



Climate Change & Increasing Severe Weather



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Rutland Rotary
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Outline

- **Climate change and severe weather**
 - **Global and local aspects**
 - **Oceans storing Earth's heat imbalance**
 - *Hurricanes*
 - **Quasi-stationary mid-latitude wave patterns increasing local floods/heat waves, droughts and fires**
 - **Warming & melting Arctic**
 - **Tight coupling of processes**
 - **Snow, temperature, cloud, cloud water, precip**

Discussion

Fundamentals

- ***Burning fossil fuels: transforming climate***
 - ***Many water cycle amplifying feedbacks***
 - ***Water vapor greenhouse 3x CO₂; loss of reflective ice***
 - ***Evaporation, precip and instability increase rapidly with Temp***
 - ***93% Earth's energy imbalance stored in oceans***
 - ***Decadal to centennial - long timescales***
 - ***Heading for high CO₂ "hot-house climate"***
 - ***Climate extremes increasing; circulation changing***
 - ***Severe weather costs increasing***
- **Global impact of technology/consumer society**
 - **Waste streams on climate/Earth's ecosystems**
 - **Fixable by changing system guidelines**
 - **Create efficient society, based on renewable energy**

Water, Snow & Ice Give Positive Radiative Feedbacks

- As Earth warms, evaporation and water vapor increase and this is 3X amplifier on CO₂ rise
- As Earth warms, snow & ice decrease and reduced SW reflection amplifies warming in Arctic in summer and mid-latitudes in winter
- Doubling CO₂ will warm globe about 5°F (3°C)
 - Much more in the cold regions and over land, which responds faster than oceans
 - Change the global circulation

January 4, 2012: NASA

Earth's climate sustains life

- Increasing greenhouse gases reduces cooling to space
- **Climate is warming: ice is melting, extreme weather is increasing**
- Water plays crucial amplifying role



Hurricane seasons

- Earth is warming as greenhouse gases increase and reflective ice cover falls
- Oceans are storing 93% of heat
 - Warmer Atlantic, Caribbean, Gulf of Mexico and Gulf Stream means stronger hurricanes; when vertical shear is low
- *2017: Harvey, Irma, Maria*
- *2018: Florence, Michael*
- *2019: Barry, Dorian*



Major Hurricane Harvey - August 25-29, 2017

Weather.gov > Corpus Christi, TX > Major Hurricane Harvey - August 25-29, 2017

Corpus Christi, TX
Weather Forecast Office

[Current Hazards](#) [Current Conditions](#) [Radar](#) [Forecasts](#) [Rivers and Lakes](#) [Climate and Past Weather](#) [Local Programs](#)

Category 4 Hurricane Harvey: South Texas Landfall & Impacts from August 25th to 29th, 2017

[Overview](#) [Stats](#) [Radar](#) [Satellite](#) [Winds](#) [Storm Surge](#) [Rainfall](#) [Rivers](#) [Seadrift](#) [Tornado](#) [Storm Reports](#) [Photos](#) [One Year Later](#)

[Hurricane Harvey Summary PDF](#)

...Hurricane Harvey is the first major hurricane to make landfall along the Middle TX Coast since Celia in 1970...

...Hurricane Harvey is the first Category 4 hurricane to make landfall along the TX Coast since Carla in 1961...



NHC Final Best Track of Harvey (Click points above to view additional information.)

Why was Harvey so Damaging?

- **Huge evaporation off warm ocean**
- **Category 4 hurricane** developed fast
- **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



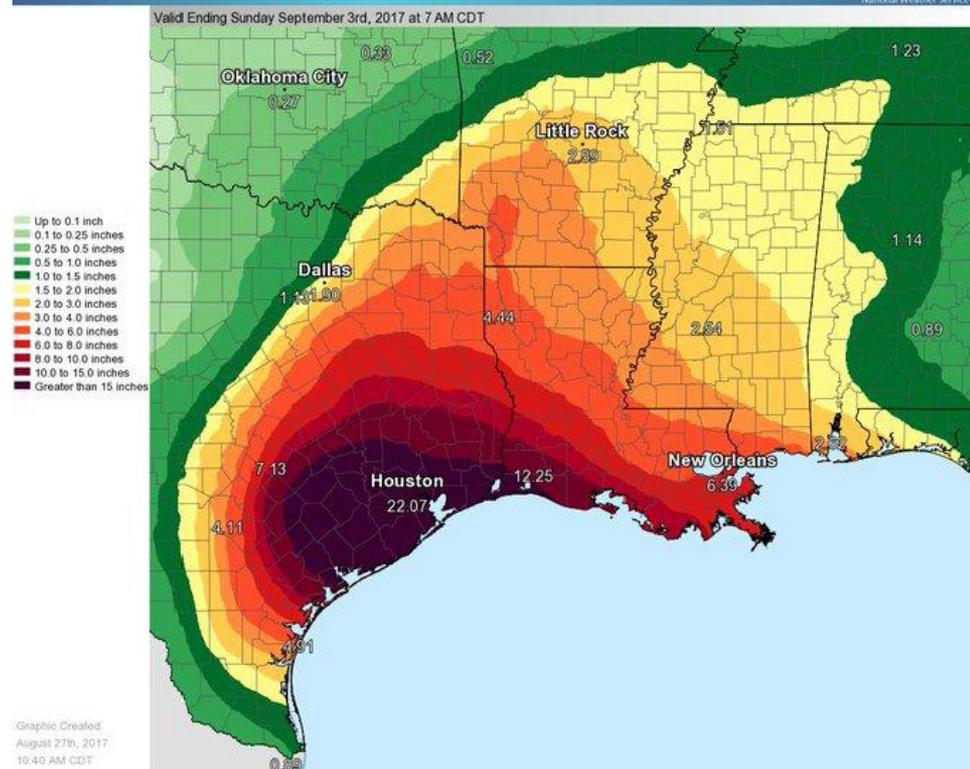
Challenge to Forecast & Emergency Services



National Weather Service
@NWS

This event is unprecedented & all impacts are unknown & beyond anything experienced. Follow orders from officials to ensure safety. #Harvey

