

Extreme Weather and Climate Change: the big picture

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Increases in Extreme Weather

- **Last decade: lack 30-year statistics!**
 - **Eg. Severe flooding: 100-yr storms**
 - Every few years (!)
- **Powerful hurricanes; coastal storms**
 - **Warming oceans; land-sea Temp contrast**
- **Increasing NH winter variability**
 - **Unstable polar vortex; snow cover coupled**
- **Severe droughts and fires**
 - **Stationary modes: vegetation coupled**
- **Global weather linked - 2-weeks**

Climate Drivers

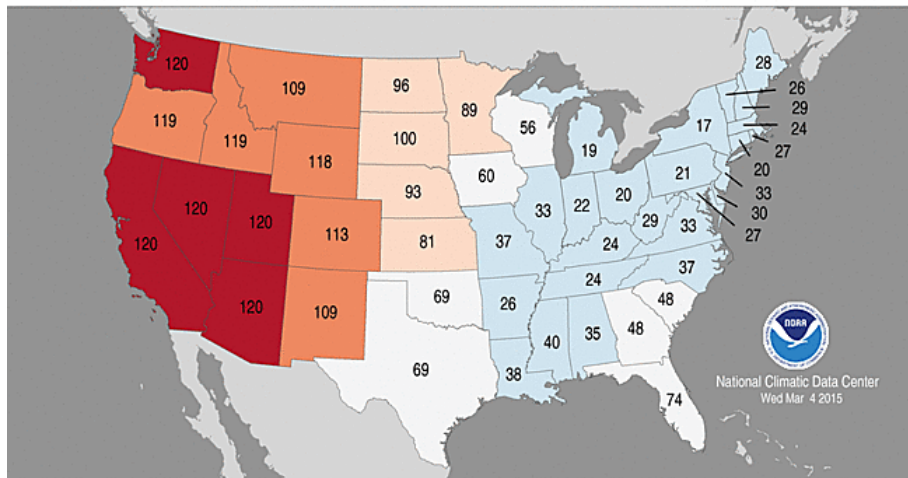
- Increase in fossil GHGs: CO₂ and CH₄
 - Amplified 3X by water vapor GHG increase
 - Doubled in Arctic and winter by ice albedo feedback
 - *Cooling to space reduced; net solar flux increased*
- 90% of Earth's energy imbalance stored in oceans: long time scales
- Arctic amplification reduces NS gradient
 - Changes in mid-latitude circulation
 - Unstable polar vortex (?)

Contrasting Winters

- **Last decade in North-East**
 - **Warm into Jan. in 2007, 2008, 2012, 2013, 2016, 2017 but not 2015 or 2018!**

DJF2015 Statewide Average Temperature Ranks

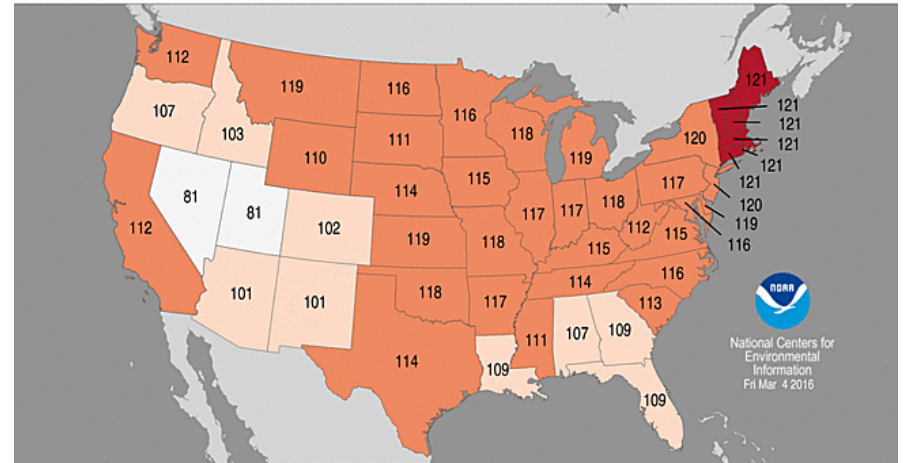
December 2014–February 2015
Period: 1895–2015



Record Coldest (1) Much Below Average Below Average Near Average Above Average Much Above Average Record Warmest (120)

DJF2016 Statewide Average Temperature Ranks

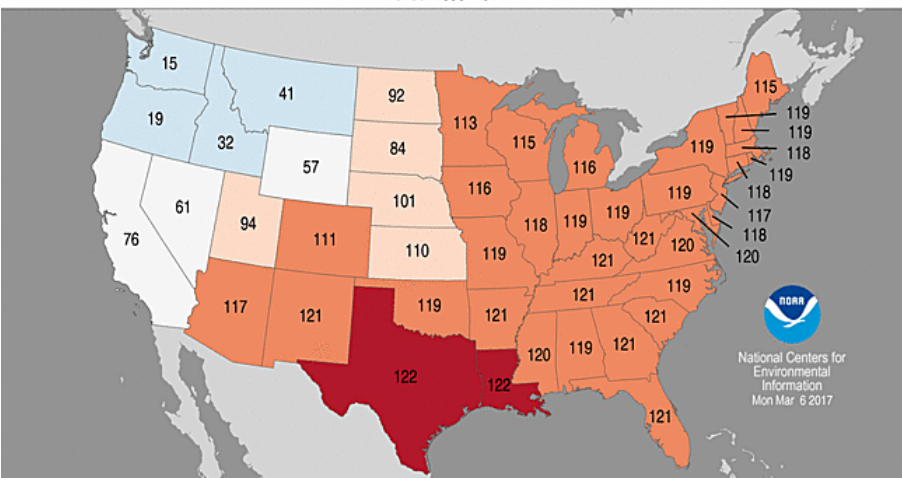
December 2015–February 2016
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Record Coldest (1) Much Below Average Below Average Near Average Above Average Much Above Average Record Warmest (121)

DJF2017 Statewide Average Temperature Ranks

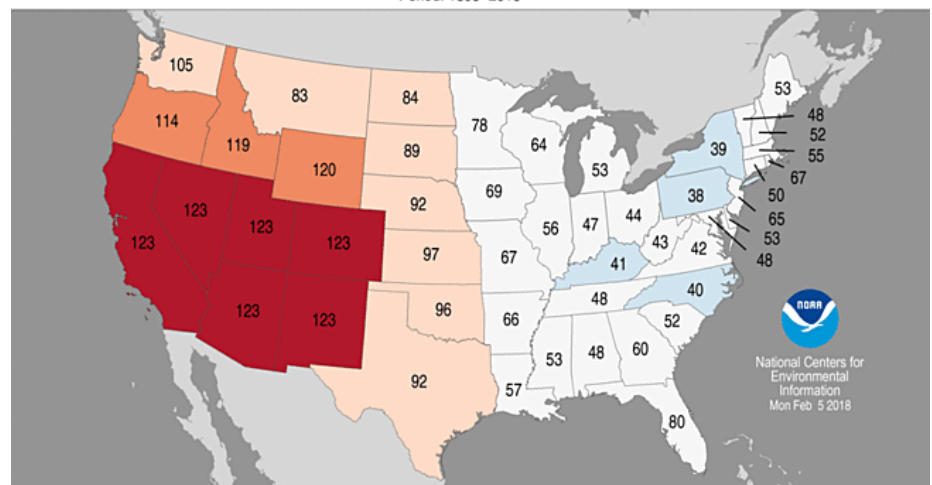
December 2016–February 2017
Period: 1895–2017



Record Coldest (1) Much Below Average Below Average Near Average Above Average Much Above Average Record Warmest (122)

NDJ2018 Statewide Average Temperature Ranks

November 2017–January 2018
Period: 1895–2018



Record Coldest (1) Much Below Average Below Average Near Average Above Average Much Above Average Record Warmest (123)

