting in 2016 (red) & 2012 (grey); 1981-2010 average melt percentage (dashed blue line), and ±2 standard deviations of the mean (shaded).

b) Change in number of melting days for 2016 relative to 1981-2010 mean. http://www.arctic.noaa.gov/Report-Card/Report-Card-2016/ArtMID/5022/ArticleID/277/Greenland-Ice-Sheet

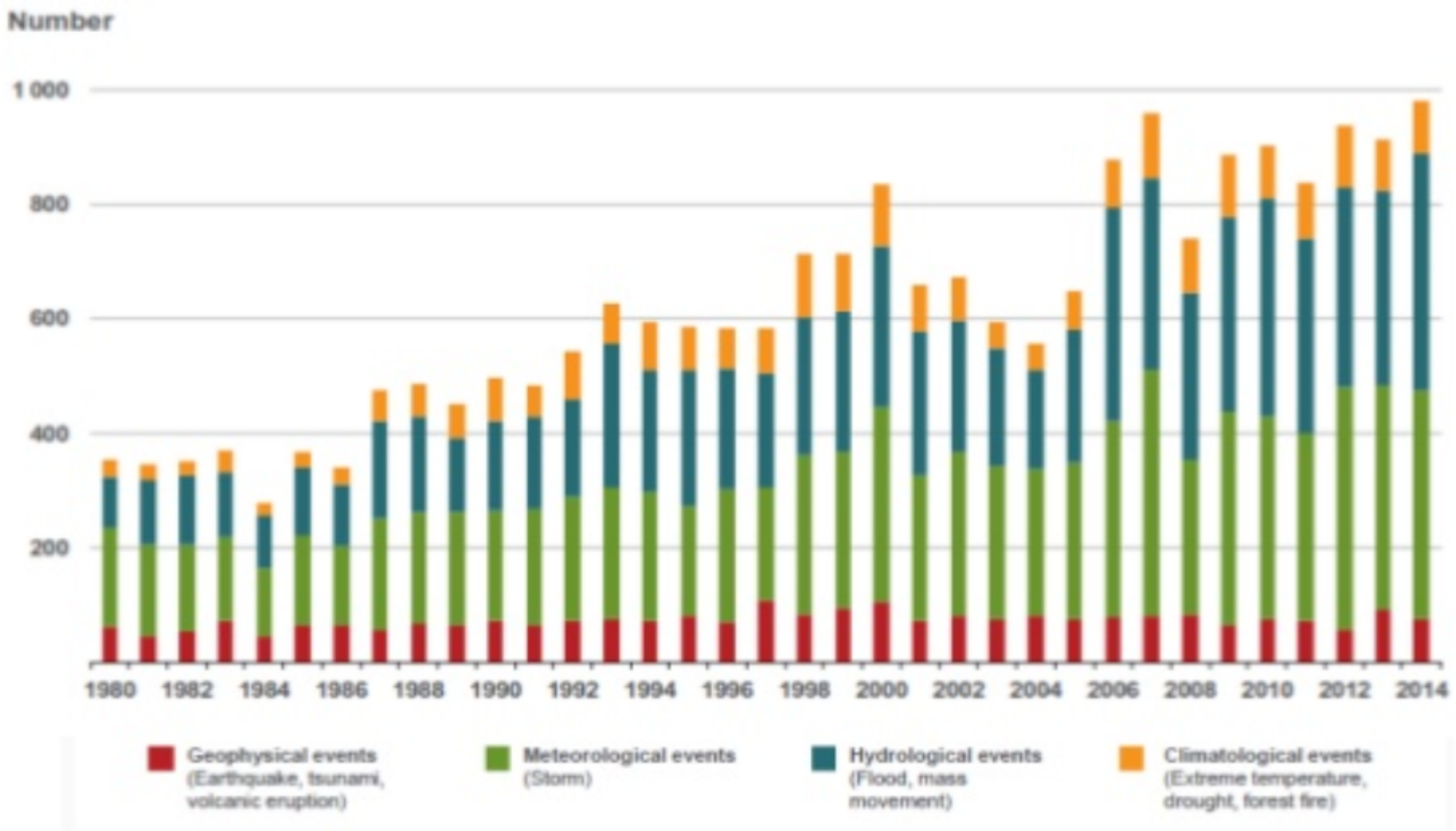
Monthly Mass Loss from Greenland Ice Sheet



Monthly change in the total mass (in Gigatonnes) of the Greenland ice sheet between Aprils in 2002 & 2016, estimated from GRACE satellite data. Red crosses denote values for the month of April in each year.

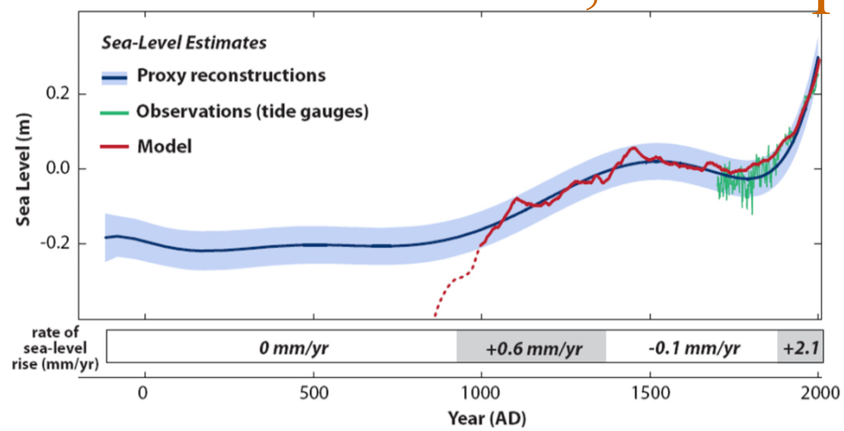
World-wide natural disaster trends

Annual rate of events has more than doubled since 1980

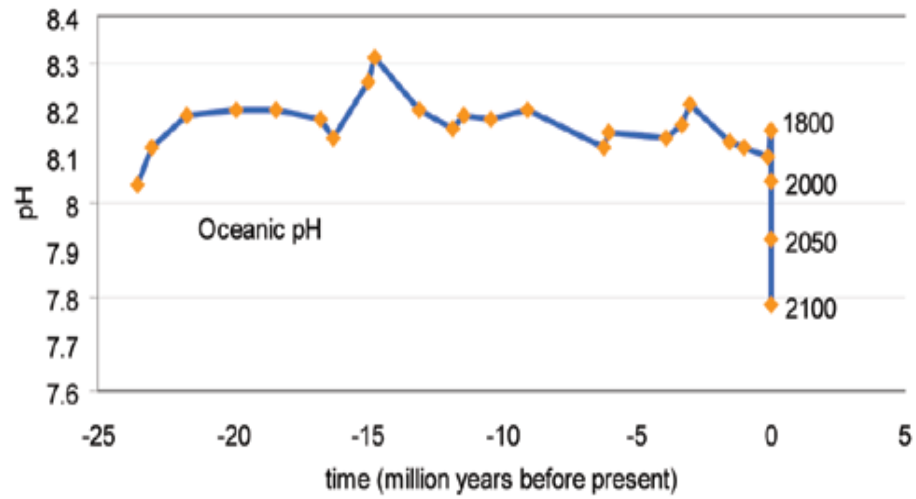


Source: "NAT CAT 2014: What's Going on with the Weather?" Munich Re, January 7, 2015

Sea-level increase, ocean pH decrease, ice cap melting



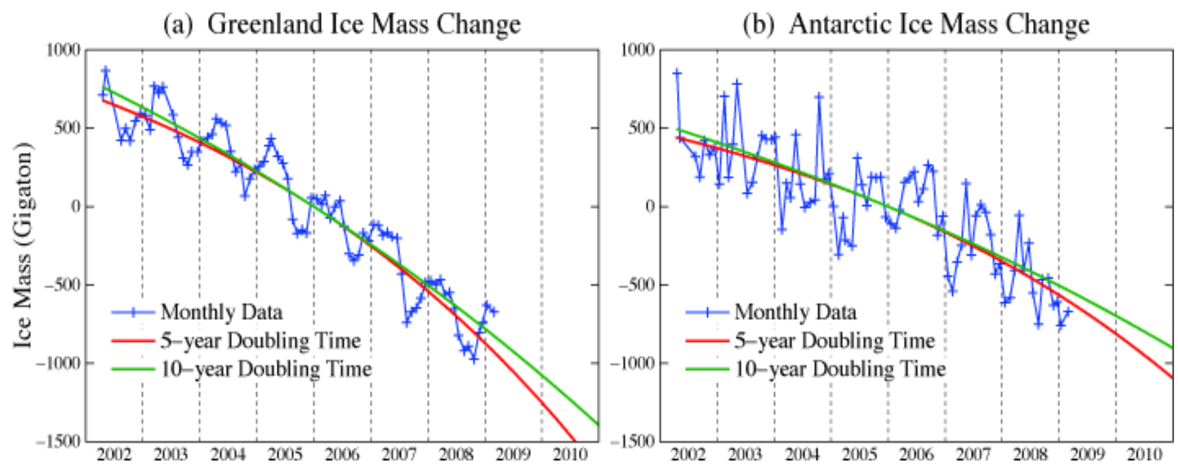
Kemp 2011



1) Expansion of water
2) mountain glacier melt
3) ice caps melt
4) Greenland & Antarctic melt

Present rise: **3.4 mm/year**; projected 1 foot rise by 2050, 2 meters by 2100; Hansen says 5 meters. In paleorecords: 121 kyr ago (Eemian); rise was 50 cm per decade for 5 straight decades (Blanchon et. al., 2009)

CO_2 in air + water vapor → carbonic acid → rains → acidifies ocean (30% more acidic than 30-40 years ago



Albedo (reflectivity) & Arctic methane feedbacks

- Albedo flipping as sea-ice melts; present sea-ice forcing 0.1 W/m^2; sea-ice gone for one month 0.3 W/m^2; eventual disappearance 0.7 W/m^2
- Rate of warming in Arctic is now about 2^oC/decade (~6x global rate); rate will increase with ice vanishing
- Methane sources

Terrestrial permafrost 1700 Gtons C; ESAS permafrost 1750 Gtons; 50 Gtons in precarious state, liable to sudden release

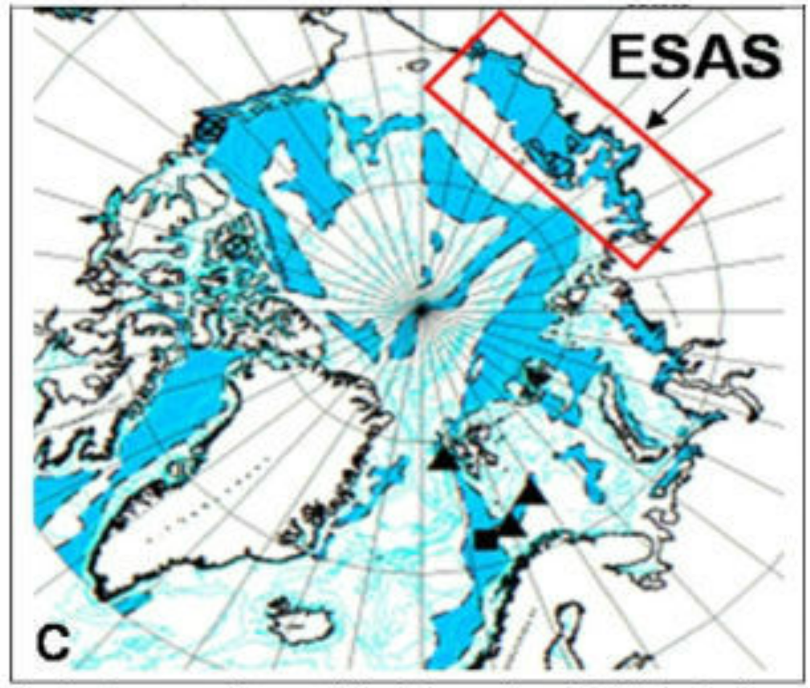
→ surge in atmospheric methane level by 11x

