Climate Change and Vermont

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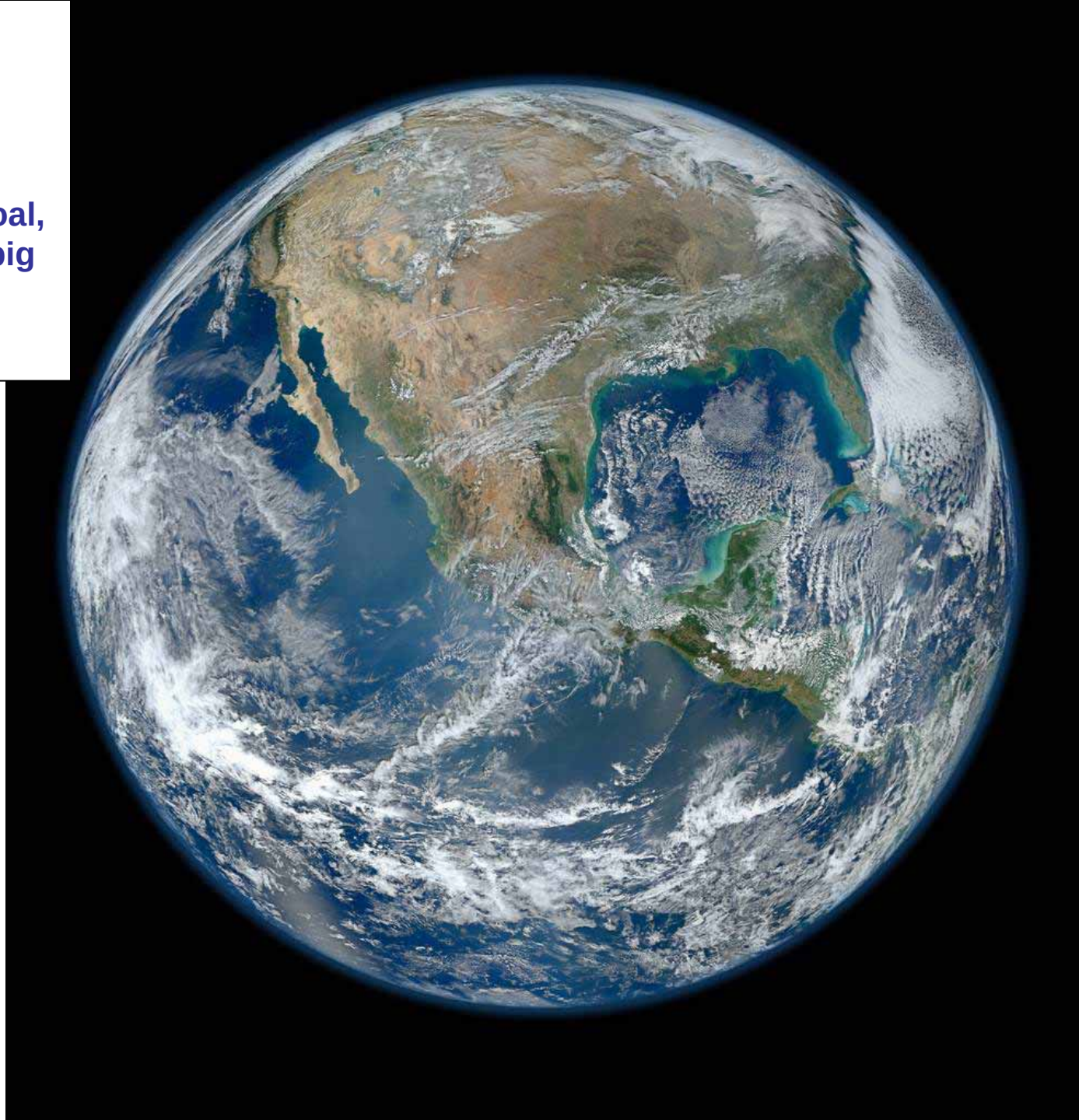
Friday, September 13, 2013