Stationary modes

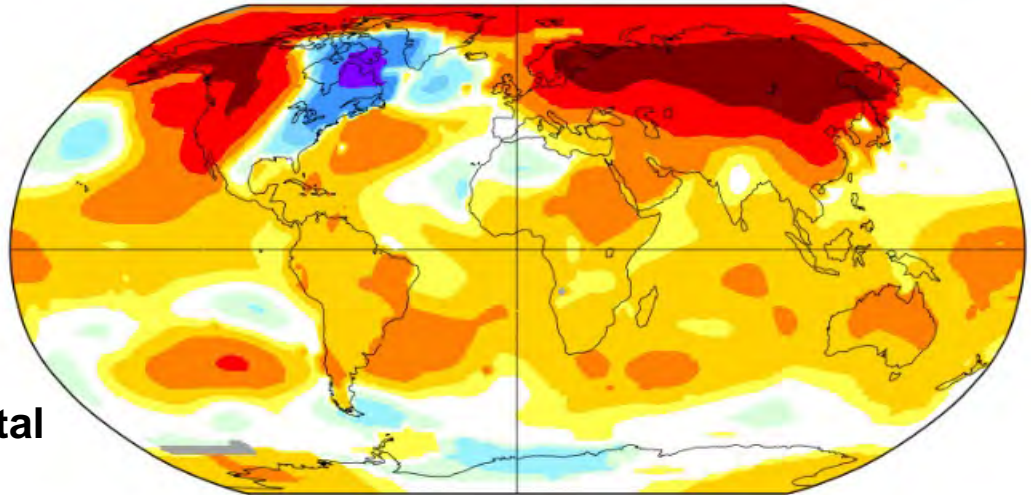
*Jan-Feb-Mar
2015*

Warm Atlantic, cold NE, strong coastal
storms - Boston record snow

Jan-Mar 2015

L-OTI(°C) Anomaly vs 1951-1980

0.86



-5.0 -4.0 -2.0 -1.0 -0.5 -0.2 0.2 0.5 1.0 2.0 4.0 6.4

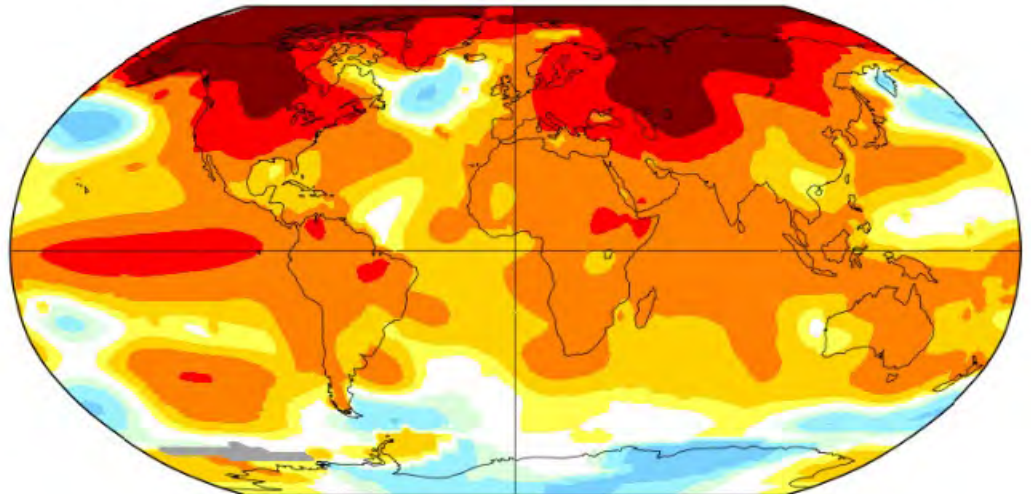
*Jan-Feb-Mar
2016*

Warm Atlantic, warm NE, little snow,
warm Arctic

Jan-Mar 2016

L-OTI(°C) Anomaly vs 1951-1980

1.24



-4.1 -4.0 -2.0 -1.0 -0.5 -0.2 0.2 0.5 1.0 2.0 4.0 8.0



January 2, 2012



March 11, 2012



October 2011– March 2012

- **Warmest 6 months on record**
- **My garden frozen only 67 days**
- **January 15, 2013**



February 5, 2016

(Digging in Feb. first time ever)