→ catastrophic feedback loop

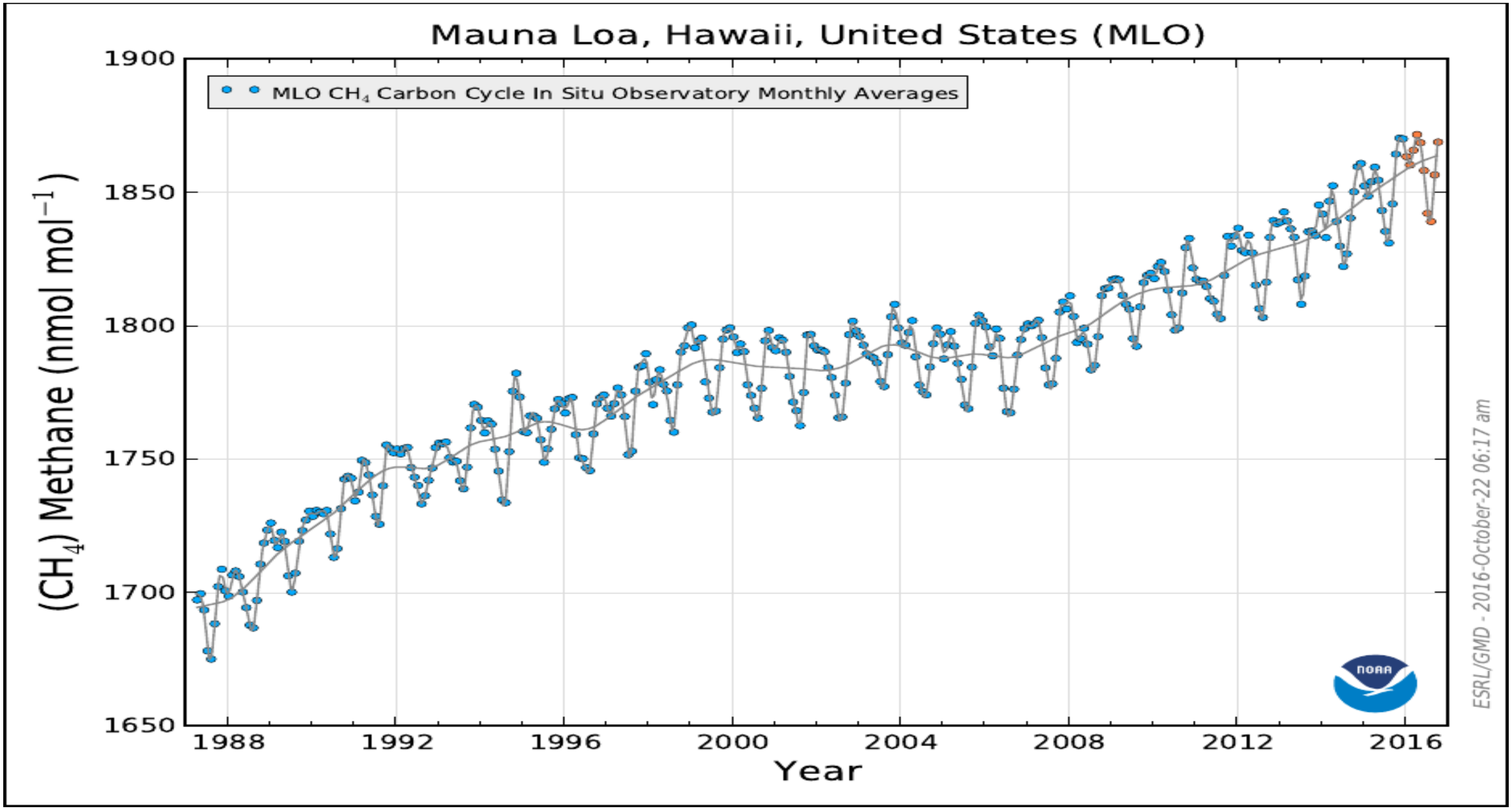
→ warming spiraling up

→ world food production spiraling down;

release of only 15 Gtons over 10 years would dominate CO_2 forcing (no chance at 2^oC stabilization)



Arctic Ocean with predicted deposits of CH4 hydrates shown in blue (Semiletov, 2012)



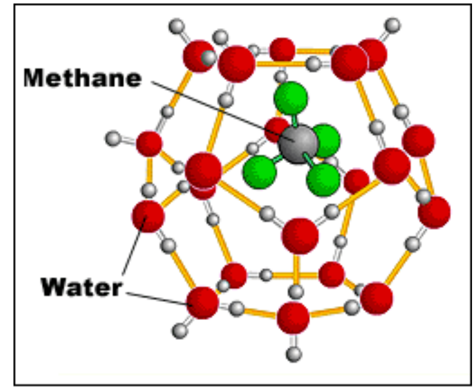
Methane levels in the atmosphere have been rapidly rising since 2007. Human sources include fracking leakage, livestock, industrial processes, & flaring, while natural sources include wetlands, permafrost thawing, & hydrates. The main sink (removal from atmosphere) is reaction with hydroxyl ions, & the atmospheric lifetime is about 12 years. The Global Warming Potential (GWP) is 34x, 86x and >150x averaged over 100 years, 20 years and a few years, respectively.

Methane in the Arctic

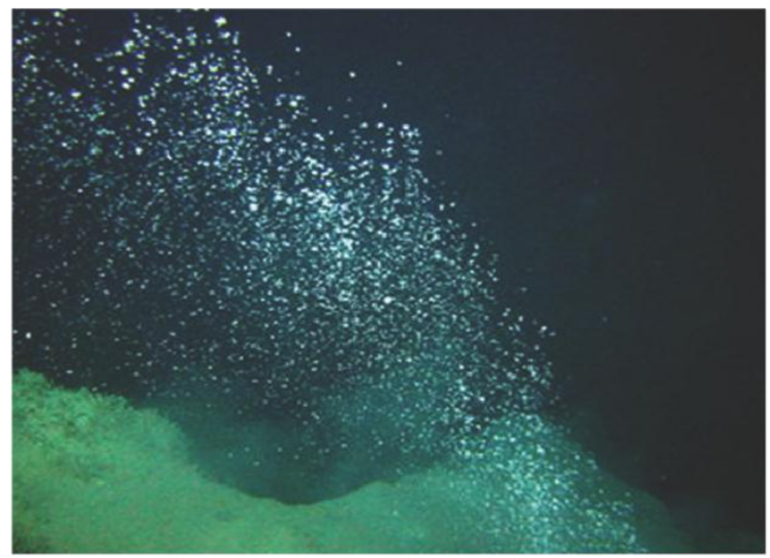
Up to now methane emissions in the Arctic are thought to be quite small (about 10-20 Mtons carbon), however there has been recent emissions escalation in the last few years from both thawing tundra on land and sea-floor sediments on shallow continental shelves.

Region to watch: Eastern Siberian Arctic Shelf (ESAS); 100s of plumes tens of meters in diameter seen a few years ago; then changed to 100s of plumes as large as 1 km diameter in a Russian study area) → ratio of areas $(1000m/20m)^2$ =

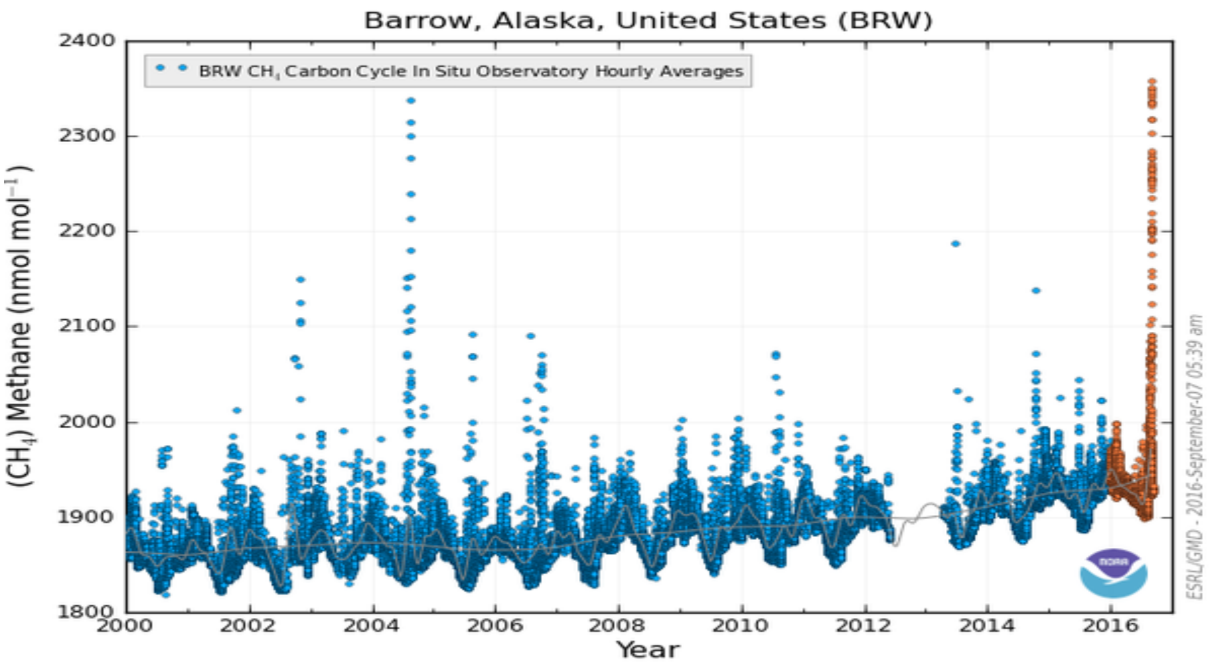
2500x larger)