RACC
Research on Adaptation to Climate Change

- **Earth is beautiful**
- **Weather changes fast**
- **Climate changes slowly**
- **Burning fossil fuels – coal, oil and gas - is having a big effect on climate**



January 2, 2012: NASA

Our Changing Climate

- **Big challenge for our lifetime**
- **Climate is being affected by global energy use**

- **What is happening to Vermont as climate changes?**
- **What is happening to the Earth?**

- **What can we do about it?**

In England, I went to Nottingham High School

- **Founded 1513**
- **1550:**

Heading into “Little Ice Age”

- **1620:**

Pilgrim fathers face bitter winters

Then I went to a college called Peterhouse, Cambridge

- **Founded 1284**
- **Medieval warm period; Vinland colony flourishes on Greenland**
- **Ships crossed Atlantic to America**

What Is Happening to Vermont?

- Climate of Vermont is changing
- Warming in winter twice as fast as in summer
- Lakes frozen less by 7 days each decade
- Spring coming earlier by 3 days each decade

Gardening in Pittsford, Vermont in January

January 7, 2007

December 2006:

- **Warmest on record**

January 10, 2008

Warm Fall:

- **Record Arctic sea-ice melt**
- **Snow cover in December, ground unfrozen**

January 2, 2012

Freeze-up was January 3

March 11, 2012

Unfrozen by March 10

Short Winter 2011-12

(Ground frozen for 67 days - used to be 130-150 days)

- **Oct - Mar warmest on record**
- **No permanent snow cover west of Green Mountains**

December 21, 2012

January 15, 2013

Past Winter

Dec 27-28: Foot of snow

- Air temperatures plunged but ground thawed under snow

- **Jan 12-14: 45-50F: Snow melted**
- **Jan 15: Time to dig again..**
- **Followed by freeze-up.. Melt**
- **Final Melt - March 11**
- **Very wet: mid-May to mid-July**

Why is it warm when there is no snow?

- When snow falls, it reflects sunlight, so it doesn’t get warm in the daytime and the temperature still drops at night