January 10 and 12, 2018



January 10, 2018

After cold snowy period

T_{\min} range -10 to -20F

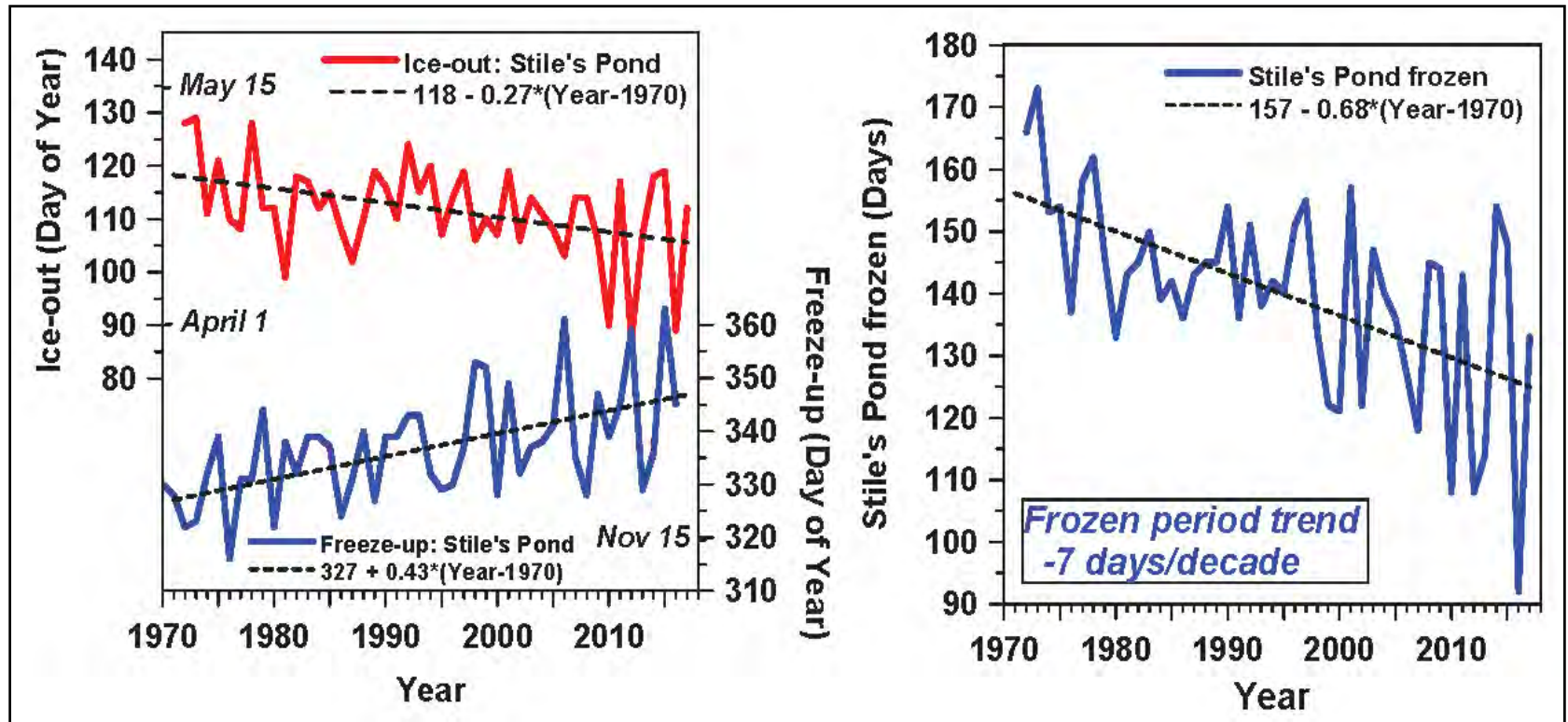


January 12, 2018

After T_{\max} up to 60F

Marker: Lake Freeze-up & Ice-out

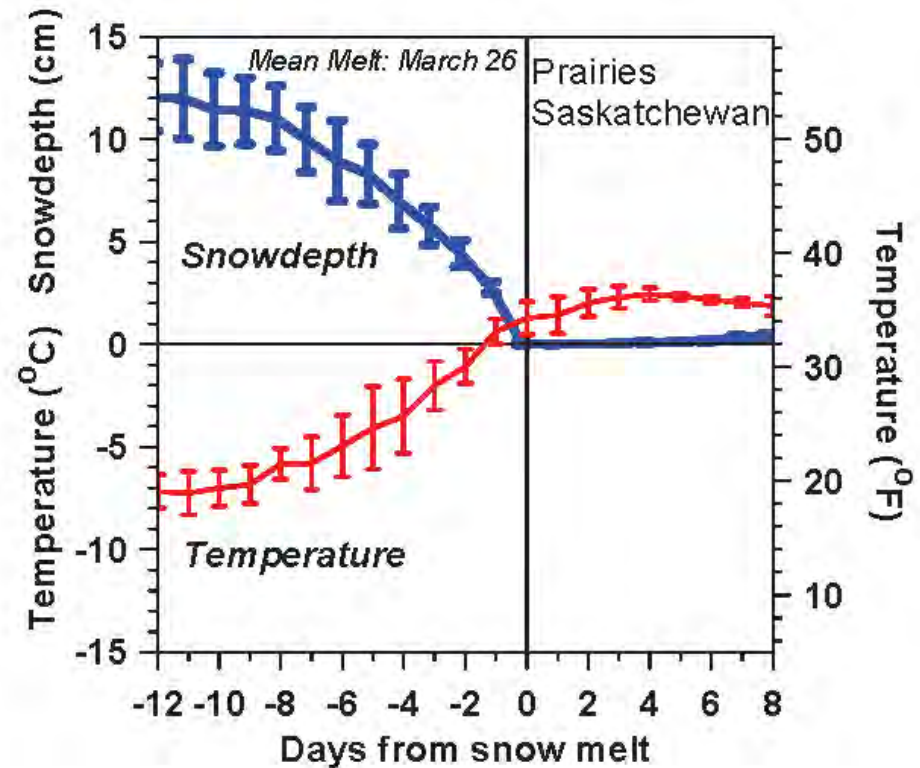
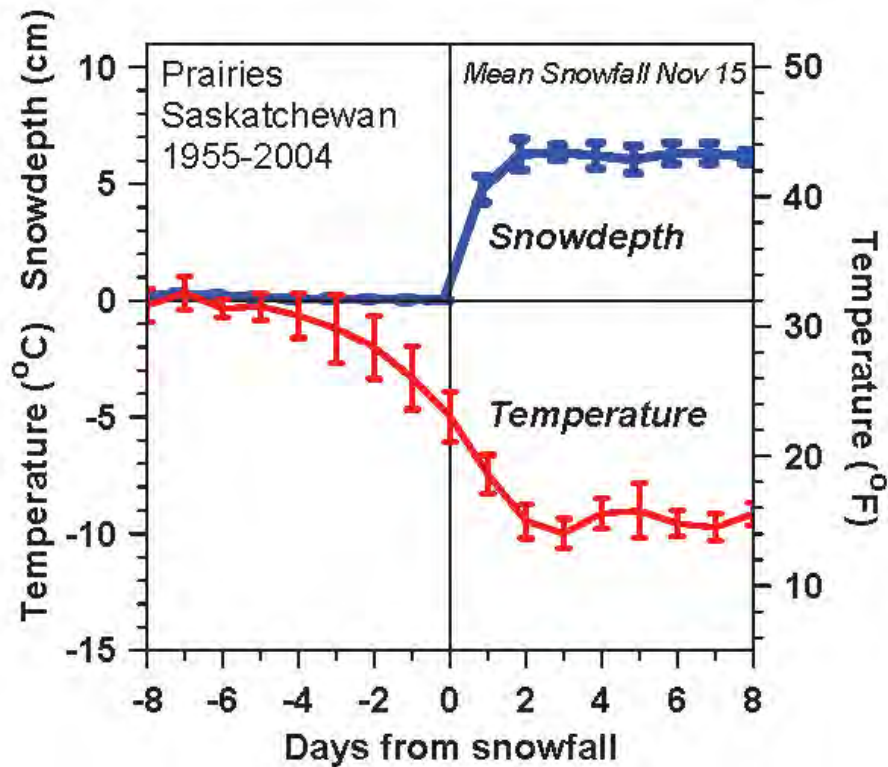
Frozen Period Shrinking: variability huge



- Freeze-up later by **+4 days / decade**
- Ice-out earlier by **-3 days / decade**
- Lake frozen period trend **- 7 days/decade**
- *Interannual variability \approx 40 yr trend*

*Stiles Pond:
"Eye on the Sky"*

Snowfall and Snowmelt



- Temperature falls 10C (18F) with first snowfall
- And rises again with snowmelt
- *Fast transitions in 'local climate'*
 - *Snow reflects sunlight: Climate Switch*
 - *Reduces evaporation and water vapor greenhouse*

Diurnal cycle: Clouds & Snow

Canadian Prairies 660 station-years of data

Winter climatology

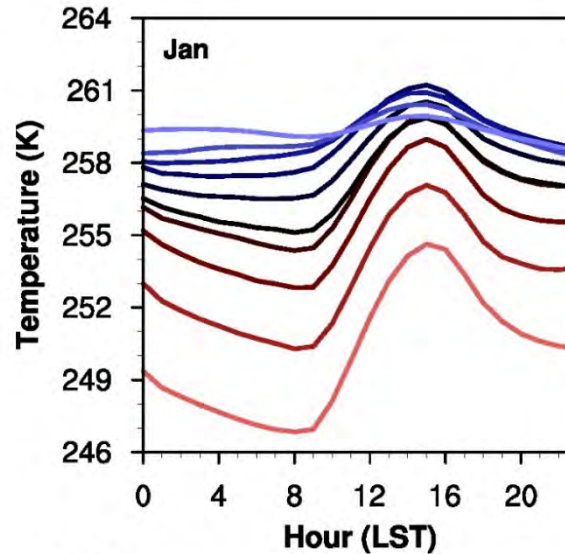
- Snow reflects sunlight: cold
- Cools more when clear
- Warmest when cloudy