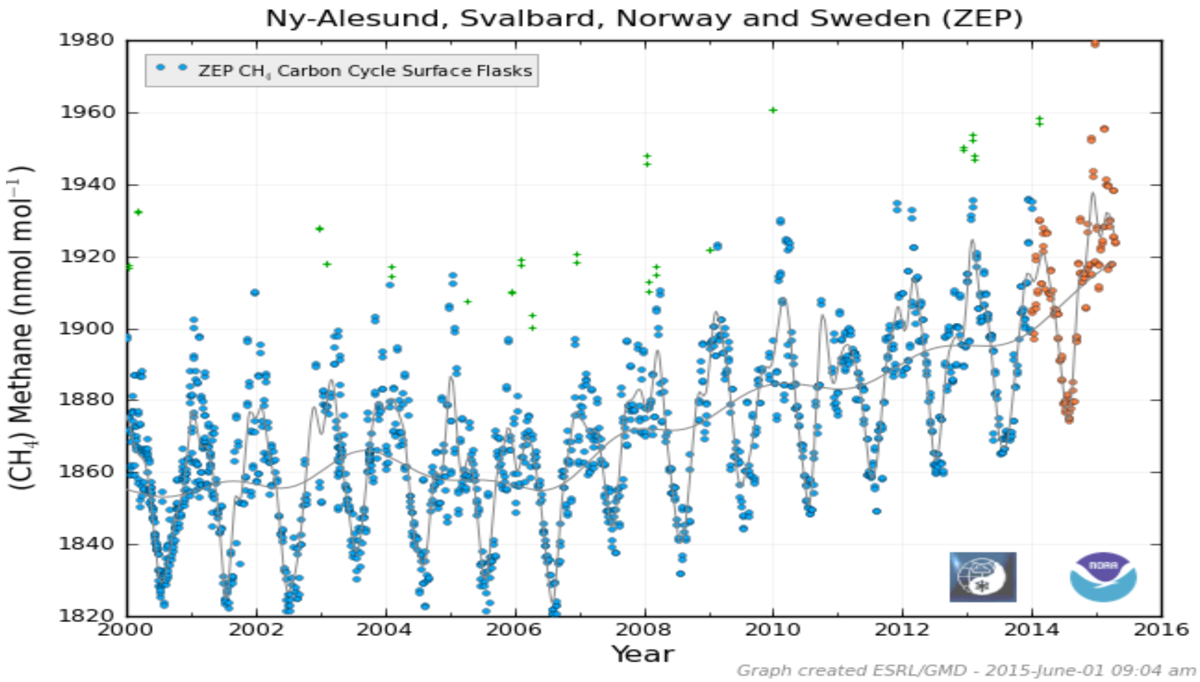


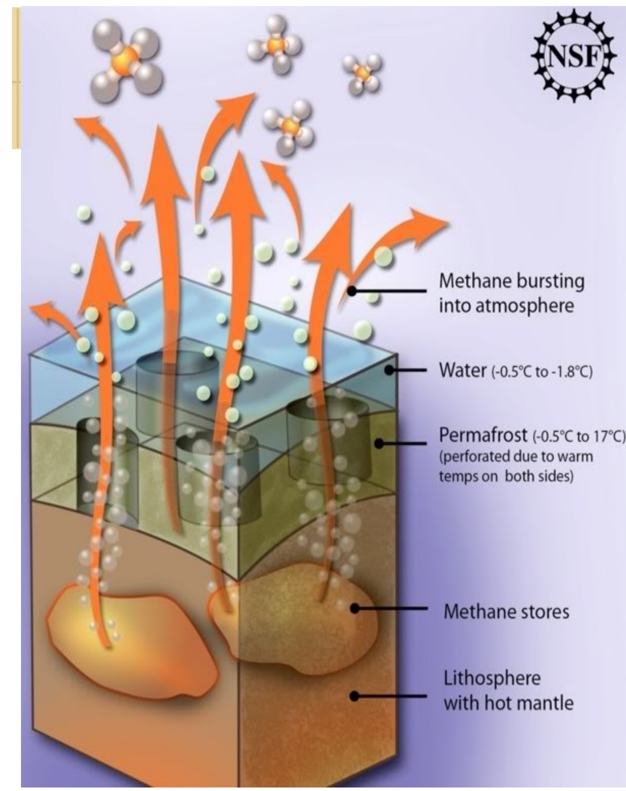
METHANE CLATHRATE



A methane plume being released from the sea bed

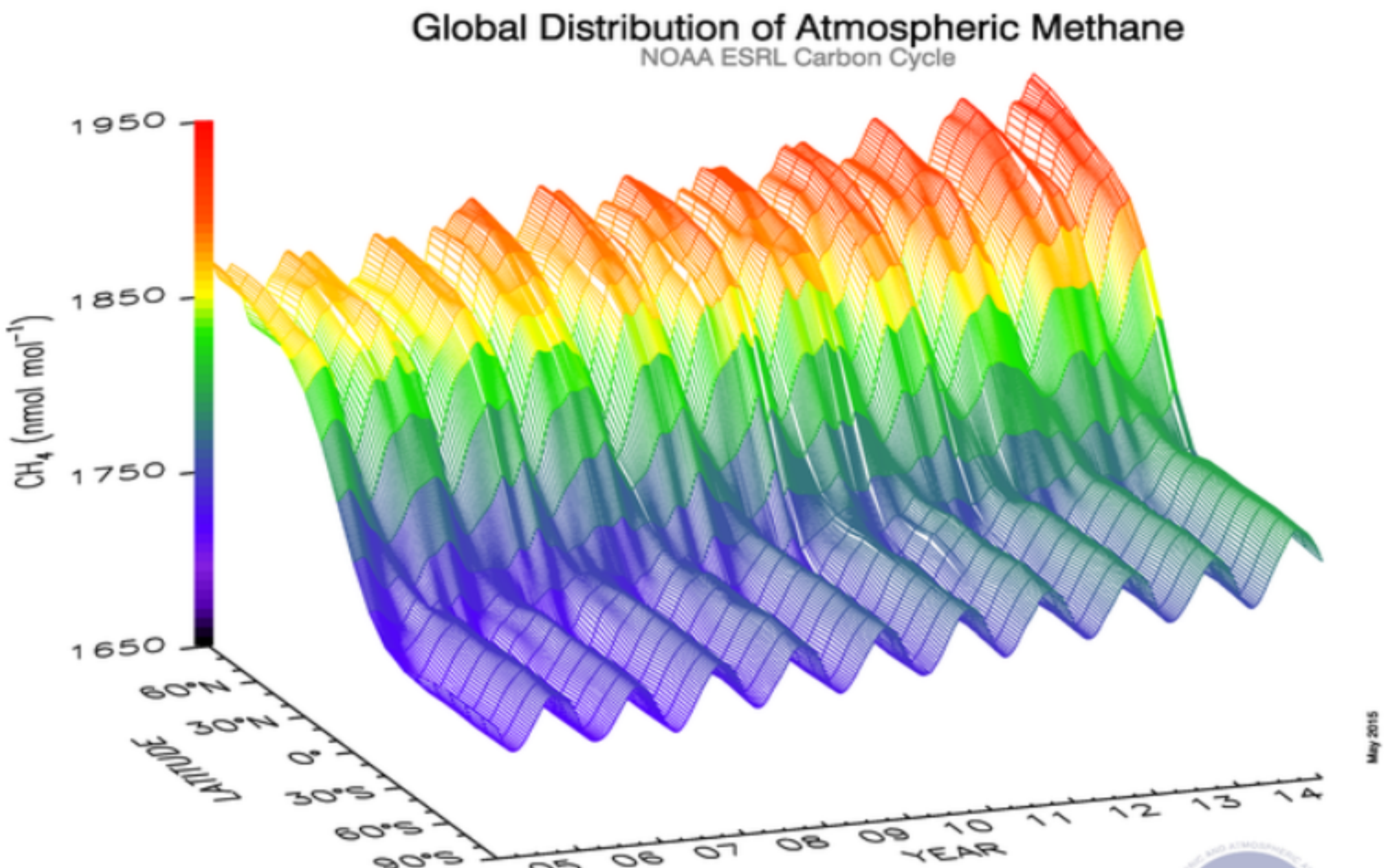




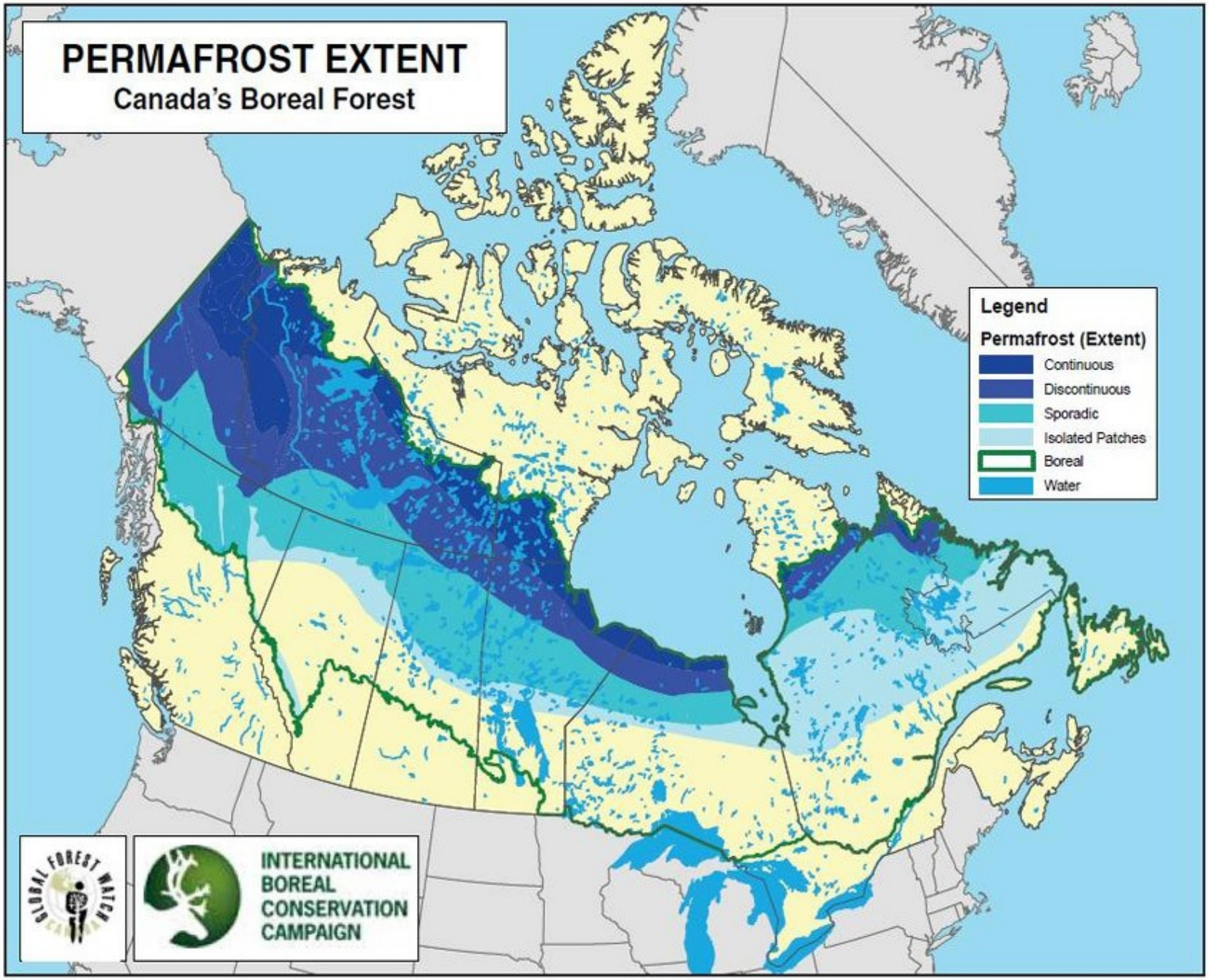


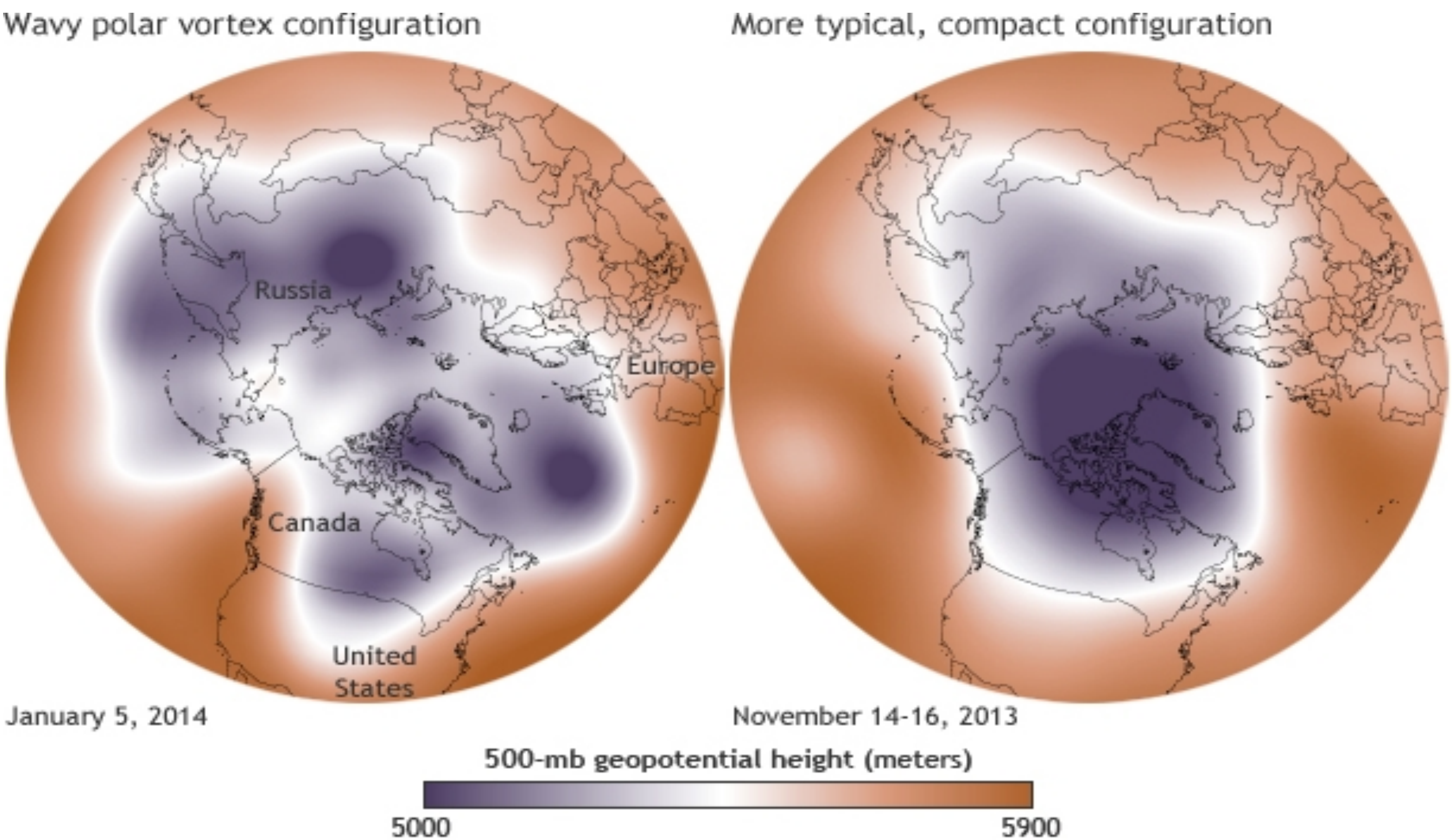
Methane sources: permafrost and ocean floor sediments

Atmospheric methane gas concentrations measured at opposite sides of the Arctic, in Alaska and Svalbard