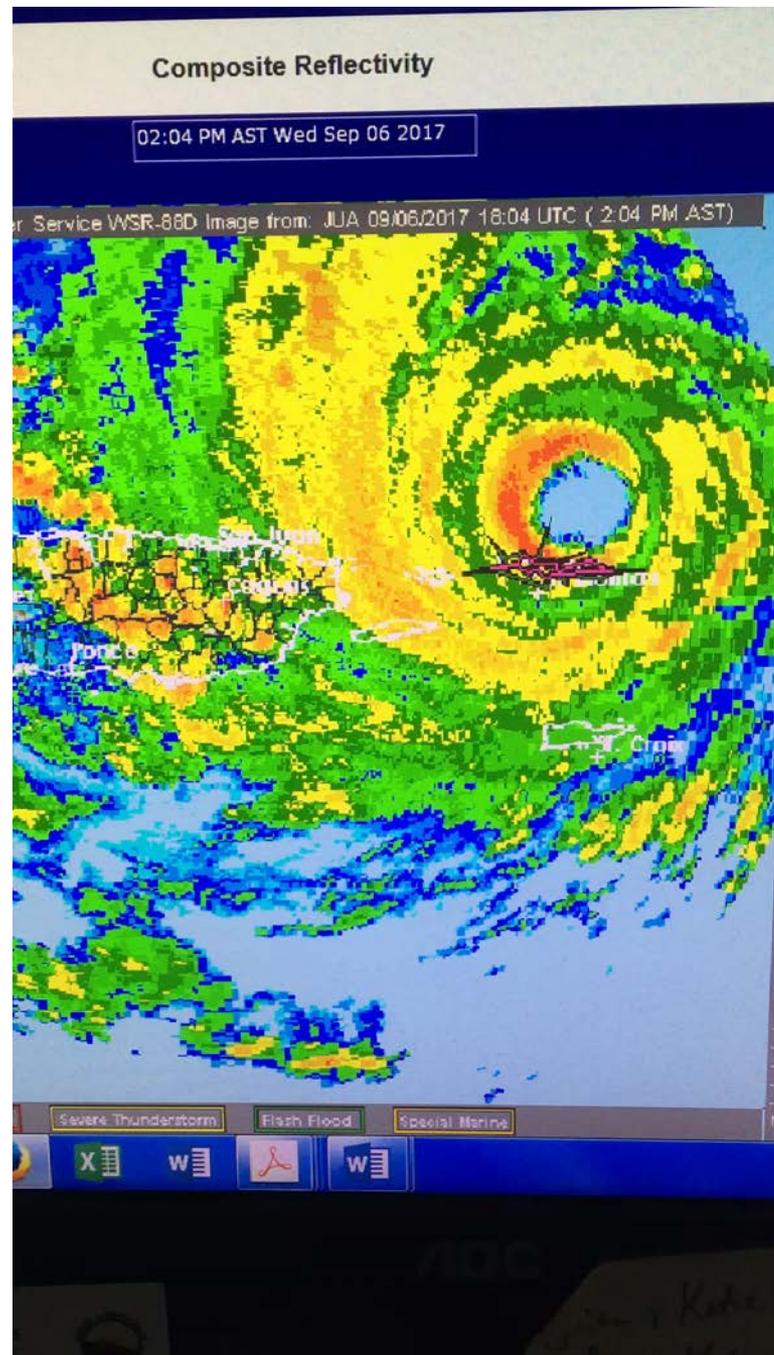
Forecast Precipitation



21.8K 11:44 AM - Aug 27, 2017

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

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

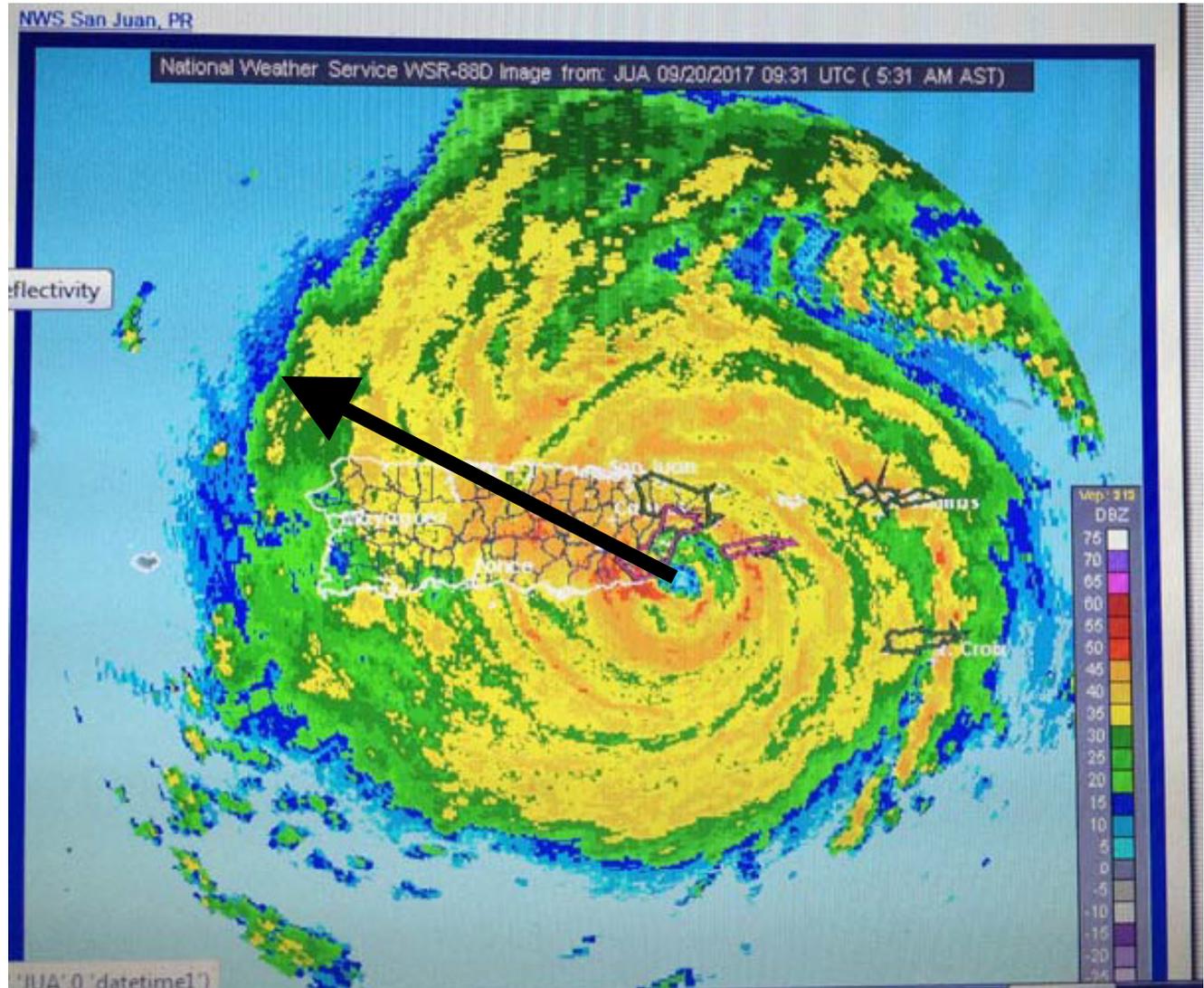


Maria: 5:30am Sept. 20 ***Category 4 hits Puerto Rico***

Cat 4
>130mph
Maria