Summer climatology

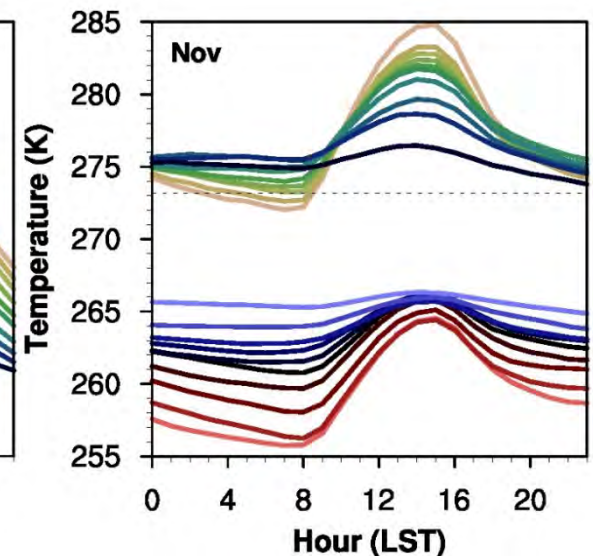
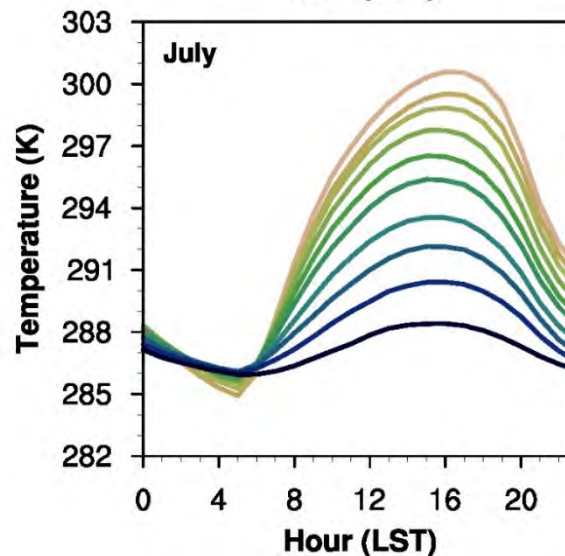
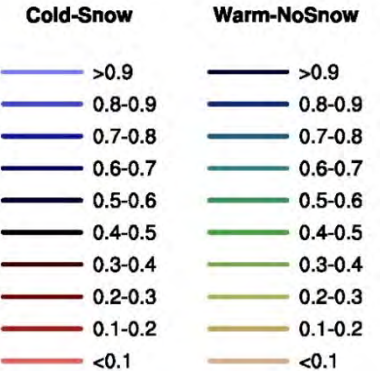
- Clouds reflect sunlight
- Warmest when clear
- Coolest when cloudy

Transition months:

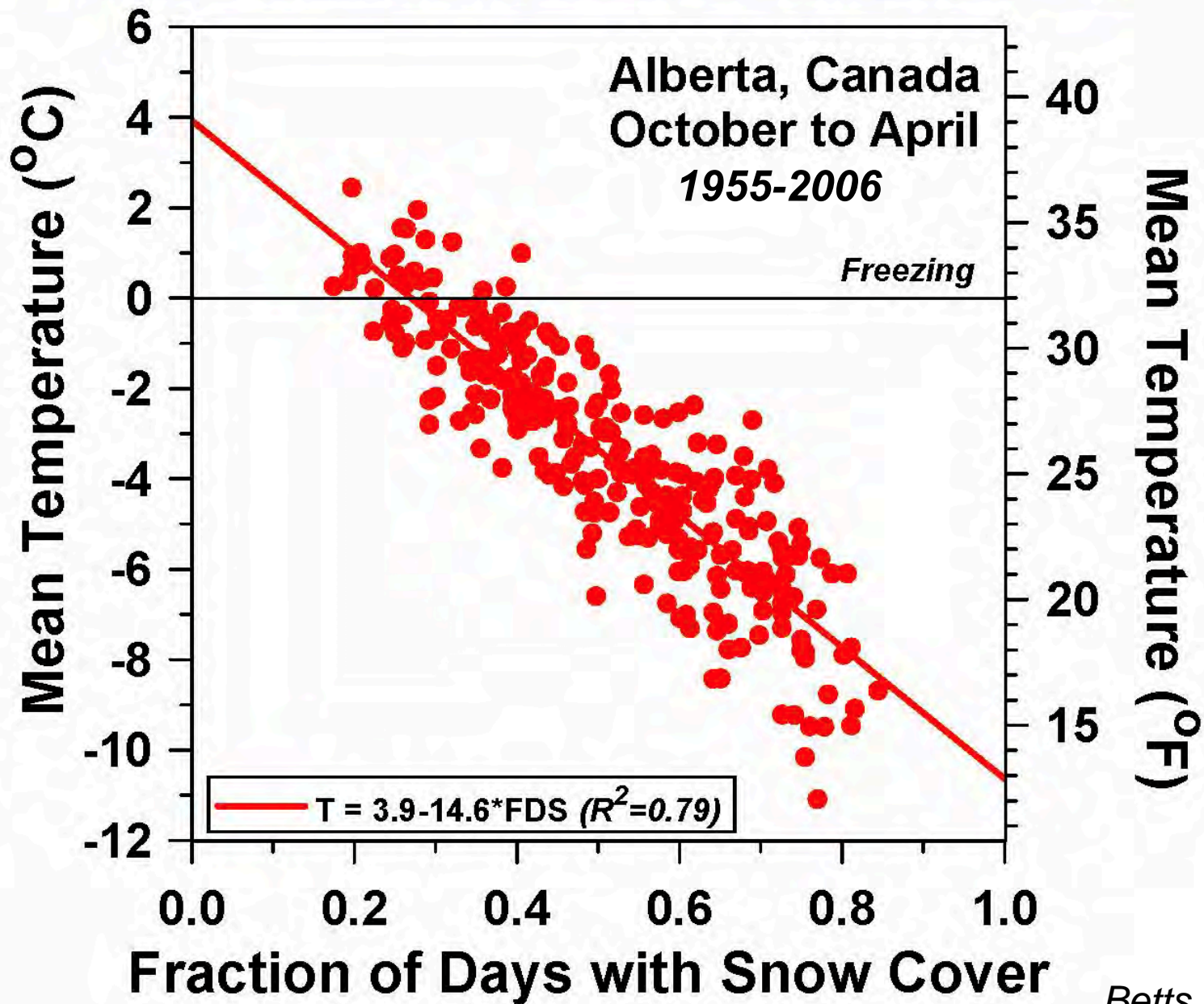
- Show both climatologies
- With 11K separation
- Fast transitions with snow
- Snow is “Climate switch”



Opaque cloud fraction



More snow cover - Colder temperatures

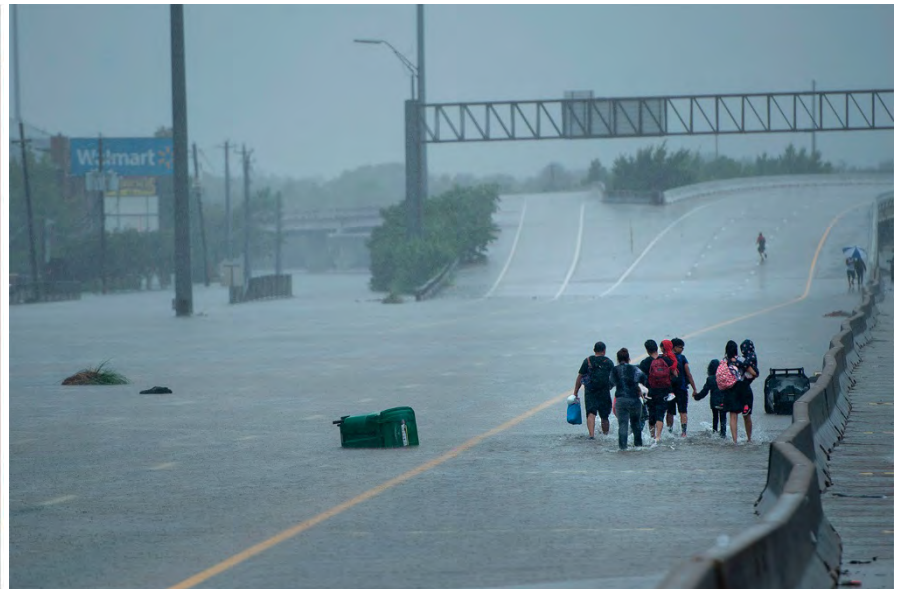


Hurricane season: 2017

- Earth is warming as greenhouse gases increase and reflective ice cover falls
- Oceans are storing 90% of heat
 - Warmer Atlantic, Caribbean, Gulf of Mexico and Gulf Stream means stronger hurricanes; when vertical shear is low
- *2017: Harvey, Irma, (Jose), Maria*