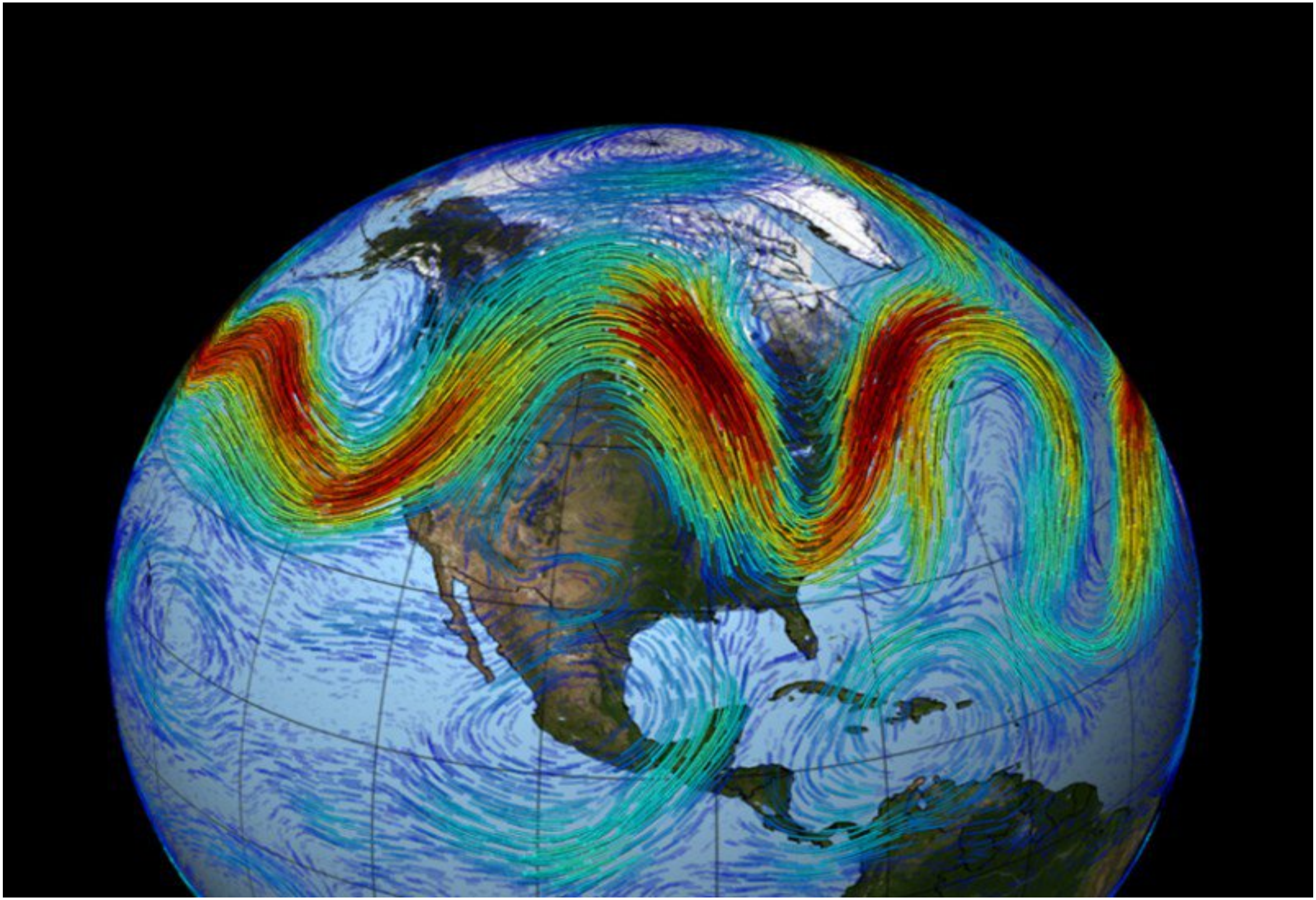
Three-dimensional representation of the latitudinal distribution of atmospheric methane in the marine boundary layer. Data from the Carbon Cycle cooperative air sampling network were used. The surface represents data smoothed in time and latitude. Contact: Dr. Ed Dlugokencky, NOAA ESRL Carbon Cycle, Boulder, Colorado, (303) 497-6228, ed.dlugokencky@noaa.gov, http://www.esrl.noaa.gov/gmd/ccgg/.


PERMAFROST EXTENT
Canada's Boreal Forest
Legend
Permafrost (Extent)
Continuous
Discontinuous
Sporadic
Isolated Patches
Boreal
Water
GLOBAL FOREST WATCH CANADA
INTERNATIONAL BOREAL CONSERVATION CAMPAIGN



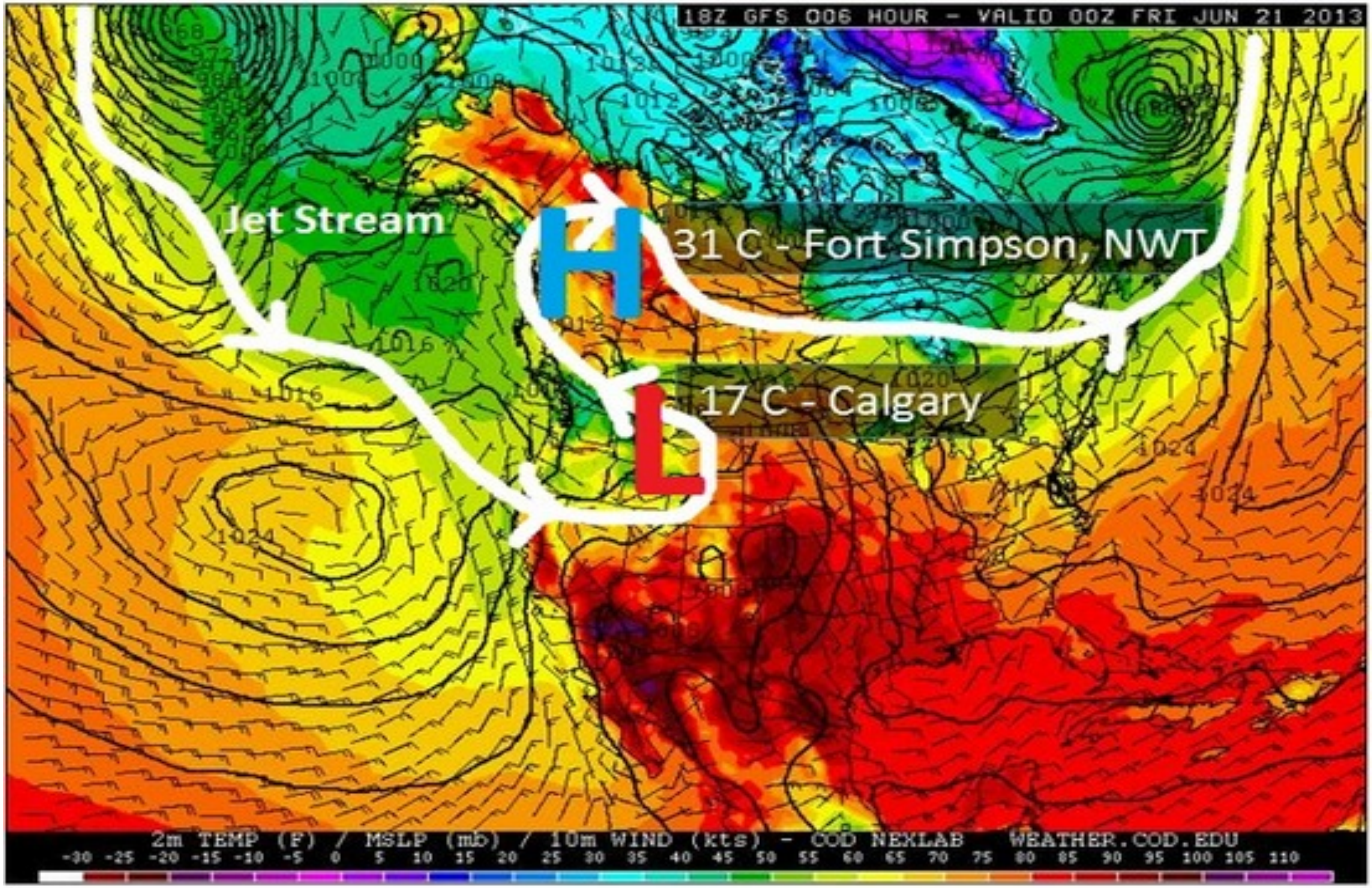
Downward looking Arctic view: shows "normal" and "wavy" jet stream configurations. Purple areas are cold and brown areas are warmer. Jet streams are white border lines between the cold and warm air masses.

http://www.climate.gov/sites/default/files/styles/inline_all/public/Jan5_Nov14-16_500mb_geopotentialheight_mean_620.jpg?itok=zdAE3xoi

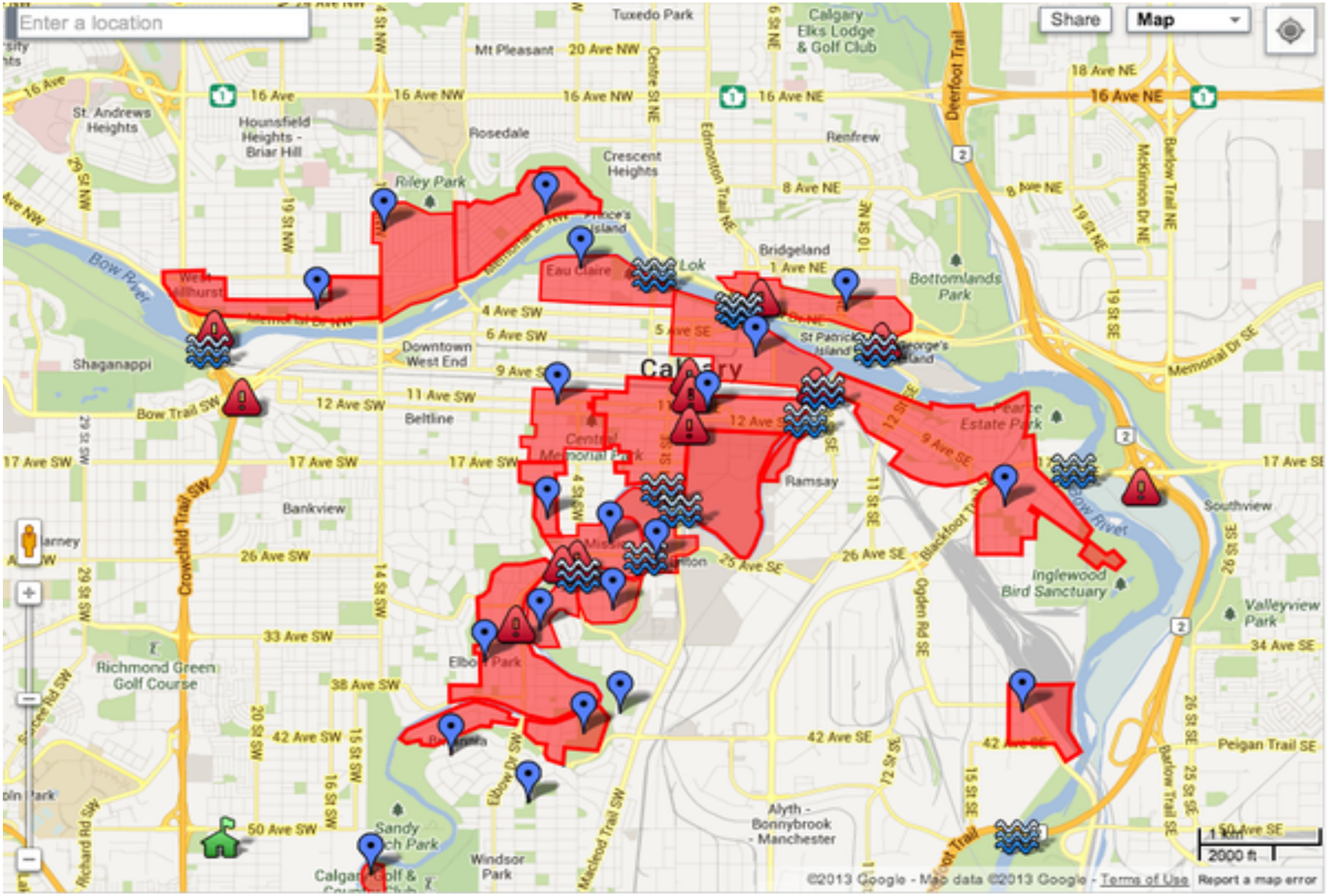


Side view of exceptionally wavy jet stream.