>150mph

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

Narratives:
alanbetts.com



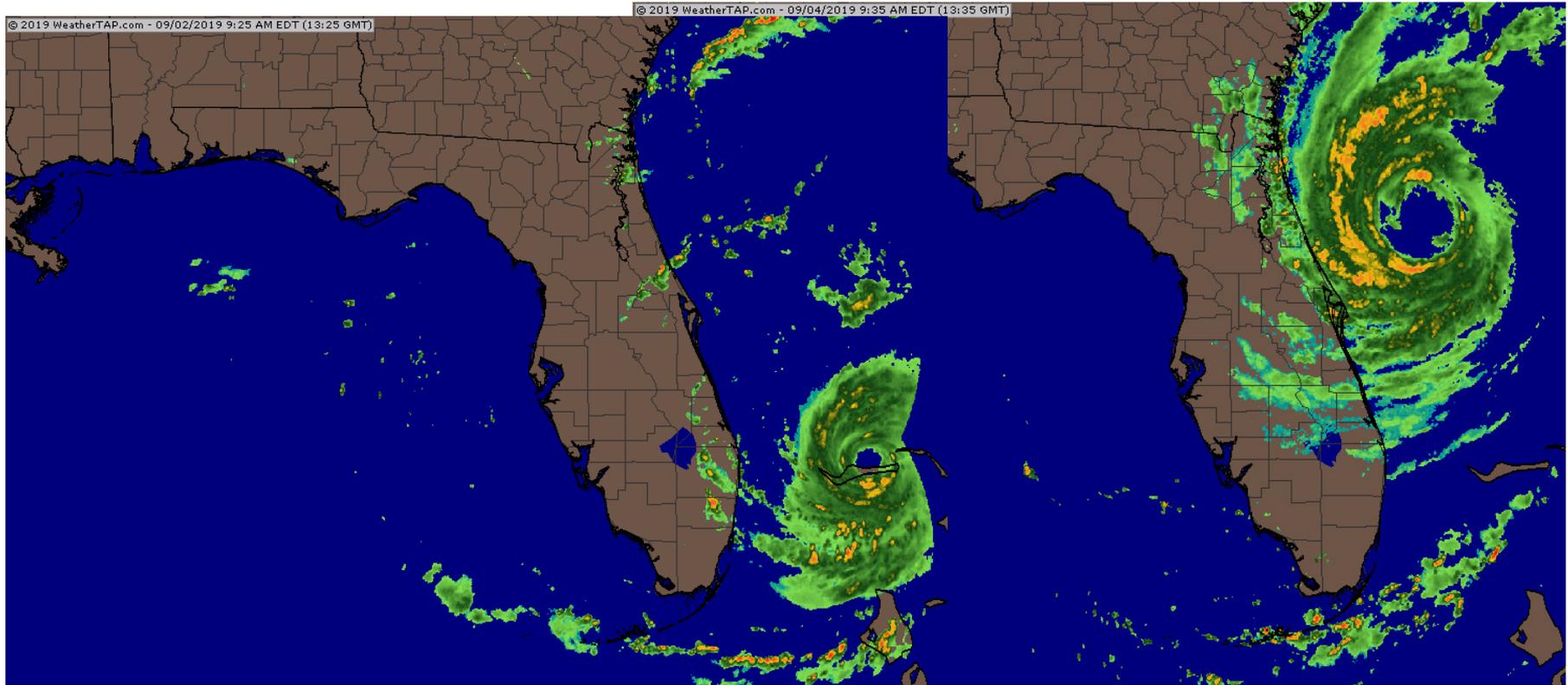
July 2019: track of Barry



Started as band of thunderstorms in Kansas, traveled in slow circle, intensified over warm water of Gulf to weak hurricane, rained on wet Louisiana [Cost: \$1 billion]