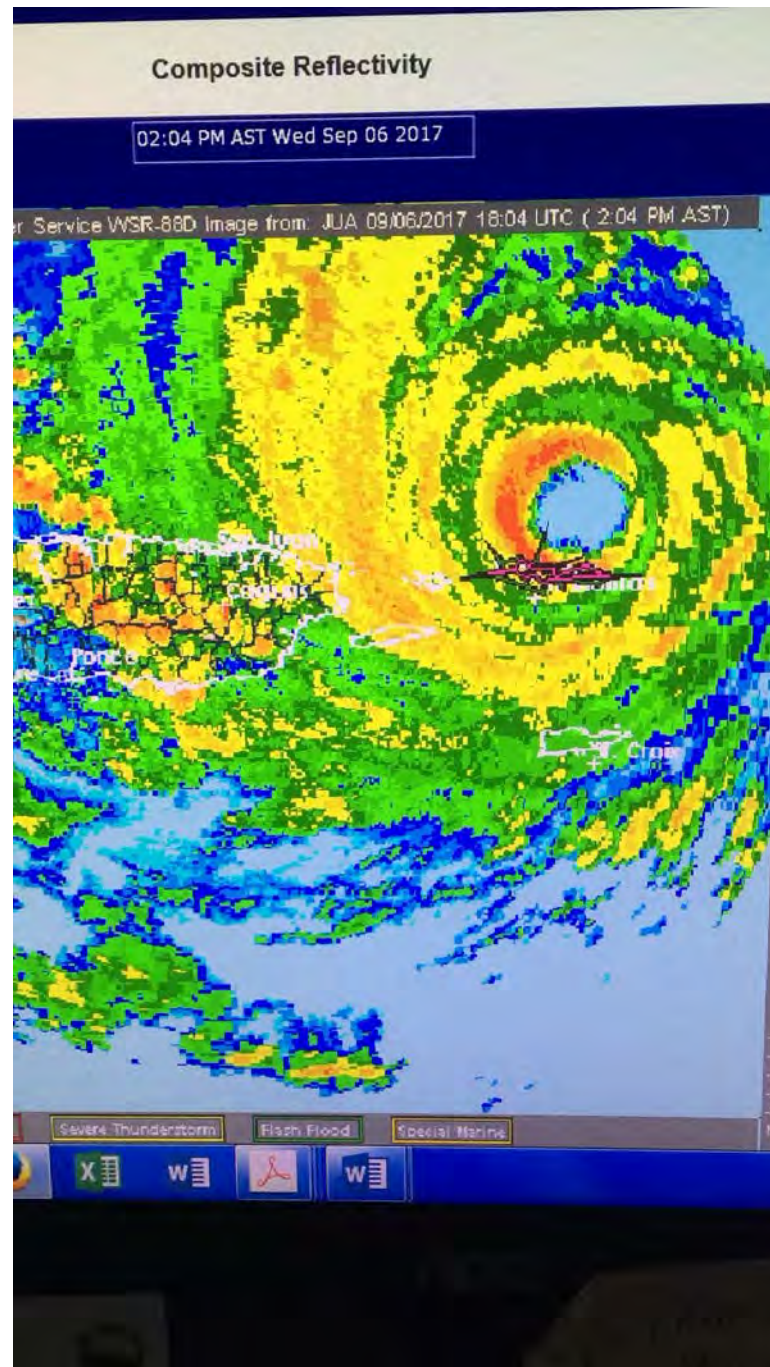
Why was Harvey so Damaging?

- Huge evaporation off warm ocean
- Category 4 hurricane developed
- Very heavy rain-rate: 10-12 inches per day
- Two stationary high pressure systems to the north **trapped** Harvey for 4 days over Houston
- Result **40+ inches** of rain & massive flooding