- When there is no snow, sunlight heats the ground and it doesn’t get so cold

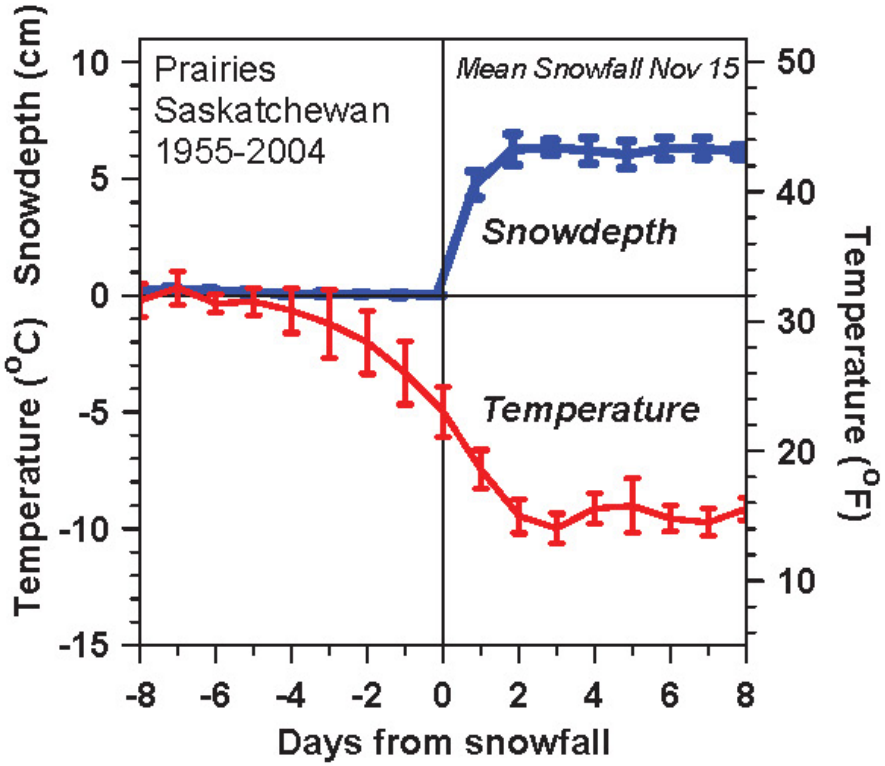
Vermont Winter 2006

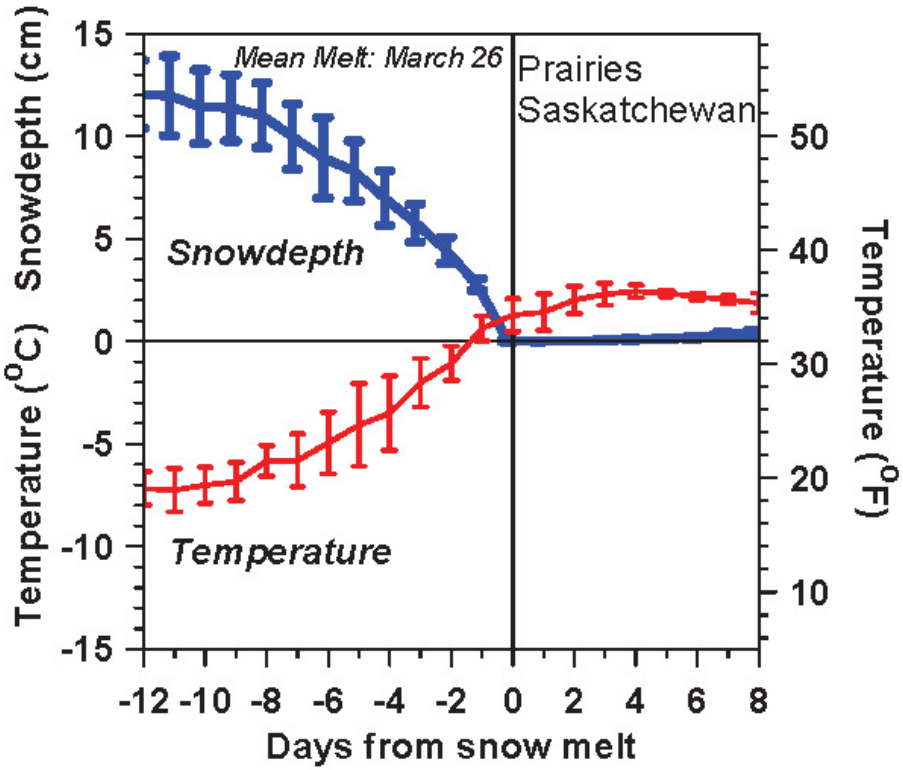
- Snow reflects sunlight, so it stays cold
- No snow – usually warmer

January 7, 2007

- Grass still green, and no snow
- Sunlight heats ground and it stays warmer

Snowfall and Snowmelt





- **Temperature falls 16F (9C) with first snowfall**
- **Same rise with snowmelt**
- ***Snow reflects sunlight; reduces evaporation and water vapor greenhouse – changes 'local climate'***

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Mild winter: crops survive

Pittsford: March 22, 2012

- **Kale survived, covered with glass in January and February – tasted good!**

This Year Kale Wintered over and Grew 5 ft tall!