Dorian: Cat 5+

Cat 2/3



**Sept 2, 2019
Stationary over
Grand Bahama**

**Sept 4, 2019
Off Florida
Coast**

TS Irene

*Rte 131,
Cavendish
Sept, 2011*

Roads in valleys

Massive damage

**Some roads took
months to repair**

Wake-up call



2011 Classic Flood Situations

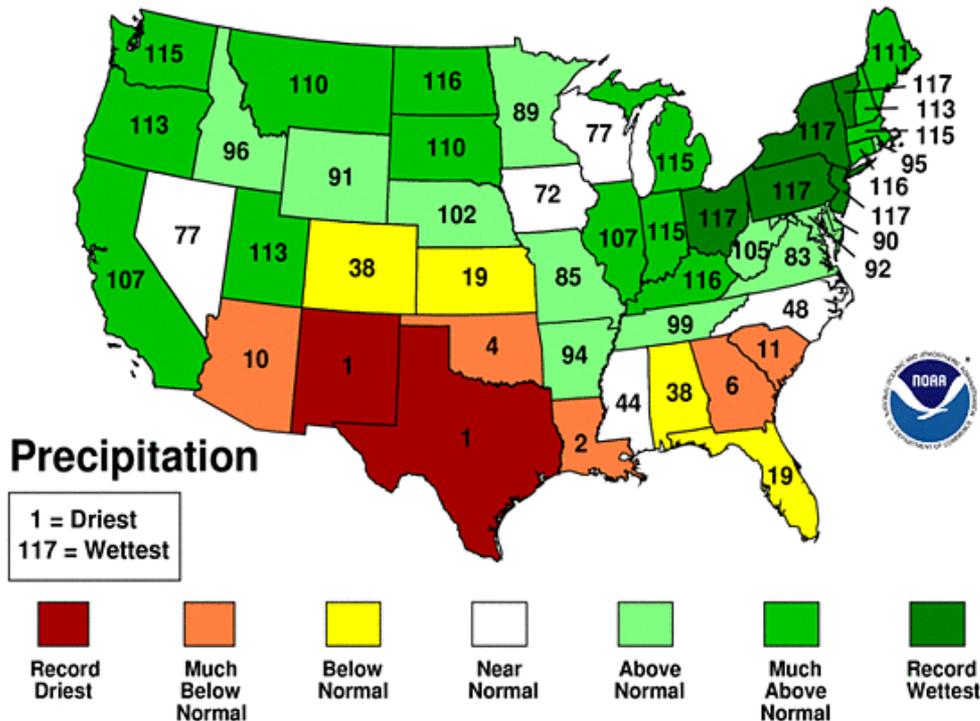
- **Spring flood:** heavy rain and warm weather, melting large snowpack from 2010-11 winter
 - 70F (April 11) and 80F(May 27) + heavy rain
 - record April, May rainfall: 3X at BTV
 - Severe floods on Winooski and Adirondack rivers
 - Lake Champlain record flood stage of 103ft
- **Irene flood: tropical storm** moved up east of Green Mountains and Catskills
 - dumped 6-10 ins rain on wet ground
 - Extreme flooding

2011 Floods: VT and NY

- 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
- Pattern nearly stationary

Value of Flood Plains

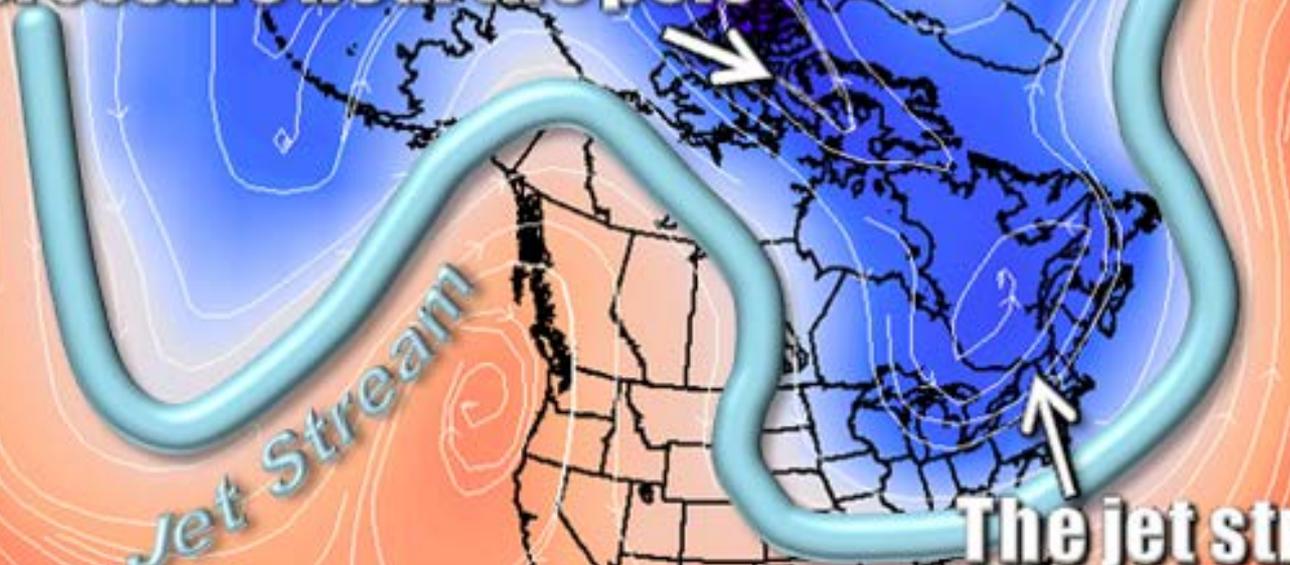


- **Otter Creek after Irene on August 30, 2011**
 - **River rose ten feet on flood plain saved Middlebury**

Irene: Resilience

- 13 towns cut off overnight
- State emergency systems flooded
- FEMA: no road access
- Communities reorganized overnight
- Those with equipment stepped in
 - “Can fix this in 72 hrs”: will need engineer to check bridge (Brandon)
 - “We worked 120hrs last week...” (Wardsboro)
 - Social networks collected supplies; and rescue services across mountains
 - Communication networks critical