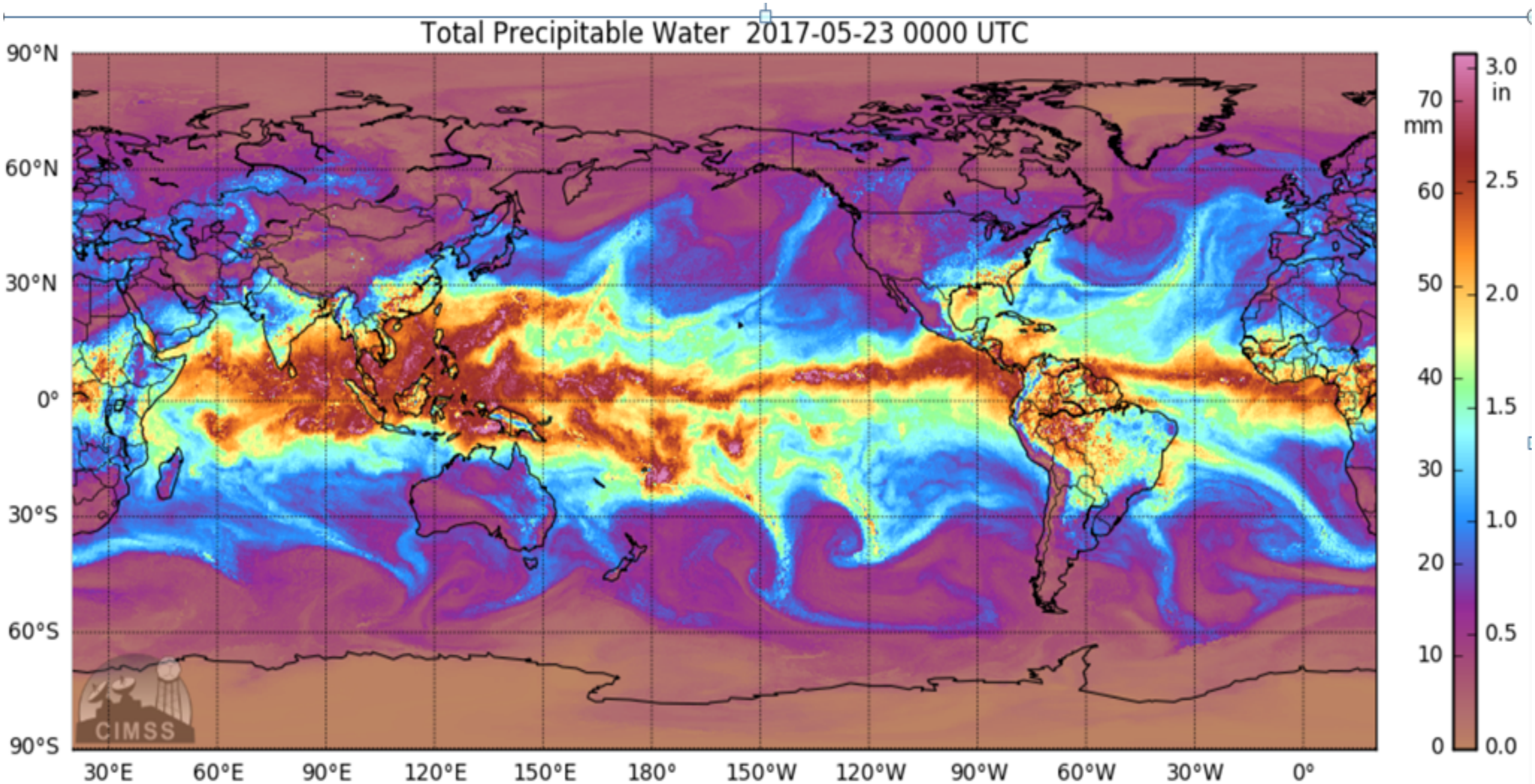
https://eos.org/wp-content/uploads/2015/02/GL060764_Hassanzadeh_cropped_web-800x600.jpg



Jet stream configuration near Calgary during record flood of June, 2013 with insured costs exceeding $6 Billion; http://media.twnmm.com/storage/11698939/15



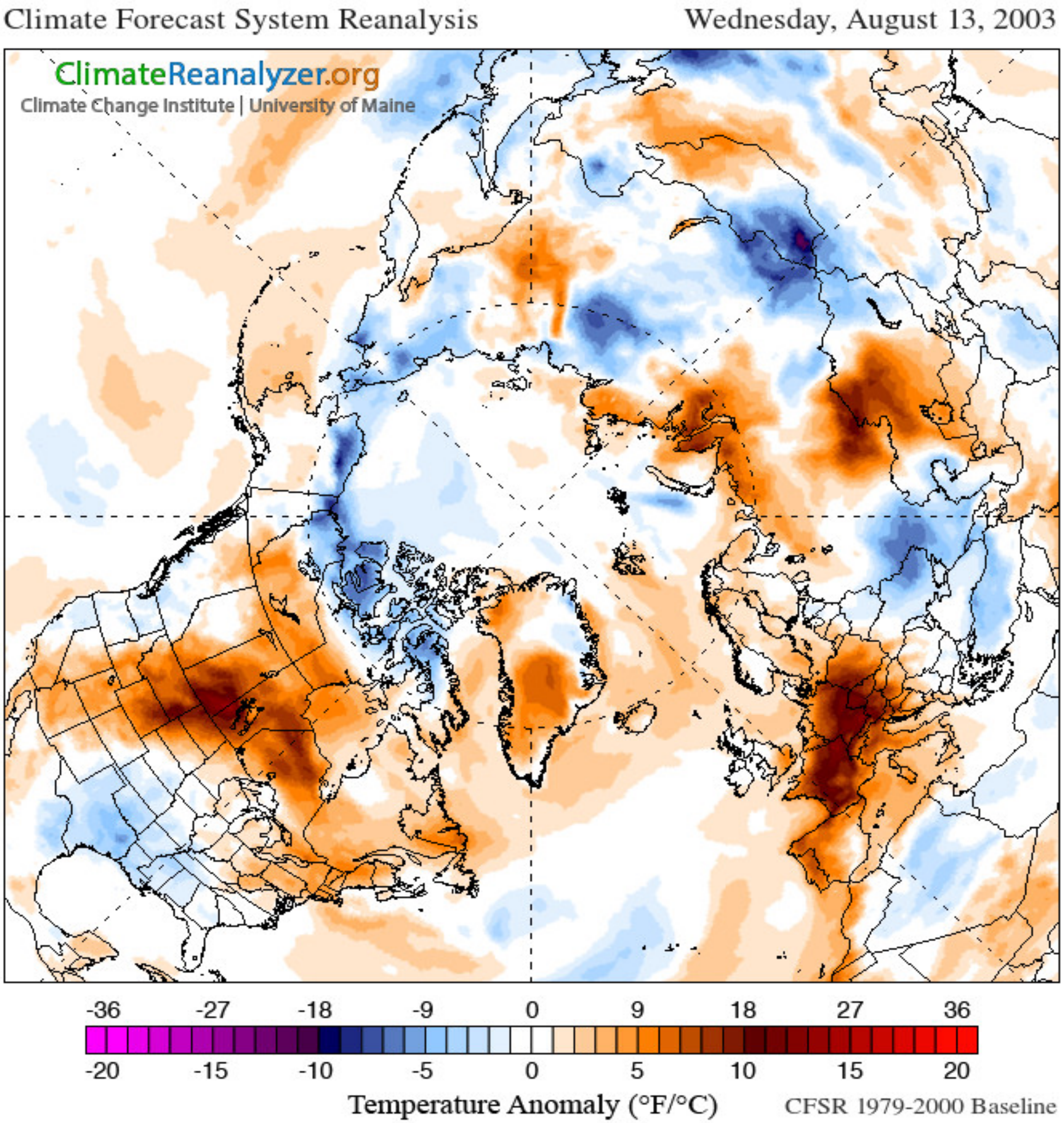
Calgary flooded sections during record flood of June, 2013 with insured costs exceeding $6 Billion; http://media.twnmm.com/storage/11698939/15



For every 1°C rise in temperature, the air can hold 7% more water vapor → as air rises & cools water vapor condenses into droplets forming clouds & releases energy to fuel storms.

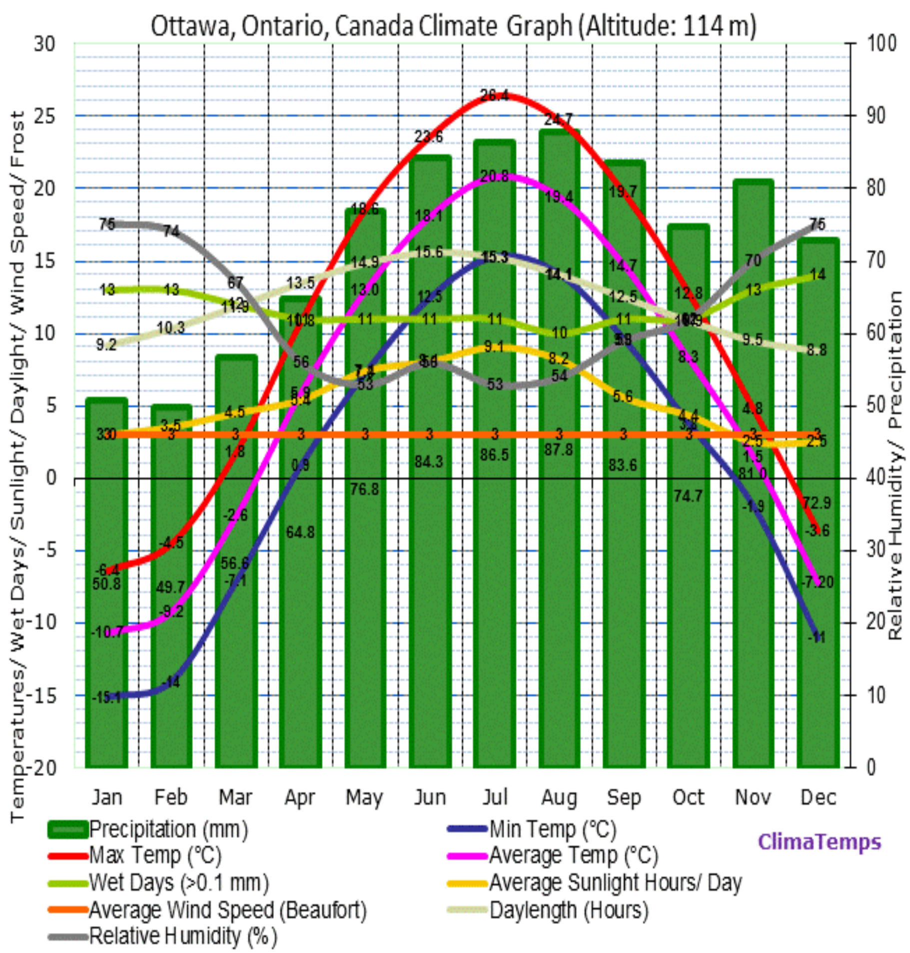
Real-time data on total precipitable water. Notice "fingers" stretching upwards to higher latitudes.

http://tropic.ssec.wisc.edu/real-time/mtpw2/product.php?color_type=tpw_nrl_colors&prod=global2&timespan=72hrs&anim=html5



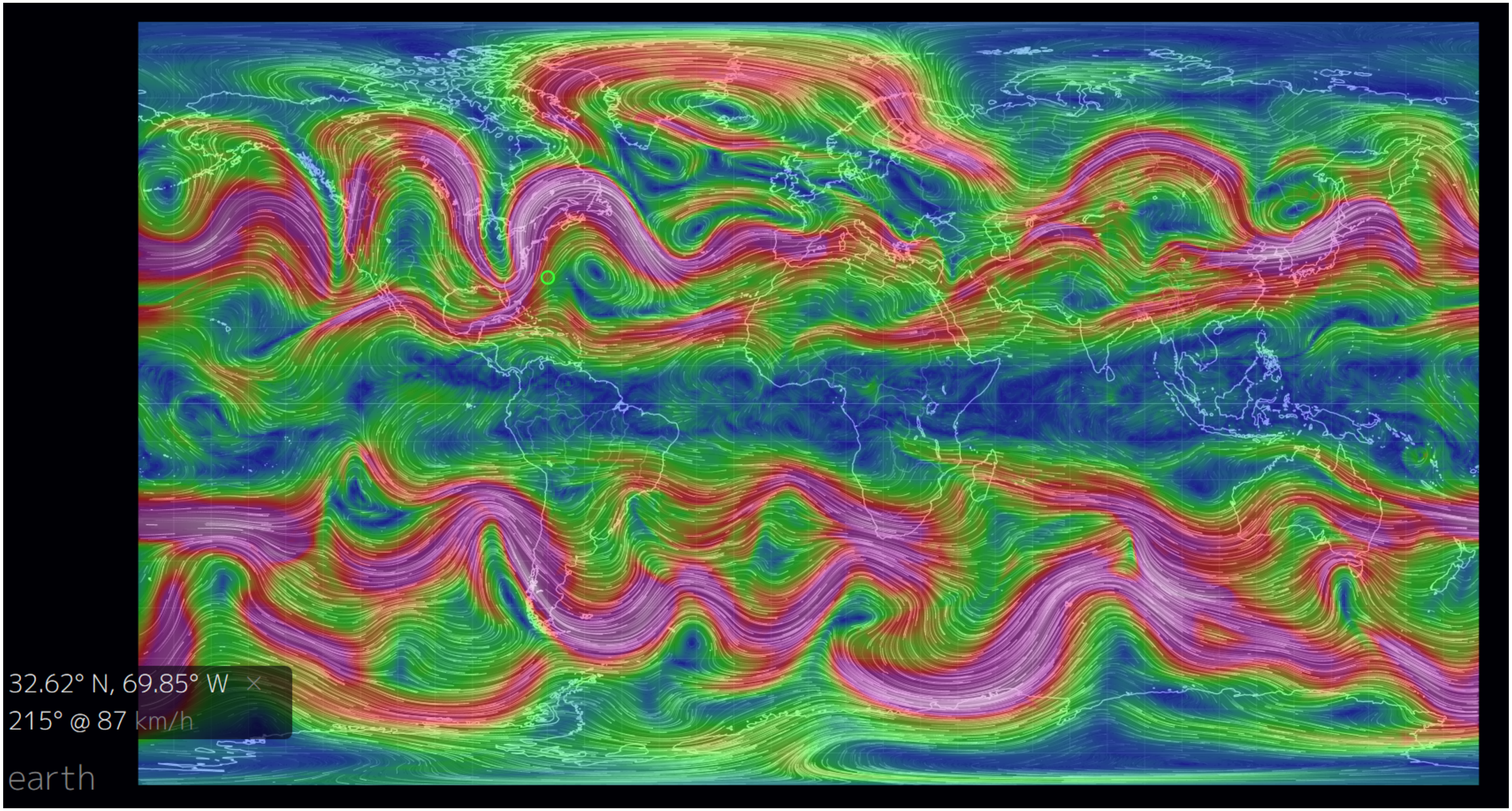
Temperature anomalies on Aug. 13, 2003, one of worst days in the extensive, long-duration European heatwave that killed >70,000 people. The root cause was the very wavy & stuck (persistent) jet stream ridge. Most of Manitoba & Saskatchewan also endured a lengthy heatwave.