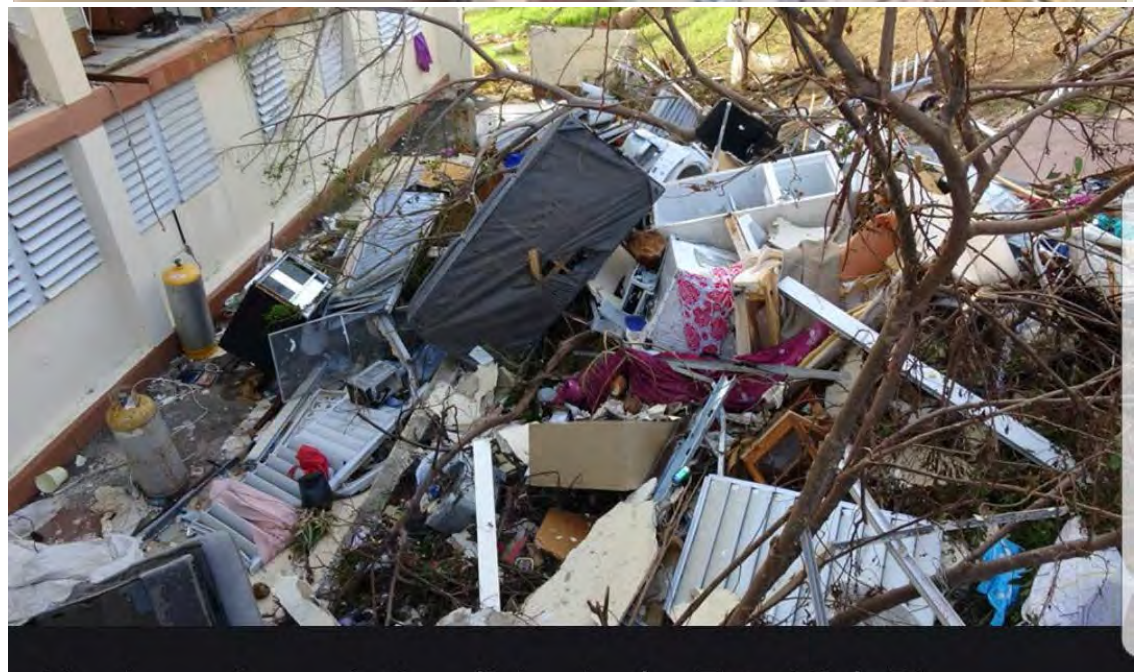


2pm Sept. 6
Category 5*
IRMA
grazing
St Thomas

****Cat 5 >155mph***
IRMA >180mph



Irma(Cat.5)
Sept. 6
St Thomas



Irma and Jose: Sept 7



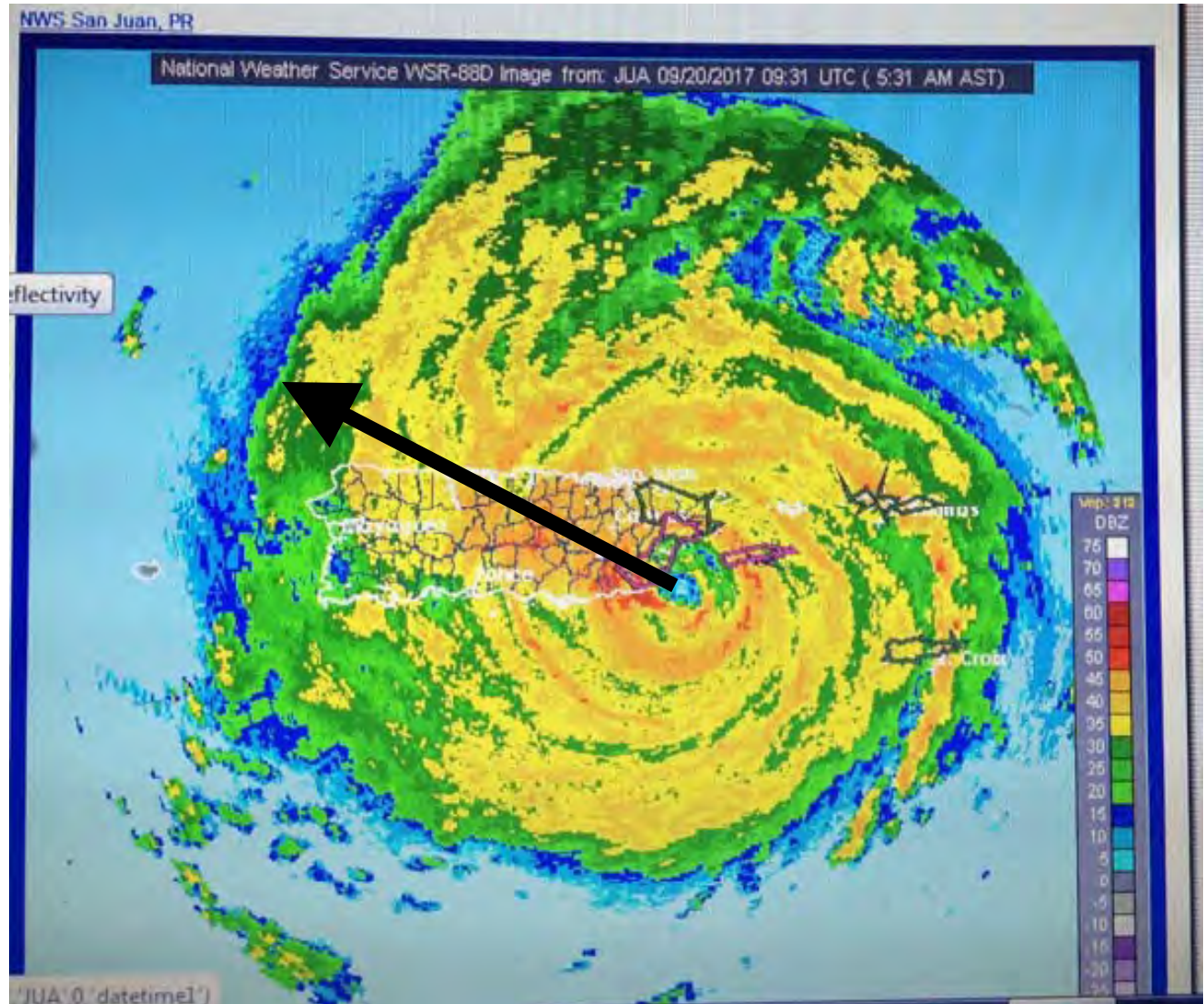
After Jose passed; Catamaran to Puerto Rico on Sept 11

Maria: 5:30am Sept. 20

Category 4 hits Puerto Rico

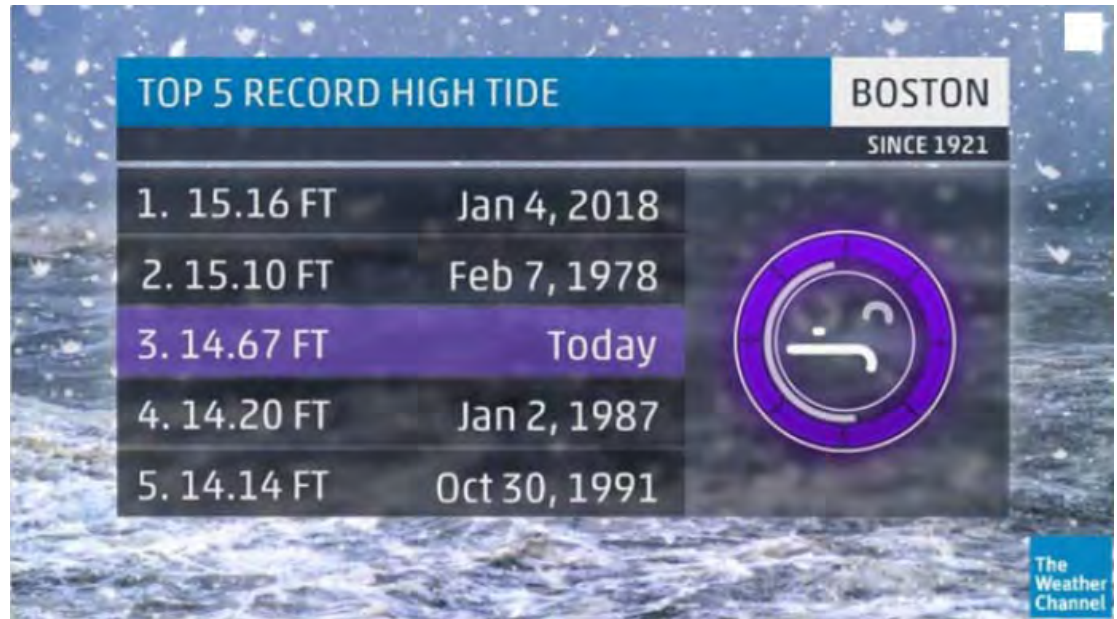
Cat 4
>130mph
Maria
>150mph

***Wiped cell
towers and
power grid
(90% back
after 6 mos!)***



Winter Coastal Storms

- Jan 4, 2018
- Mar 2-3, 2018



- Both rapid development over warm Gulf Stream, cold continent
 - 3ft storm surges, high tide, coastal flooding
 - *Sea-level rising 2-5 ft this century*
 - *Ice-sheet instability (Antarctica/Greenland)*

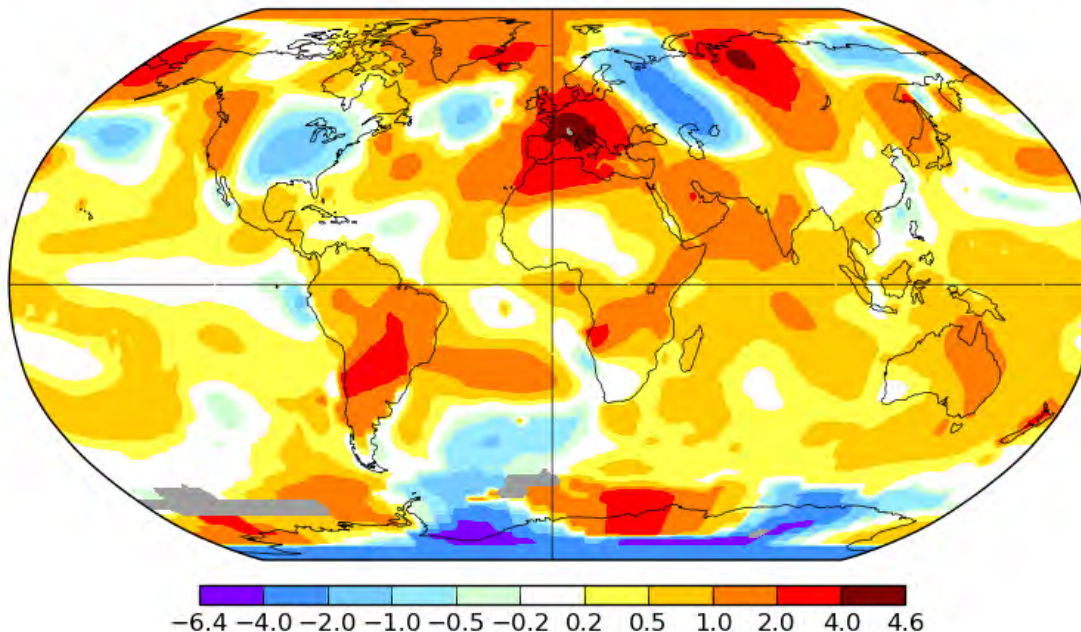
Warm Dry Climate Extremes lead to crop failure & fires

- Records in Europe is 2003, 2010, 2017
- Extremes attributed to warming climate
- **2003: France;** **2010: Russia**