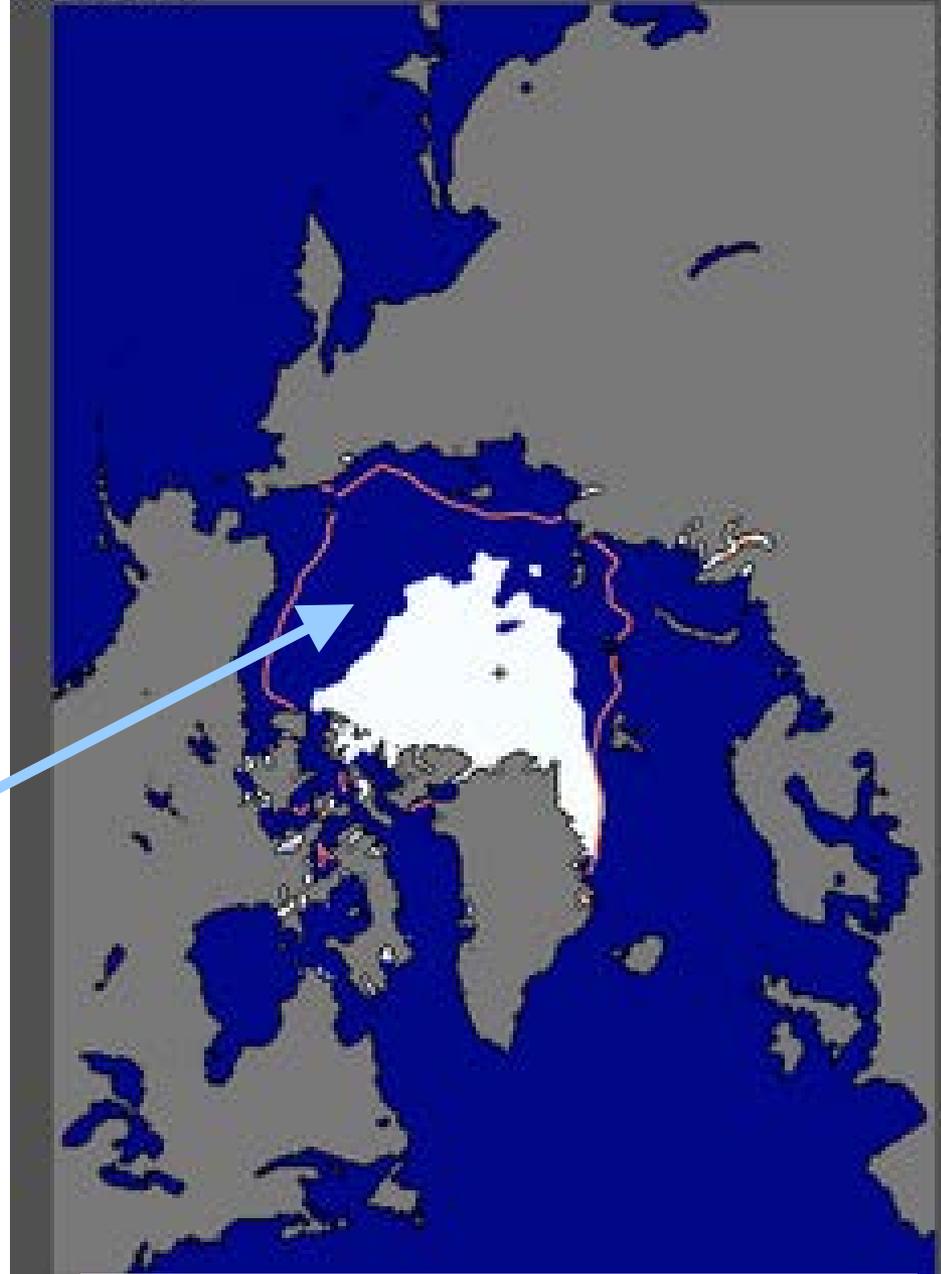
**“Polar Vortex”:
Cold air and low
pressure near the pole**



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

- **Half the Arctic Sea Ice Melted in 2012**
- **Open water in Oct. Nov. gives warmer Fall in Northeast**

- *Positive feedbacks:*
- *Less ice, less reflection of sunlight*
- *More evaporation, larger vapor greenhouse effect*
- *Same feedbacks as in our winters*





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)