Record Rainfall in April & early May, 2017 → Record Water Levels & Flooding in Quebec, Ontario & B.C.



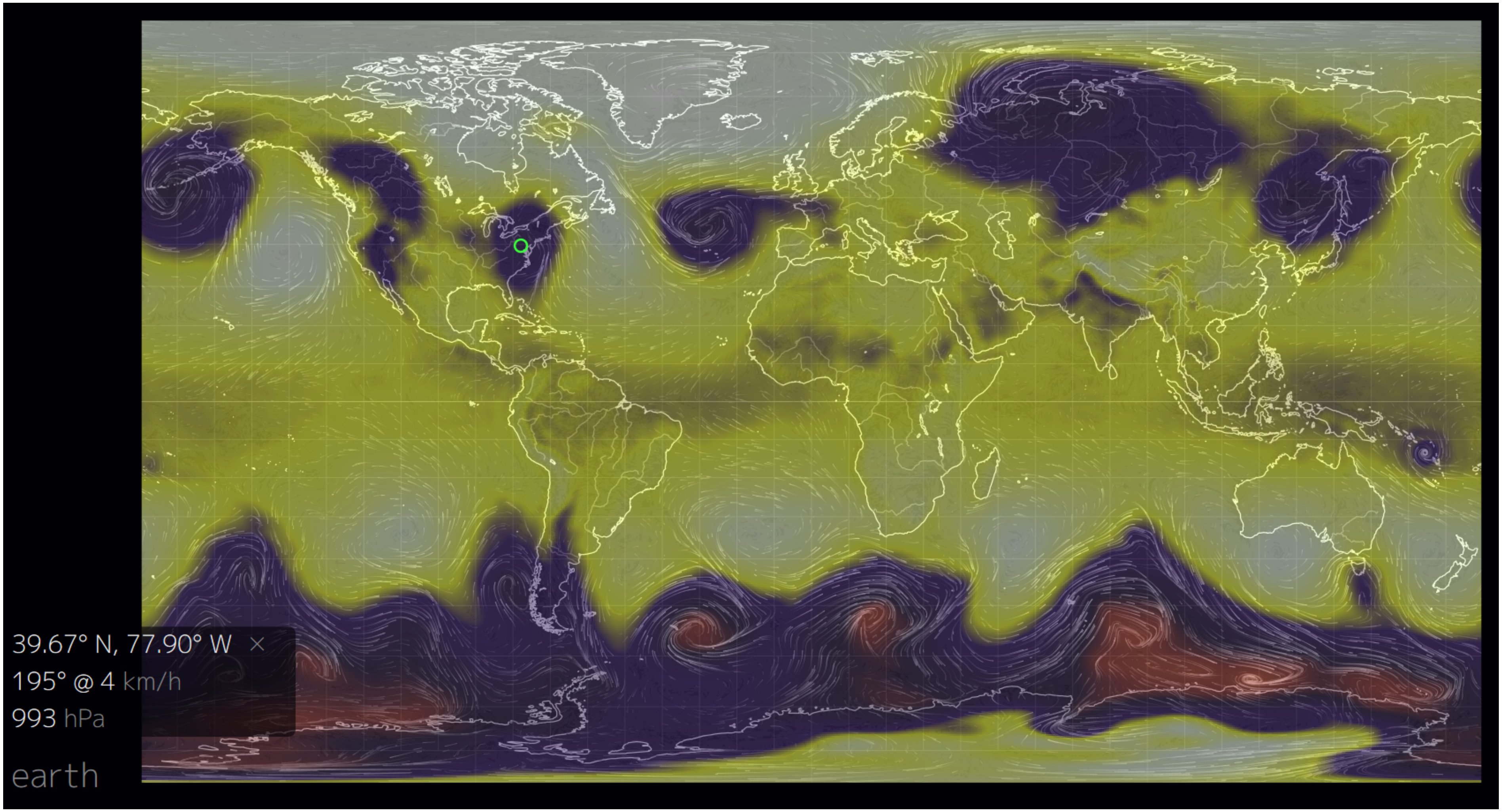
Ottawa (& much of Ontario and Quebec) received >150 mm of rain in April (more than double normal), & 117 mm in the first week of May. Normal rainfalls for April & May (64.8 mm and 76.8 mm, respectively; see climograph) were greatly exceeded. River systems were inundated & floods exceeding 1-in-100 years were reached, peaking in Ottawa on May 6th. Record water levels in Lake Ontario & the St. Lawrence River are ongoing.

Natural disasters always have a natural & human component; in Ottawa's case the human control of reservoir levels & water dumping decisions is a large factor.



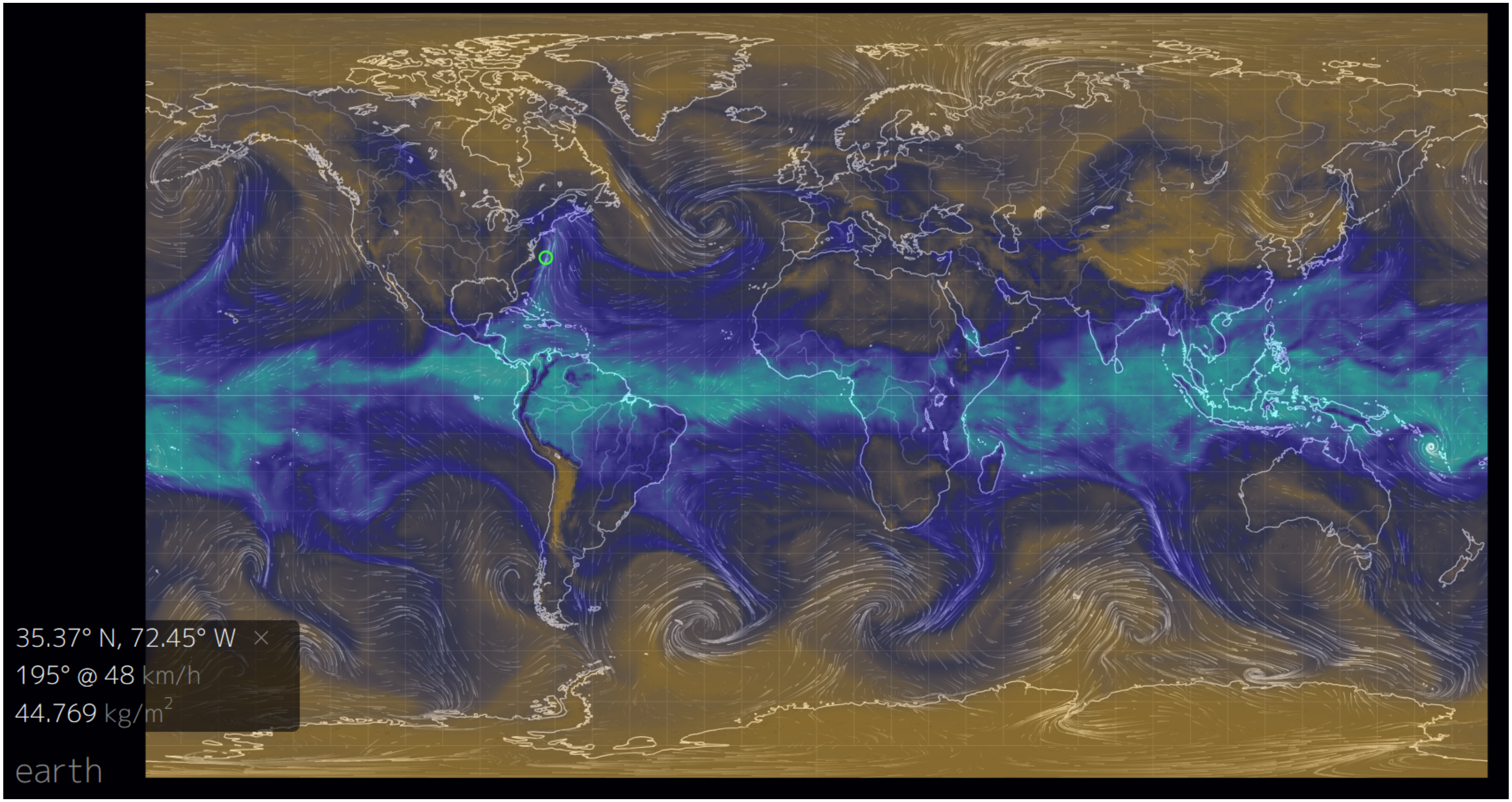
Flooding Disaster: Example from Earth Nullschool showing jet-stream winds at 250 mb pressure level on May 6th, 2017. The pattern over North America is a classic stuck pattern (“omega” block: low pressure over east and west coasts; high pressure over central region)

https://earth.nullschool.net/#2017/05/06/0600Z/wind/surface/level/patterson/loc=-69.850,32.617



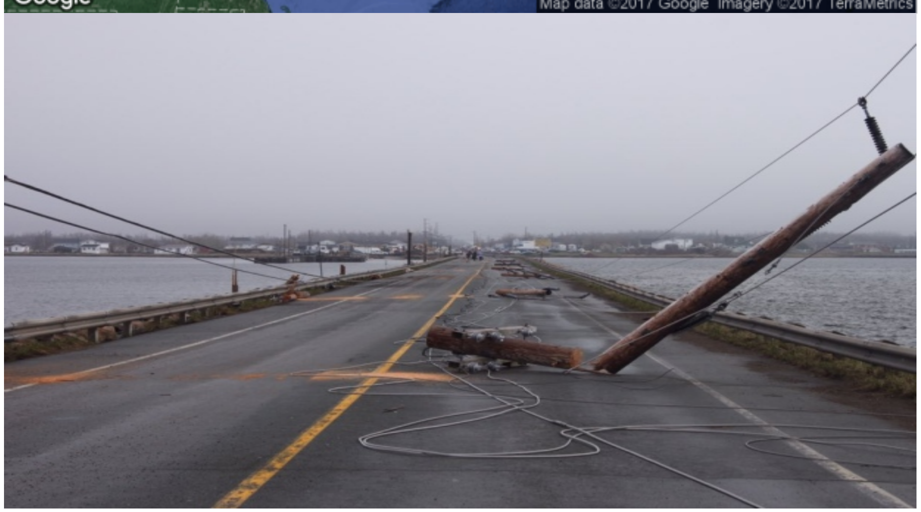
Flooding Disaster: Earth Nullschool showing mean sea-level pressure (MSLP) on May 6th, 2017. The pattern over North America is a classic “omega” block (low pressure over east and west coasts; high pressure over central region); low pressure → stormy conditions

https://earth.nullschool.net/#2017/05/06/0600Z/wind/surface/level/patterson/loc=-69.850,32.617