June 2003

L-OTI(°C) Anomaly vs 1951-1980

0.48



GISS
June 2003

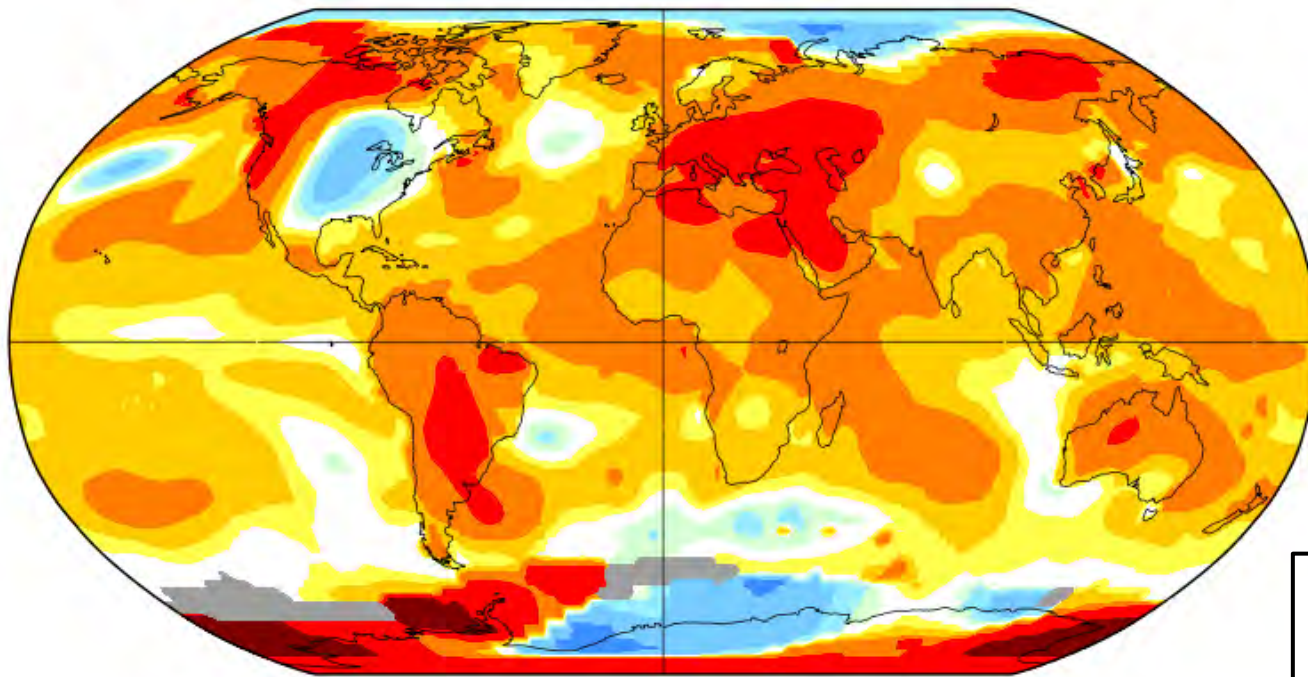
Warm Climate Extremes:2017

- **NH Fires: summer, fall 2017**
 - **Vegetation-climate coupling**

August 2017

L-OTI(°C) Anomaly vs 1951-1980

0.86



-4.1 -4.0 -2.0 -1.0 -0.5 -0.2 0.2 0.5 1.0 2.0 4.0 7.3

GISS
Aug 2017

Warm Dry Climate Extremes Lead to Fires

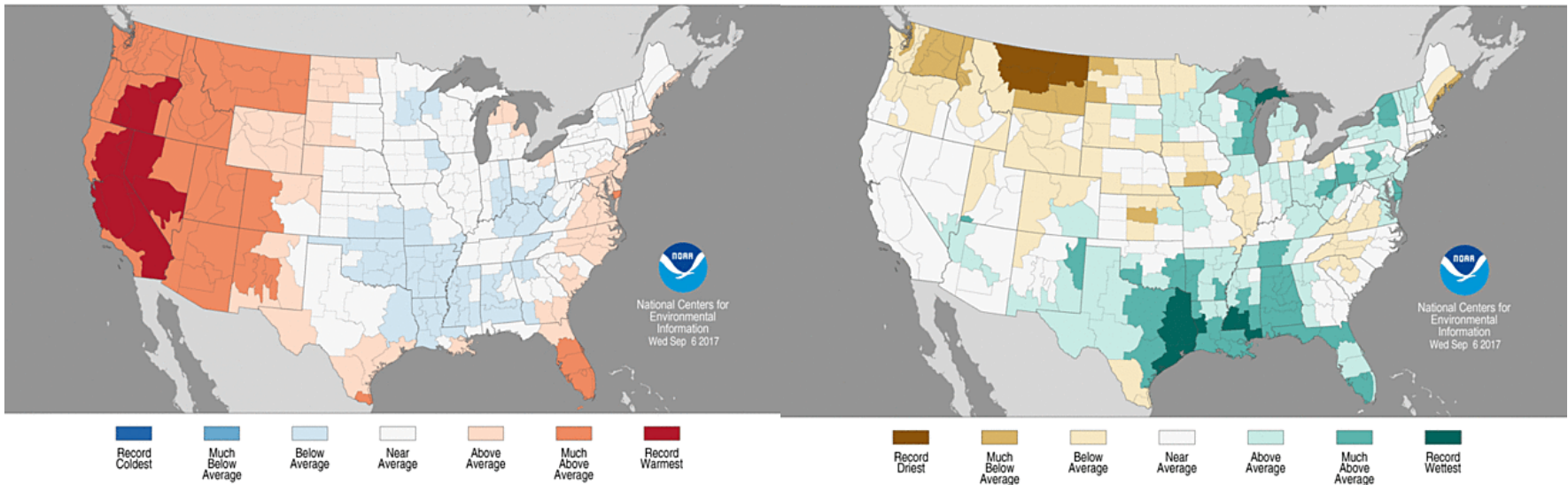
Jun-Jul-Aug, 2017

(West: hot and dry after wet winter

South: cool and wet with Harvey)

Divisional Average Temperature Ranks
June–August 2017
Period: 1895–2017

Divisional Precipitation Ranks
June–August 2017
Period: 1895–2017



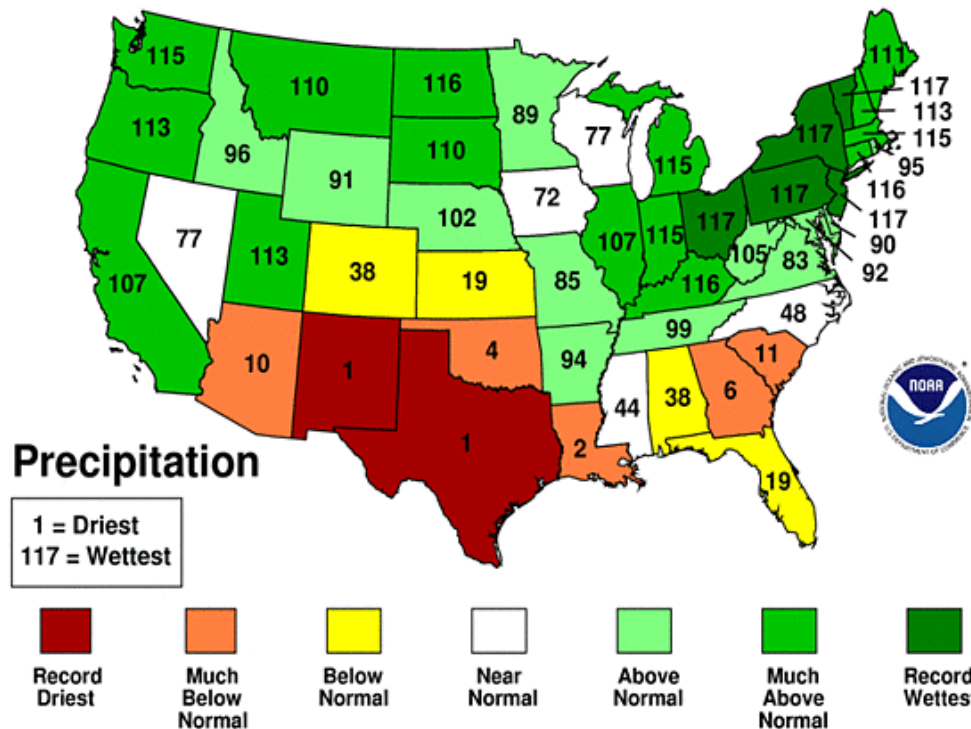
Caused severe fires in western US and Canada