March 3, 2017



January 10 and 12, 2018



January 10, 2018

**After cold snowy period
 T_{\min} down to -10 to -20F**



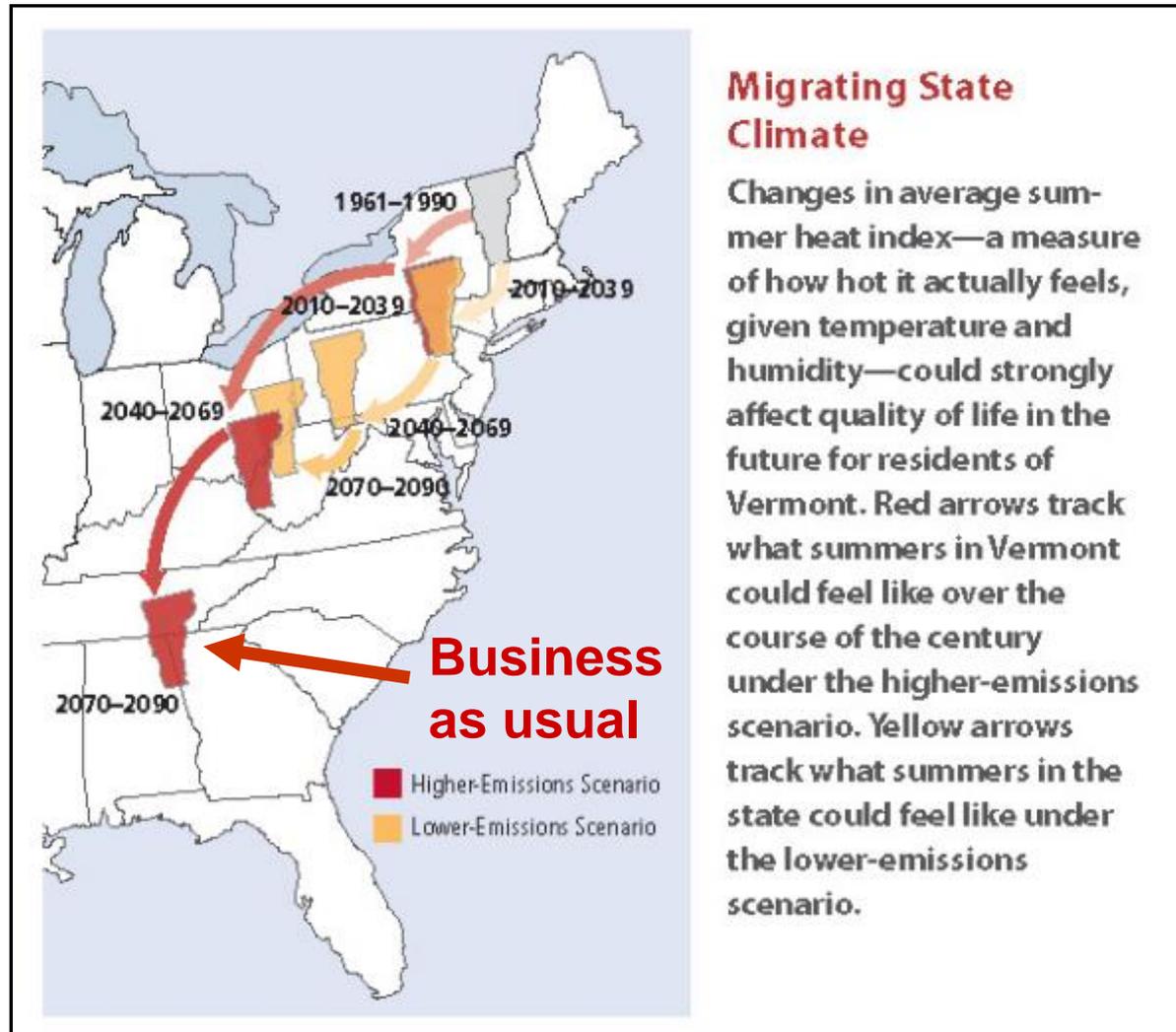
January 12, 2018

After T_{\max} up to 50F

Vermont's Future with High and Low GHG Emissions

What
about VT
forests?

Sub-tropical
drought areas
moving into
southern US



*NECIA,
2007*

3-month mean

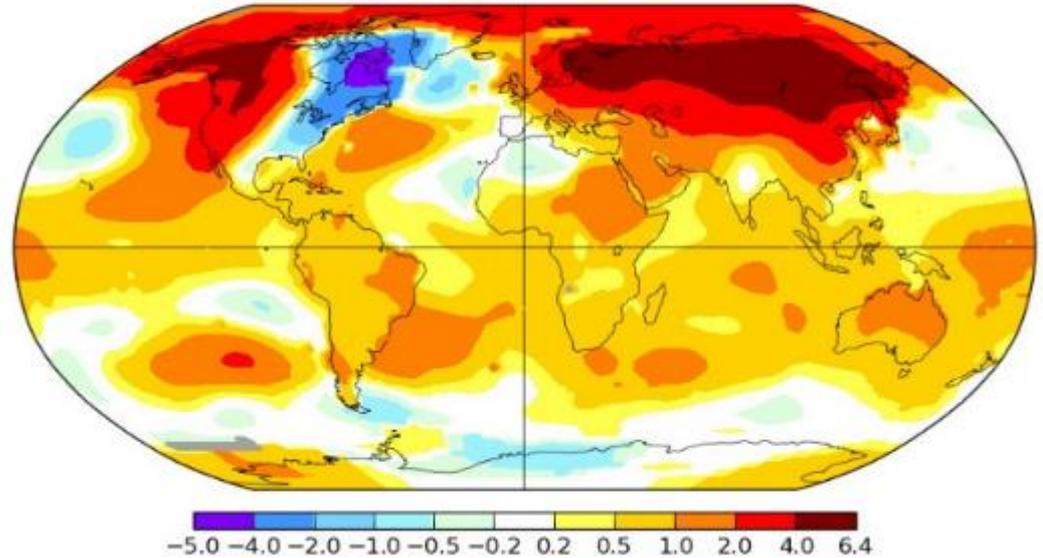
Jan-Feb-Mar 2015

Warm Atlantic, record temp in west; cold NE, strong coastal storms - Boston record snow