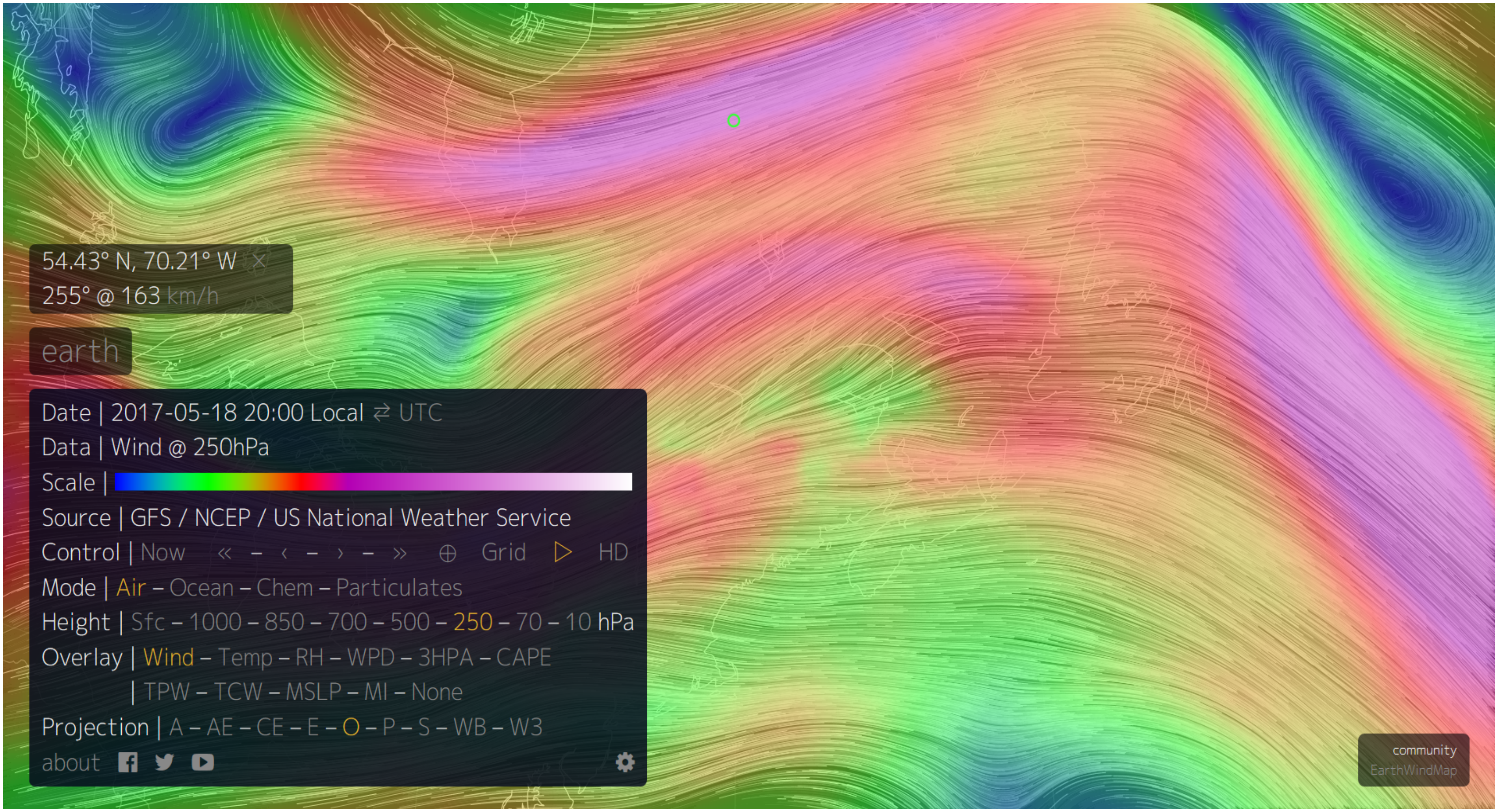
Flooding Disaster: Earth Nullschool showing wind & Total Precipitable Water (TPW) on May 6th, 2017. Large amounts of water are being carried north over the extremely warm waters of the Gulf Stream.
https://earth.nullschool.net/#2017/05/06/0600Z/wind/surface/level/patterson/loc=-69.850,32.617

New Brunswick island cut off from mainland due to thunderstorm – CBC News – Friday May 19th, 2017



Heavy winds split power poles in half and tore roofing tiles off a building; damage was observed over a wide geographical area (not characteristic of tornadoes). Damage is more indicative of straight-line winds, that are not associated with rotation.

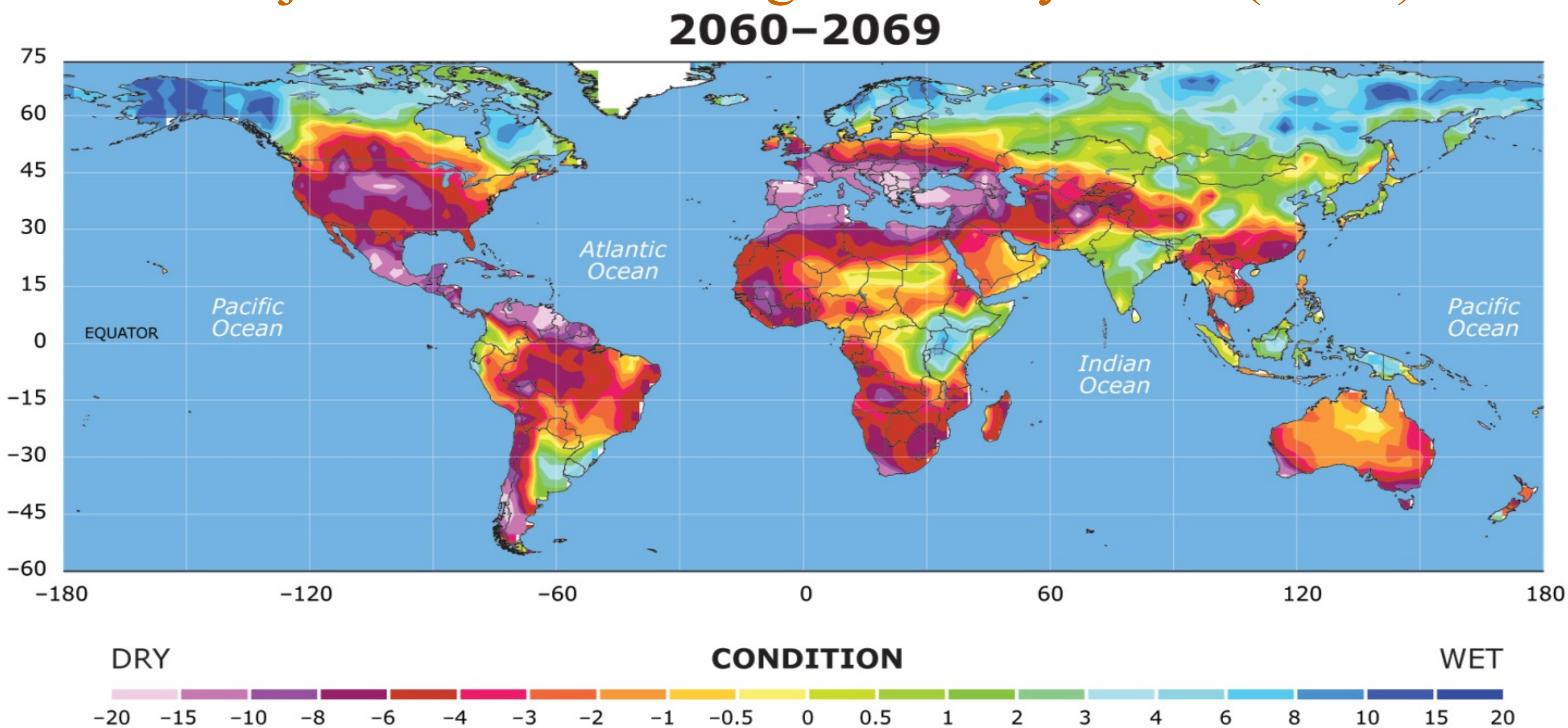
Based on the extent of damage, it appears that wind gusts may have reached 190 km/hr. Up to 20 power poles fell during the storm (12 on the causeway between the island and the mainland; these were encased in the cement on the bridge). http://www.cbc.ca/news/canada/new-brunswick/lameque-power-outages-storm-1.4123039



New Brunswick Storm: Earth Nullschool showing jet stream winds on the night of May 18th, 2017. Local near-surface wind gusts up to 190 km/hr were reported on Lameque Island.

https://earth.nullschool.net/#2017/05/19/0000Z/wind/isobaric/1000hPa/orthographic=-69.55,47.93,3000/loc=-55.501,39.751

Projected Palmer Drought Severity Index (PDSI)

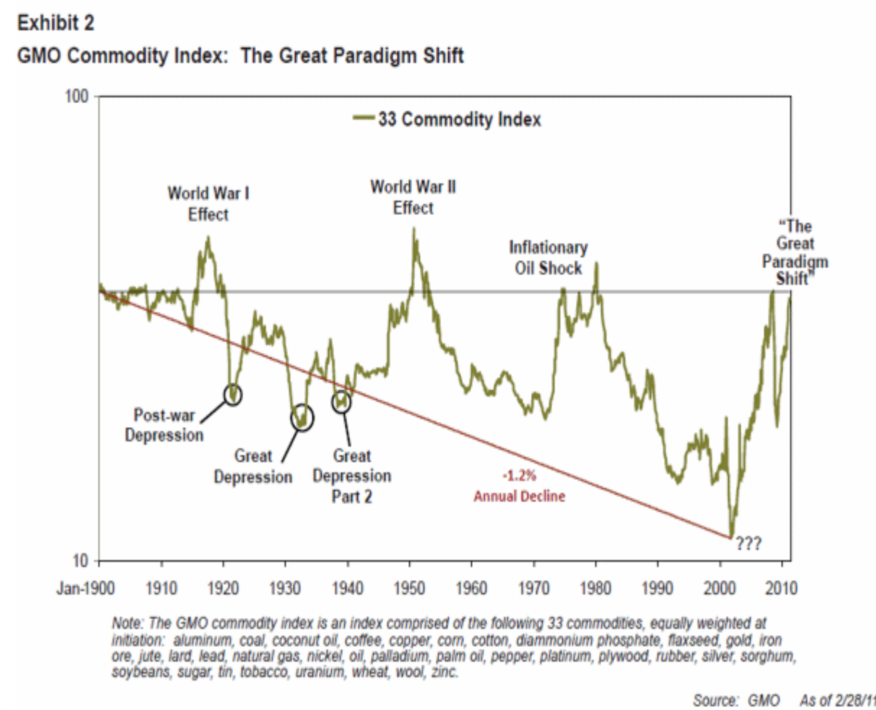


Projection of global wet & dry conditions (Dai, 2011) → many farming regions are expected to get much drier. Southern Manitoba straddles the pink & red regions (-3 to -6), reaching -6 to -8 as you move westward.

Procrastination to action: climate Pearl Harbor(s)?

Drivers of serious government action: "bad things must happen to regular people in rich countries right now"; media must report them as being a result of climate change; requires a change in "world view"

1) ice-free Arctic in September likely this decade
2) extremely rapid warming acceleration
3) permafrost thaw (land & marine) methane surges
4) mega-drought hits U.S. southwest & Great Plains
5) more Katrina like superstorms
6) heat waves hitting U.S. & Canadian breadbaskets
7) accelerating sea-level rise, ice shelf collapses
8) Amazon rainforest collapse



More comprehensive presentation at:
http://www.cmos.ca/Ottawa/SpeakersSlides/PaulBeckwith_19Jan2012.pdf

"Owing to past neglect, in the face of the plainest warnings, we have entered upon a period of danger…. The era of procrastination, of half measures, of soothing and baffling expedience of delays, is coming to its close. In its place we are entering a period of consequences…. We cannot avoid this period, we are in it now…."

Winston Churchill, Nov. 12, 1936, British House of Commons

Global-to-Local Scale: Impacts to Manitoba and the EIS

1) Climate history (temperature & precipitation) over the last century in Manitoba (historical averages & trends) are often used as a basis for expected future changes. This method is prone to large errors & uncertainties since rapid global climate changes discussed have essentially changed the statistics of climate & thus weather events & recurrence intervals (i.e. 1-in-100 year flood).