2011 Precipitation Extremes

- *Record spring flood: Lake Champlain*
- *Record flood with tropical storm Irene*

March-August 2011 Statewide Ranks

National Climatic Data Center/NESDIS/NOAA



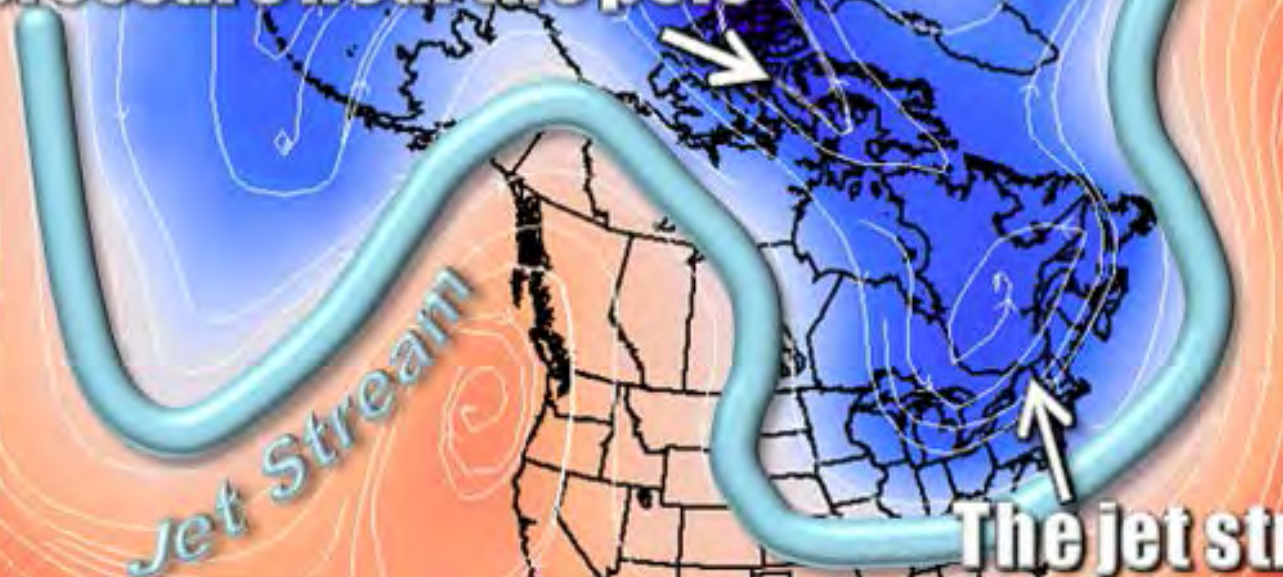
March-August, 2011

- Record wet : OH to VT
- Record drought: TX & NM
- ‘Quasi-stationary’ pattern

Conclusions

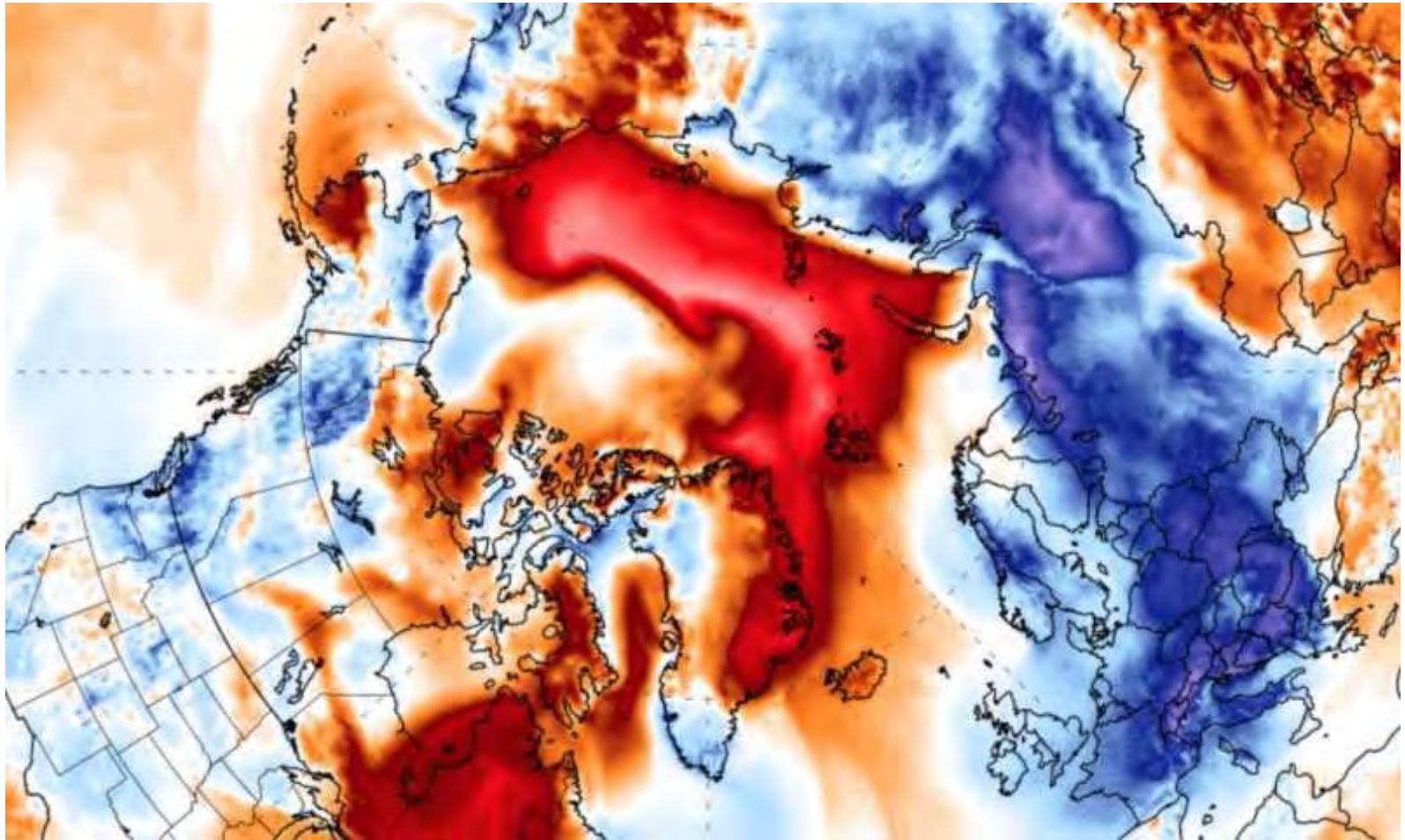
- **Weather embedded in a changing climate system**
 - **Warmer on average, but extremes increasing**
 - **Quasi-stationary modes more frequent, yet warming Arctic vortex less stable (?)**
 - **Oceans warming, expanding**
 - **Stronger hurricanes and coastal storms**
 - **Sea-ice and ice-sheets melting**
 - **Sea level rising and stronger storm surges**

**"Polar Vortex":
Cold air and low
pressure near the pole**



**The jet stream
and cold air surge
south into the U.S.**

Early March 2018



Arctic sea-ice 2018 winter Low