Minimum temperatures in winter increasing 3ºF per decade

- **VT in past *-25ºF, now -15ºF***
- **Hardy peaches can grow**
- **More pests survive winter**

- **What is this?**
  - **Oct 1, 2012**

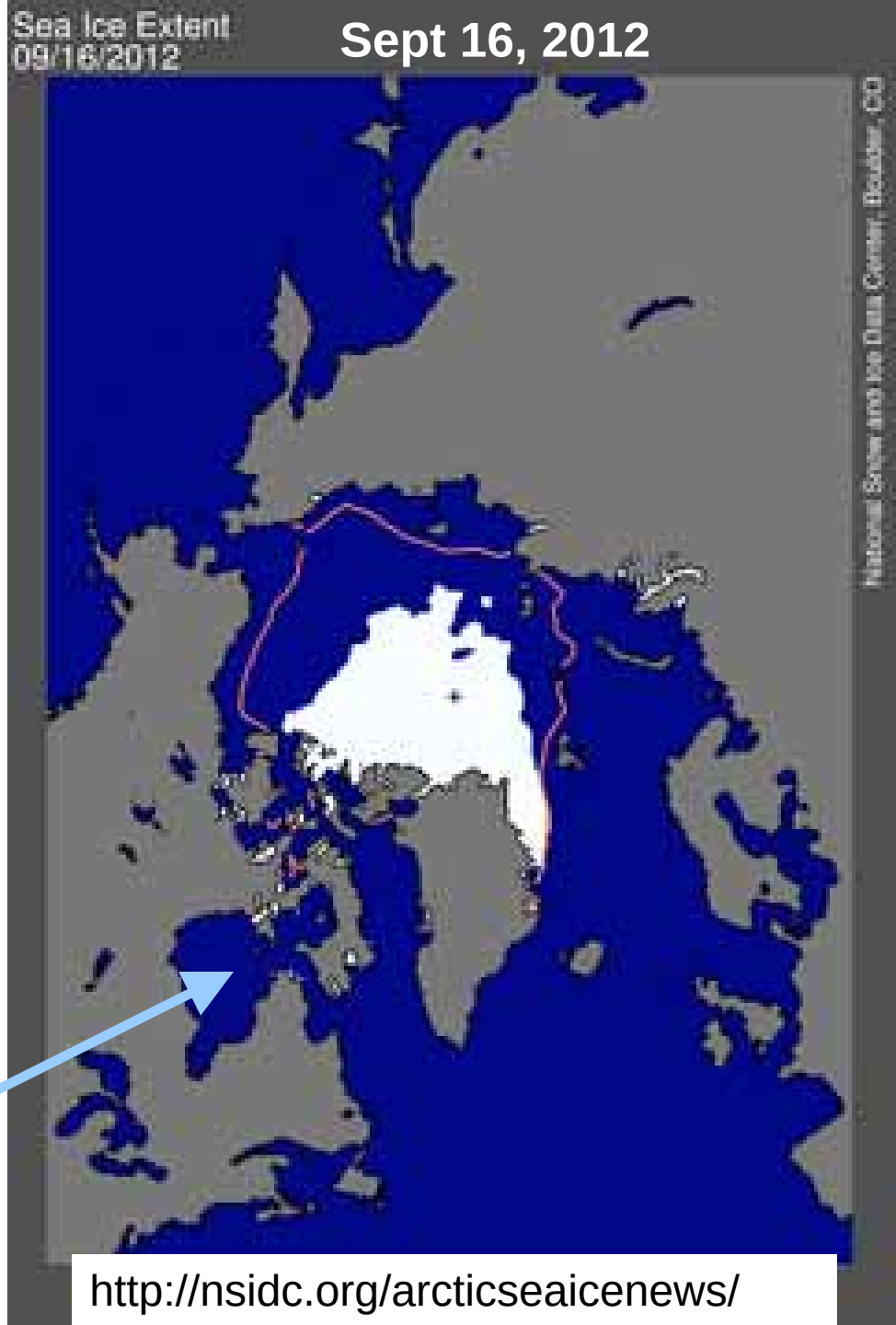
Minimum temperatures in winter increasing fast

- **What is this?**
  - **Oct 1 2012**
- **Avocado**
  - **Didn't survive frost**
  - **2100 survive in CT**
  - **Our forests?**