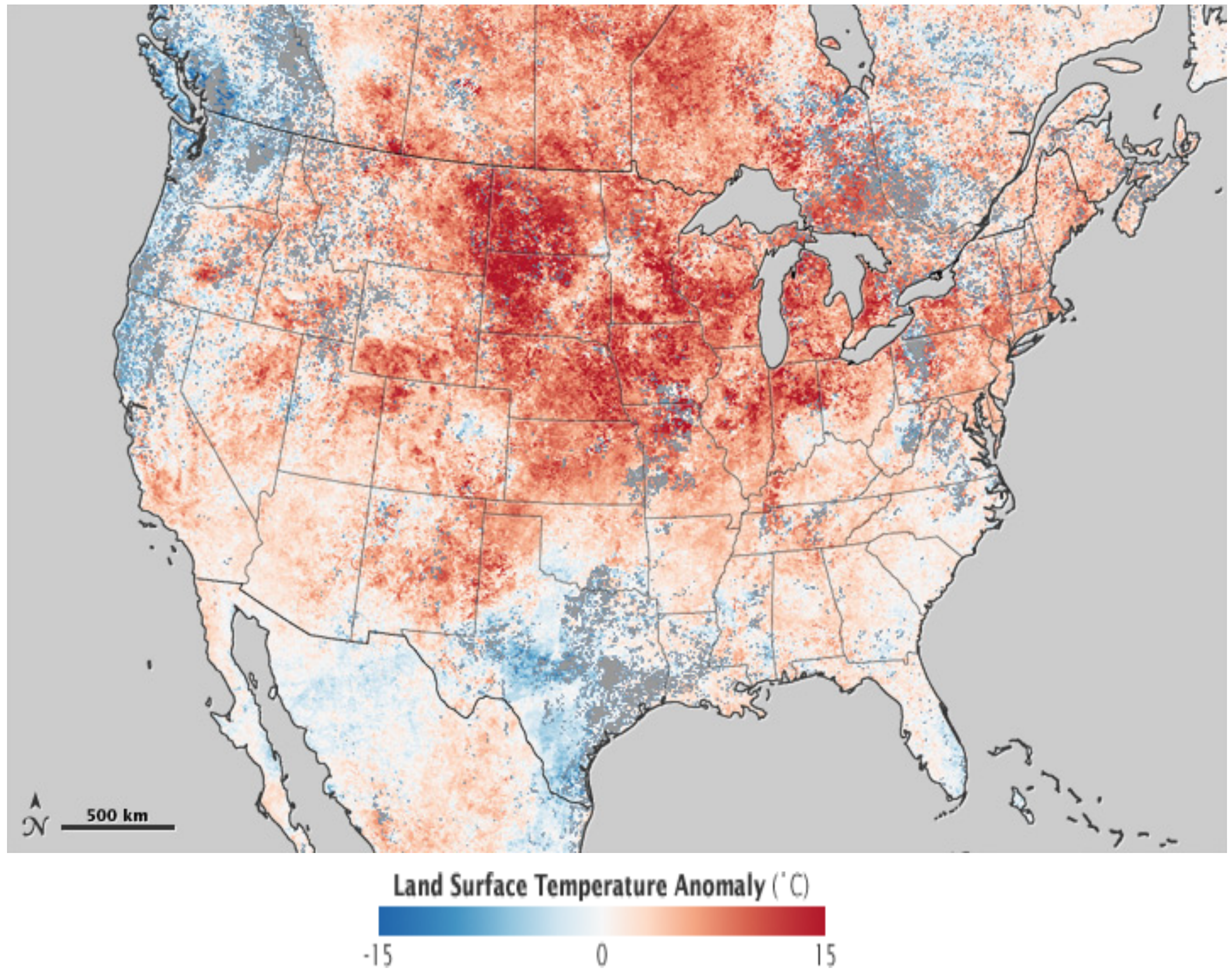
2) Variability has increased across most timescales (decadal, year-to-year & even seasonal, monthly & weekly timescales). The term "weather whiplashing" applies. A particular city or region can experience record high temperatures one week, record low temperatures the next week, & swing back to record high temperatures the subsequent week. The risk of "weather wilding" is dependent on the location relative to the jet stream waves. For example; the "Summer in March", 2012 heat wave in North America; 1st week of March had normal cold temperatures; 2nd week was up to $15^{o}C$ warmer than normal; followed by a killing frost causing $100 million damage to Ontario's apple crops.

Global-to-Local Scale: Impacts to Manitoba and the EIS

"The duration, areal size, & intensity of the "Summer in March", 2012 heat wave are simply off-scale, & the event ranks as one of North America's most extraordinary weather events in recorded history." (Wunderground, 2012)

In 2012, the growing season started 5 weeks early; early snowpack loss caused low river flows in summer, and the stage was set for summer heat & droughts.

North American Heat Wave: March 8 – 15, 2012



(NASA Earth Observatory
http://earthobservatory.nasa.gov/IOTD/view.php?id=77465&src=share

Global-to-Local Scale: Impacts to Manitoba and the EIS

3) Climate projections for Manitoba are based on "downscaling" the Global Circulation Climate Models (GCMs) to the specific region. This makes sense when the GCMs closely mirror a slowly varying, linear climate system (which is NOT the case). However it can be very risky to rely on these models when we are experiencing the rapid changes in the climate system that have been described earlier.

4) Manitoba climate/hydroclimate studies assess atmosphere & water conditions (including lake levels, streamflows & water temperatures) based on data from the last century as well as projections from the regional models. With much greater variability due to global climate system changes, these studies are expected to be less reliable.

5) Since climate statistics have changed, probabilities that are based on a stable climate, namely the risks of "one-in-a-hundred" or "one-in-a-thousand" events need to be carefully evaluated since they are highly likely to no longer be valid. In this case, more weighting on recent behaviour over the nearest decade will be expected to lead to better modelling and risk assessments.

Global-to-Local Scale: Impacts to Manitoba and the EIS

6) Lake Winnipeg water temperature is very important during heat waves with extended droughts. Annual evaporation will remove much more than 20% of the inflow, the lake volume will decrease & there will be much greater risk of eutrophication & blue-green algae blooms, similar to what occurred on the west shore of Lake Erie in the summer of 2014. Less lake volume will reduce hydro-electric power generation and perhaps reduce electricity supply for the MMTP grids.

7) Decreases in mean discharge of the Saskatchewan River need to be studied carefully since many glacially fed rivers are drying up due to rapidly declining snowpacks in the mountains. Steadily rising temperature trends at mountain elevations are causing rapid glacier declines, as well as a 20% decline in spring snow cover throughout the Rockies in the U.S. since 1980 (Pederson et al., 2013). The Peyto glacier which helps feed the Mistaya & North Saskatchewan Rivers has lost about 70% of ice mass. Glaciers in the Rocky Mountains supply the majority of the stream flow used in Alberta, Manitoba & Saskatchewan. Also, runoff from snowpack supplies between 60 - 80% of annual water supplies to 70 million people in the American West. Water flow is vital for generation of the power production supplying the MMTP grid.

http://e360.yale.edu/feature/loss_of_snowpack_and_glaciers_in_rockies_poses_water_threat/2785/

Global-to-Local Scale: Impacts to Manitoba and the EIS

7) (continued): The glacier covered regions in the South & North Saskatchewan River Basins in Alberta have declined in area by 37% & 22% respectively since 1975 (Pomeroy, 2014). In the short term, glacially sourced water flows can temporaily increase during a "last gasp" of the glacier. Water access rights for one unit of water input in Alberta into the Saskatchewan River dictate the division: Alberta 50%, Saskatchewan 50% of the remainder (25% of input), and Manitoba the remainder (25% of input). These ratios were determined under drought conditions & useage may need to be reevaluated. Thus, any climate change caused reduction of high elevation glacier water storage is a large risk to people around the planet, not just in Manitoba but also, notably to people relying on water storage in the Himilayas, Andes & Rockies Mountains.

8) Climate normals from the thirty year period 1981 to 2010 are usually used in the analysis of climatic characteristics in Manitoba. Since most of the rapid changes in the global climate system have occurred in the time period from 2000 to present, it makes sense to also analyze climate based on the older 1971 to 2000 climate normals. Using the more recent climate normals is actually hiding climate change in the previous decades.

Global-to-Local Scale: Impacts to Manitoba and the EIS

9) The Lake Winnipeg Basin in Manitoba has been experiencing a "wet cycle" for the last 15 years or so. There is no expectation that this will continue as rapid global climate system changes accelerate. Many climate models (noted previously to underestimate the rate of change) project increased global aridity in the 21st century over much of the planet (most of Africa, the Americas, Australia, Southeast Asia, southern Europe & the Middle East). It seems clear that variability between exceptional drought & severe flooding will increase in many regions.

10) There are many ways in which the MMTP grid can be severely tested by extreme weather events. Converter stations & substations spread over a large region can become inundated by flood waters from widespread torrential rain events that greatly exceed rainfall rates and amounts in short periods of time (i.e. five months of rainfall in a few days, as experienced by Calgary & Toronto events in 2013, and large regions of Ontario, Quebec & British Columbia in April & May, 2017.

Global-to-Local Scale: Impacts to Manitoba and the EIS

11) Tornadoes are always a risk to power line infrastructure. It is important to accurately quantify the risks based on the existing statistics of storms that generate tornadoes, and try to determine how these statistics are changing with ongoing abrupt climate change. One major concern is that the existing region in the central U.S. known as "tornado alley" migrates northward over the border to Canada. The location is the region where there is a large and frequent clash of air masses, namely the warm humid air moving northward from the Gulf of Mexico collides with the cool dry air masses moving southward from the Arctic. With a warming climate, it is very possible that the collision region shifts northward, perhaps as far north as southern Manitoba?

12) Derechos are straight-line winds lacking the rotation leading to tornadoes, but with winds strong enough to damage transmission line towers & thus power grids. They are mostly a phenomena caused by a rapidly moving frontal system and can extend over a large region (hundreds of km long, by 30 km wide); i.e. the New Brunswick storm on May 19th, 2017 toppled 20 power poles.

Global-to-Local Scale: Impacts to Manitoba and the EIS

13) Ice storms (freezing rain) are generally very rare events since the conditions that generate them are extremely rare due to extremely tight temperature ranges (slightly colder & the precipitation falls as snow, & slightly warmer & you get rain instead of freezing rain). Also, the meteorological conditions for ice-storms need to stay in this tight range for a long period of time, for example days as in the widespread Quebec/Ontario ice storm of 1998. These rare conditions are unlikely to become more frequent as rapid climate change accelerates, however the locations for freezing rain events may shift locations.

14) The increased frequency of heat waves & associated droughts with rapid climate change may become problematic to the MMTP grid. Heat waves cause power lines to expand & sag, potentially increasing the risk of fires if the lines sag into tall vegetation. The conductivity of the conductors in the lines decreases as temperature increases, and there is a feedback to even higher temperatures from increased resistive heating of the lines. Risks of fire greatly increased as vegetation dries and is stressed, and fires can shut down the grid.

Global-to-Local Scale: Impacts to Manitoba and the EIS

15) Manitoba Hydro and many other companies, and the CEC and many other regulatory bodies consistently have an over-reliance on IPCC (Intergovernmental Panel of Climate Change) climate models. There is a lot of money invested in large scale GCMs (Global Climate Models), and these models are used to make projections on how climate change will play out in the near-term to far-term. Unfortunately, these models are unable to project what is happening now on the ground.

Global-to-Local Scale: Impacts to Manitoba and the EIS

16) The Prairie Climate Atlas uses data from 12 downscaled global climate models (GCMs) to make projections on climate conditions for the prairies, including Manitoba. This capability is extremely useful, but since the GCMs do not account for the extremely rapid changes that are occurring in the Arctic such as the complete loss of sea ice within a few years as opposed to the modeled 30 years or so, any results from these projections is likely to be on the conservative side. It is important to incorporate all of the Arctic feedbacks effects into these models, such that they more closely resemble the observations. Clearly, if there is a discrepancy between the model and the observations, then the model is simply wrong. Observations are reality.

Global-to-Local Scale: Impacts to Manitoba and the EIS

17) The increasing prevalence of extreme weather events, namely of intense wind storms, including derechos (straight line frontal winds), downbursts and tornadoes requires a re-examination of the traditional lattice stand-alone towers, versus guyed towers, versus the newer streamlined pole towers used in many places in Europe (these newer design pole towers are shorter, so the wind stress is lower; also the tower cross section is much smaller so they are more durable, with less sway in strong windstorms as compared to the traditional lattice towers).

Outline of Evidence: CEC MMTP Hearings 2017

- Update on climate change globally, continentally, & regionally
- A forecast to pay attention to – climate change in Manitoba
- Events globally & in Canada that show that climate change is here
- Investigation of abrupt climate change
- Latest science on global greenhouse gas concentrations, global average temperatures, Arctic climate, jet stream behaviour, methane emissions from terrestrial permafrost & sea-floor sediments, northern hemisphere versus southern hemisphere differences & implications for Manitoba
- Nonlinear changes in climate systems already affecting Canada & Manitoba
- Ways operation of a transmissions system with converter stations, substations, etc. spread throughout a large region could be affected by climate change, including extreme weather events
- Application of all of the above to MMTP, review of the MMTP EIS, and consideration of climate change adaptation for MMTP