Jan-Mar 2015

L-OTI(°C) Anomaly vs 1951-1980

0.86



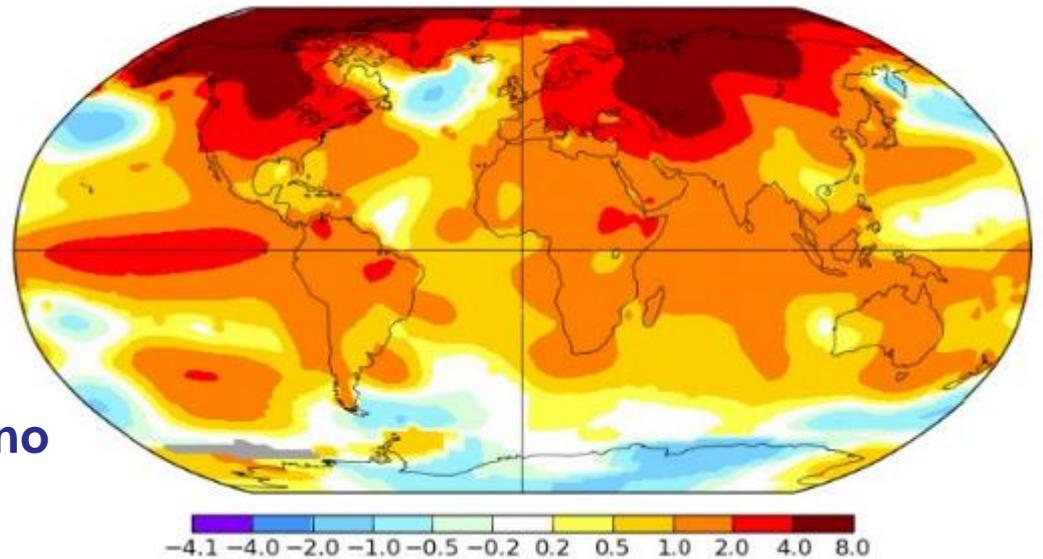
Jan-Feb-Mar 2016

Warm Atlantic, warm NE, little snow, warm Arctic; Pacific El Nino

Jan-Mar 2016

L-OTI(°C) Anomaly vs 1951-1980

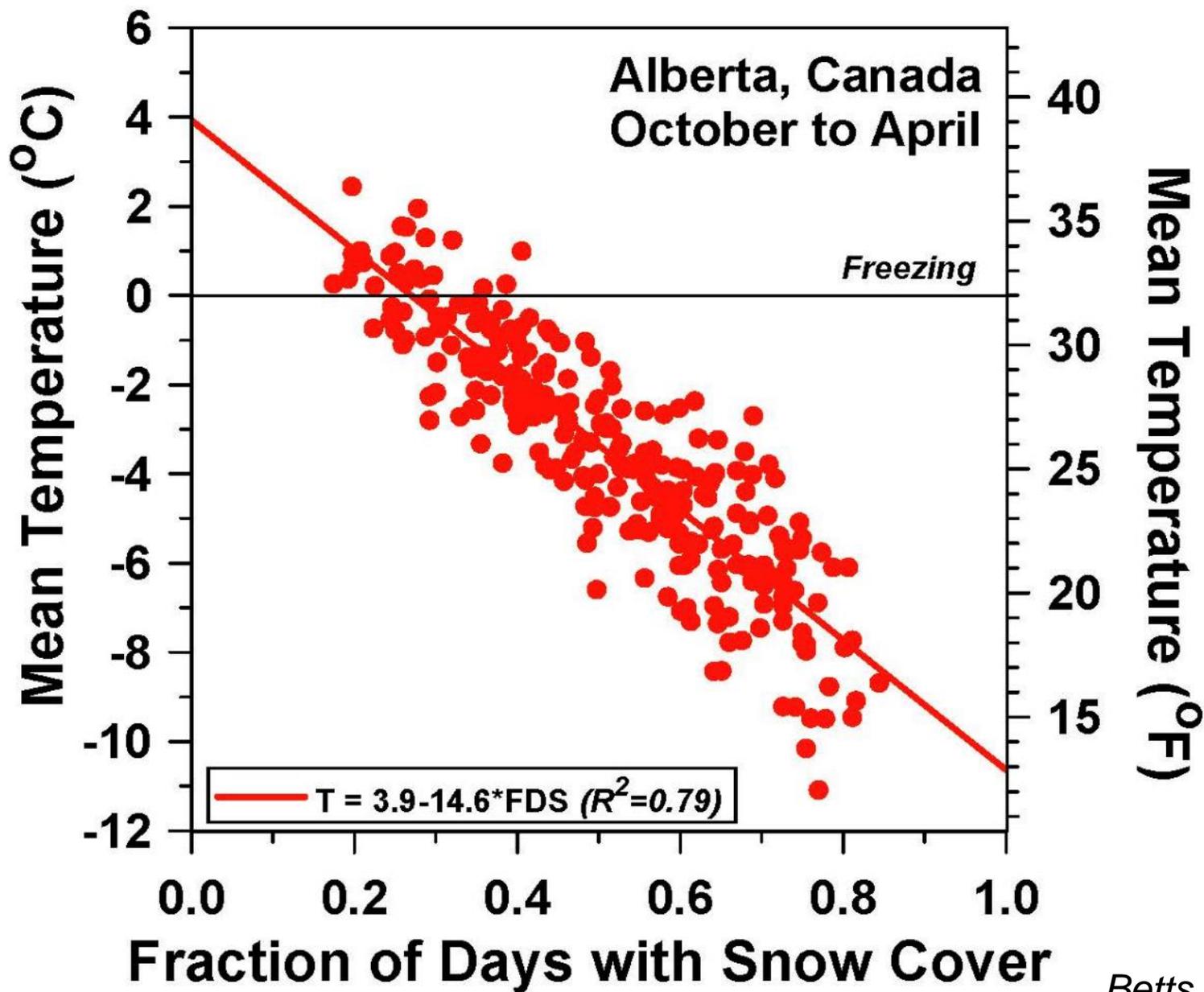
1.24



CA Tornadic Supercell, 2" hail: 24 May 2019



More snow cover - Colder temperatures



Impact of Snow

- **Distinct warm and cold season states**
- **Snow cover is the “climate switch”**