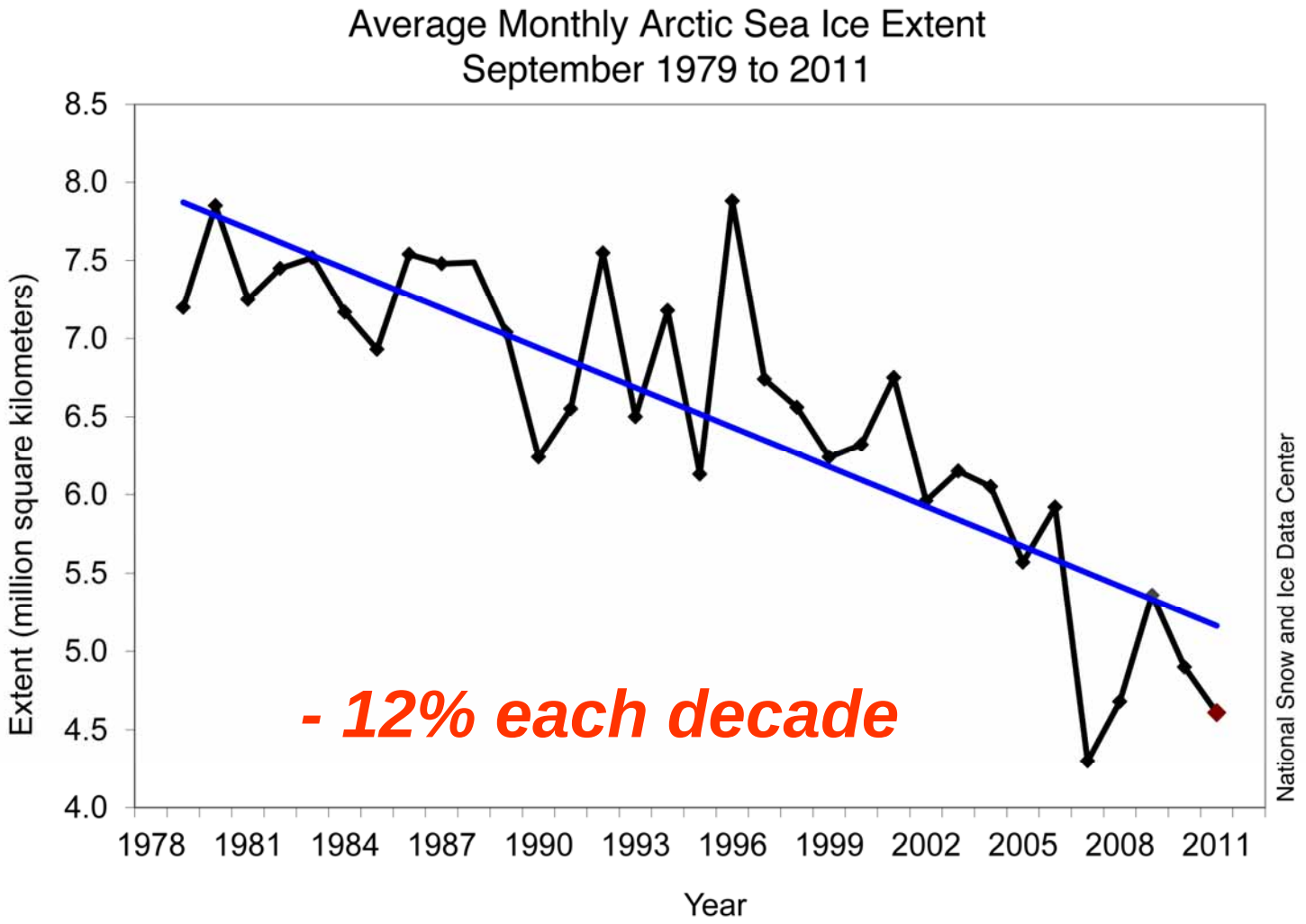
- **Half the Arctic Sea Ice Melted in 2012**
- **Open water in Oct. Nov. gives warmer Fall in Northeast**

- ***Positive feedbacks:***
- ***Less ice, less reflection of sunlight***
- ***More evaporation, larger vapor greenhouse effect***
- ***Ice thin: most 1-yr-old***