With snow

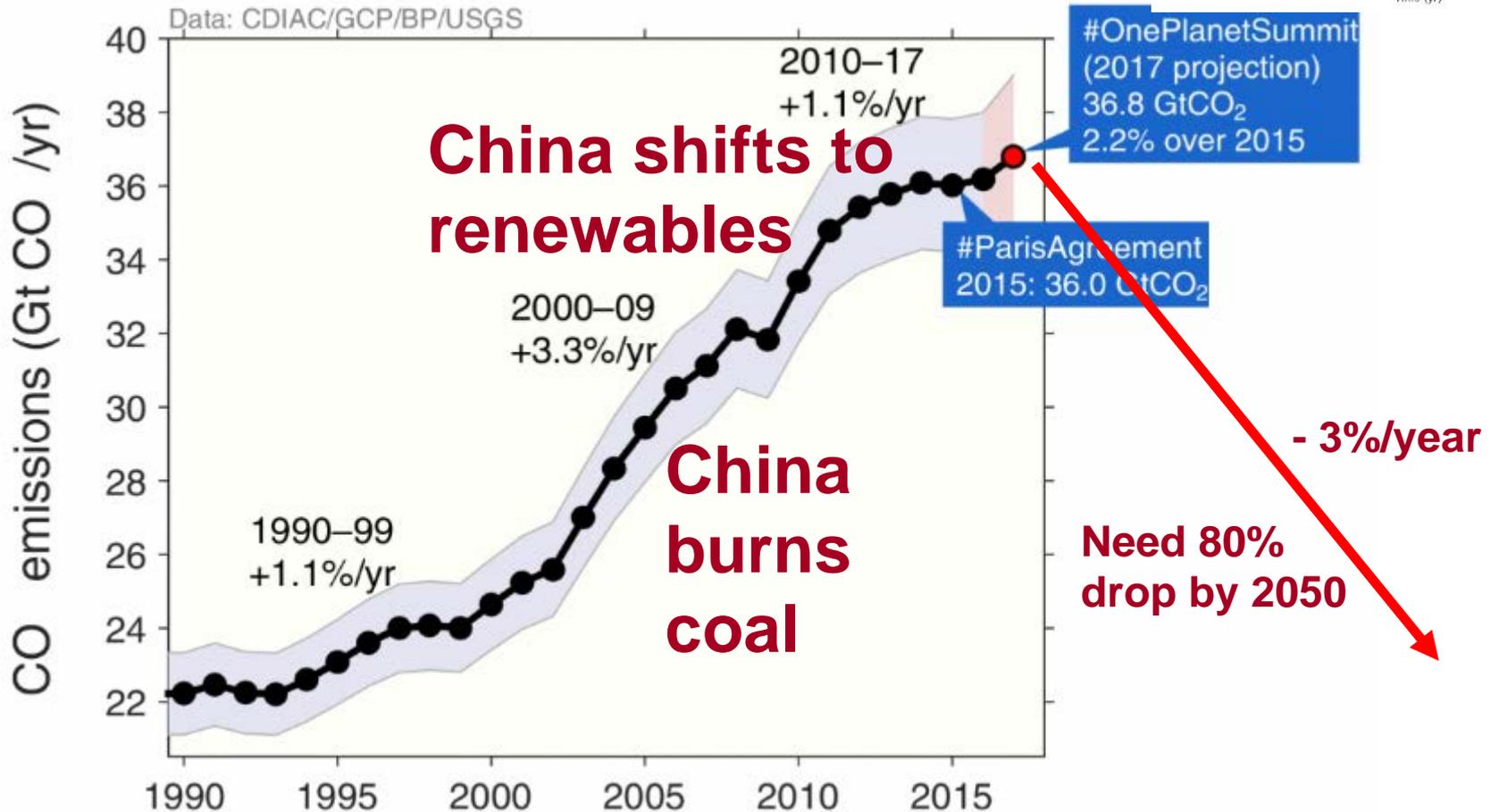
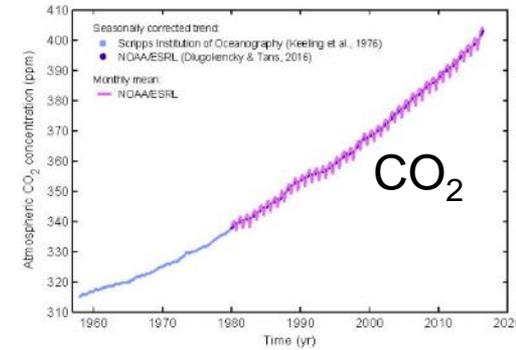
- Prairies: Temperature falls 10°C (18°F)
 - snow reflects 70%
- Vermont: Temperature falls 6°C (10°F)
 - snow reflects 35% (because more forest)

Promised to Stop “Dangerous Climate Change”?

- signed by 197 countries (UNFCCC 1992)

- **Can we? Quickly stabilize atmospheric CO₂**
- **This means an 80% drop in CO₂ emissions!**
- **This is possible but very difficult**
 - **Fossil fuels have driven our industrial growth and population growth for 200 years**
 - **“Lifestyle” has become dependent on fossil fuels**
 - **Powerful vested interests: trillions \$ at stake**

Growth of CO₂ Emissions slowed – now increasing



IPCC Reports Map Disasters Ahead

- **Oct 8, 2018: *Limiting global warming to 1.5°C would require drop of carbon emissions of 45% by 2030***
- **Aug 7, 2019: *Special Report on climate change, desertification, land degradation, sustainable land management, food security***
- **Sep 25, 2019: *Special Report on the Ocean and Cryosphere in changing climate***
- **Nov. 6: *World Scientists' Warning of Climate Emergency: 11250 scientists from 153 countries***
- ***Climate and extinction disasters coming***

Review: Challenges

- **Capitalism based on fossil fuel & exploiting planet is incompatible with a stable climate**
 - Trillions at stake; enough to bribe politicians & people
 - A trillion in mitigation saves \$50 trillion this century
 - Yet resistance to escalating carbon tax
 - Suppression of climate change science
- **Long-term costs now off-scale (\$100's trillions)**
 - No budget to pay them
 - Insufficient funds to rebuild from weather disasters
 - Massive ecosystem losses threaten life on Earth
- ***Global Rebellion has started***

Greta Thunberg (born Jan 2, 2003)



Swedish parliament last year

Crossing Atlantic in August



September 20-27, 2019

- 7.6 million, 185 countries: School strikes demanding climate action



Extinction Rebellion

- Destruction of Earth now a Civil Rights issue
 - Can only be checked by civil disobedience
 - To defend the rights of our children
 - To defend the rights of the Earth
- Shut down London 4/15 to 4/17 till UK and Scottish governments declared “Climate Emergency”
- October 7-14: in 60 cities around the world
 - *Motto: Compassion; awareness; courage*
 - *Visionary and creative* <https://rebellion.earth>
 - Force large reductions in C-emissions this decade

Discussion

**Talk available at
<http://alanbetts.com>**

Efficient transport

- Gasoline to hybrid: 50% gain to 50mpg
- Hybrid to plug-in hybrid: now 135mpg
- Electricity from community solar array



>3000lbs and 135 mpg
Payload: 750 lbs at 60 mph



180lbs: solar panel on roof
Payload: 350lbs at 20 mph

73lb Cargo bike;
300 lbs at 20 mph



Historic Floods on the Otter Creek



W. Creek Rd

***Flood height relative to Irene (2011) on rock;
Estimate flood plain depth in Pittsford***

Year	Height relative to Irene	Flood plain depth
1811	+0'1"	10'1" ± 6"
1913	-3'1"	6'11" ± 6"
1927	+2'4"	12'4" ± 6"
1938	-1'4"	8'8" ± 6"
2011 (Irene)	0	10'0" ± 6"

Recommend we collect height of other floods around VT