End of Nov. 2011 Hudson Bay was still nearly ice-free

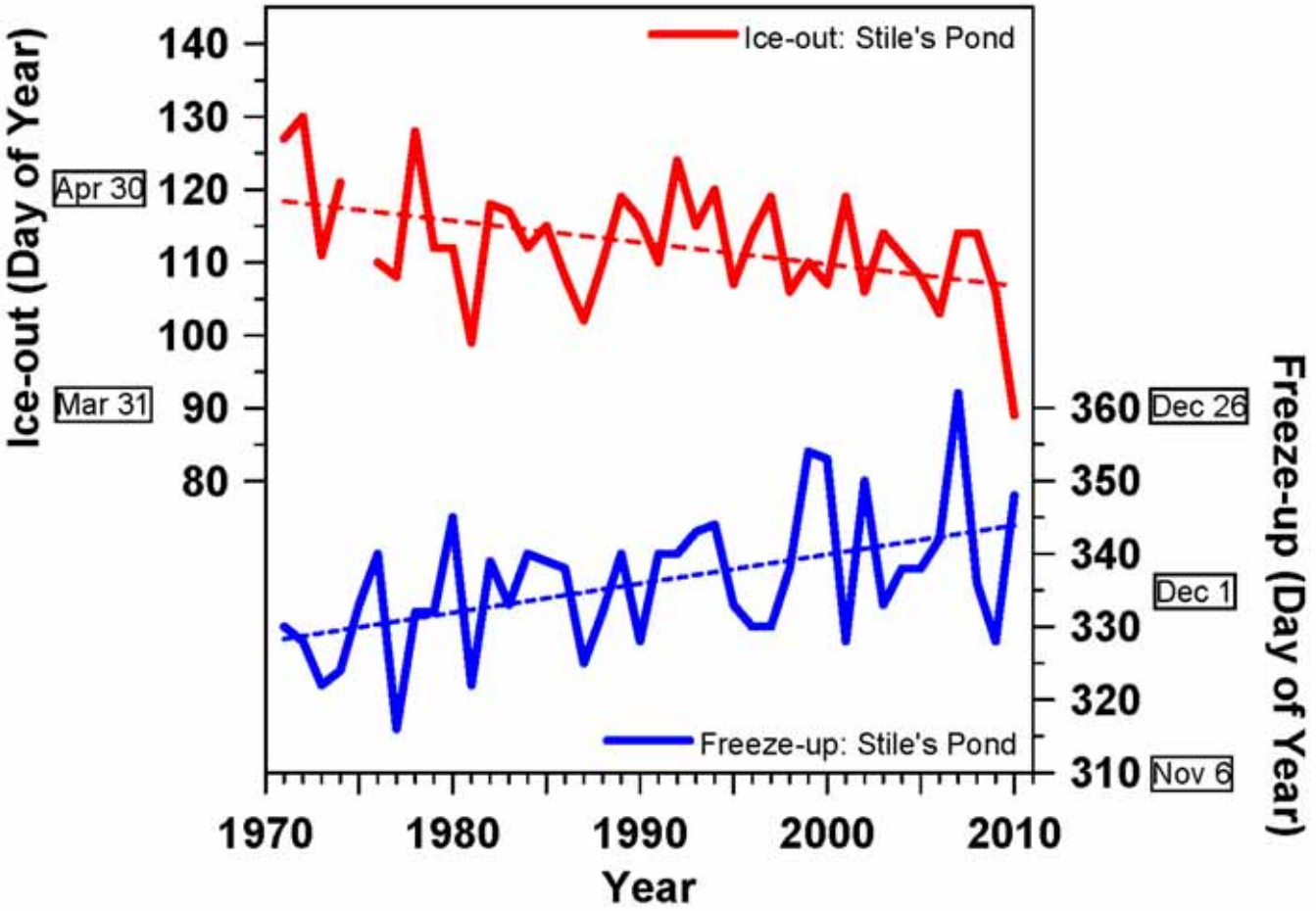


Sea Ice Trend in September



- **Sea ice is shrinking and thinning rapidly**

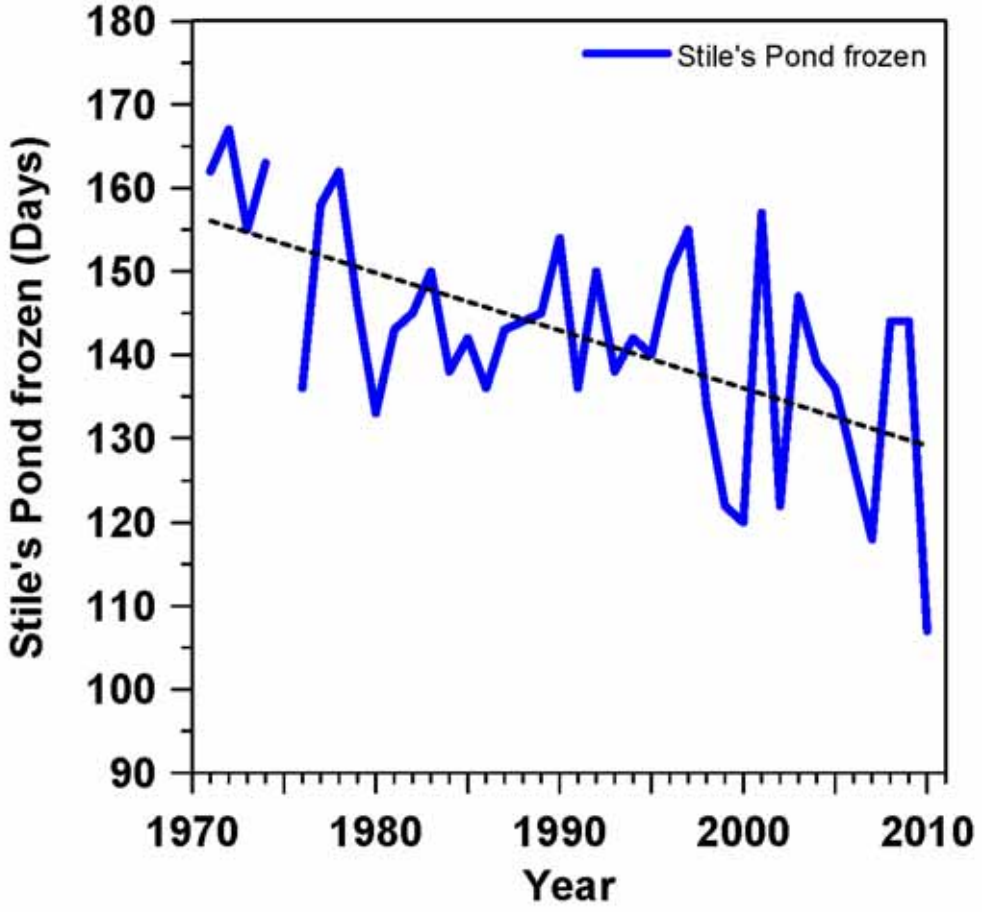
Stiles Pond: near St. Johnsbury: 1970-2010



- **Ice-out earlier by 3 days each decade**
- **Freeze-up later by 4 days each decade**

Lake Frozen Period Shrinking

Stiles Pond: east of St. Johnsbury: 1970-2010



- ***Frozen period is decreasing by 7 days each decade***

Spring Climate Transitions

- **After snow and ground melt**
- **Before forest leaf-out**

Little evaporation → Dry atmosphere, clear sky
→ Warm days, cool nights and frost

- **After forest leaf-out**

Large evaporation → Wet atmosphere, low cloudbase
→ Cooler days for a while
→ But warmer nights and no frost

- ***Spring is coming earlier***
- ***Last spring frost coming earlier***

Daffodils in Bloom
March 22, 2012 (79ºF)

Pittsford

Vermont

3/22/12

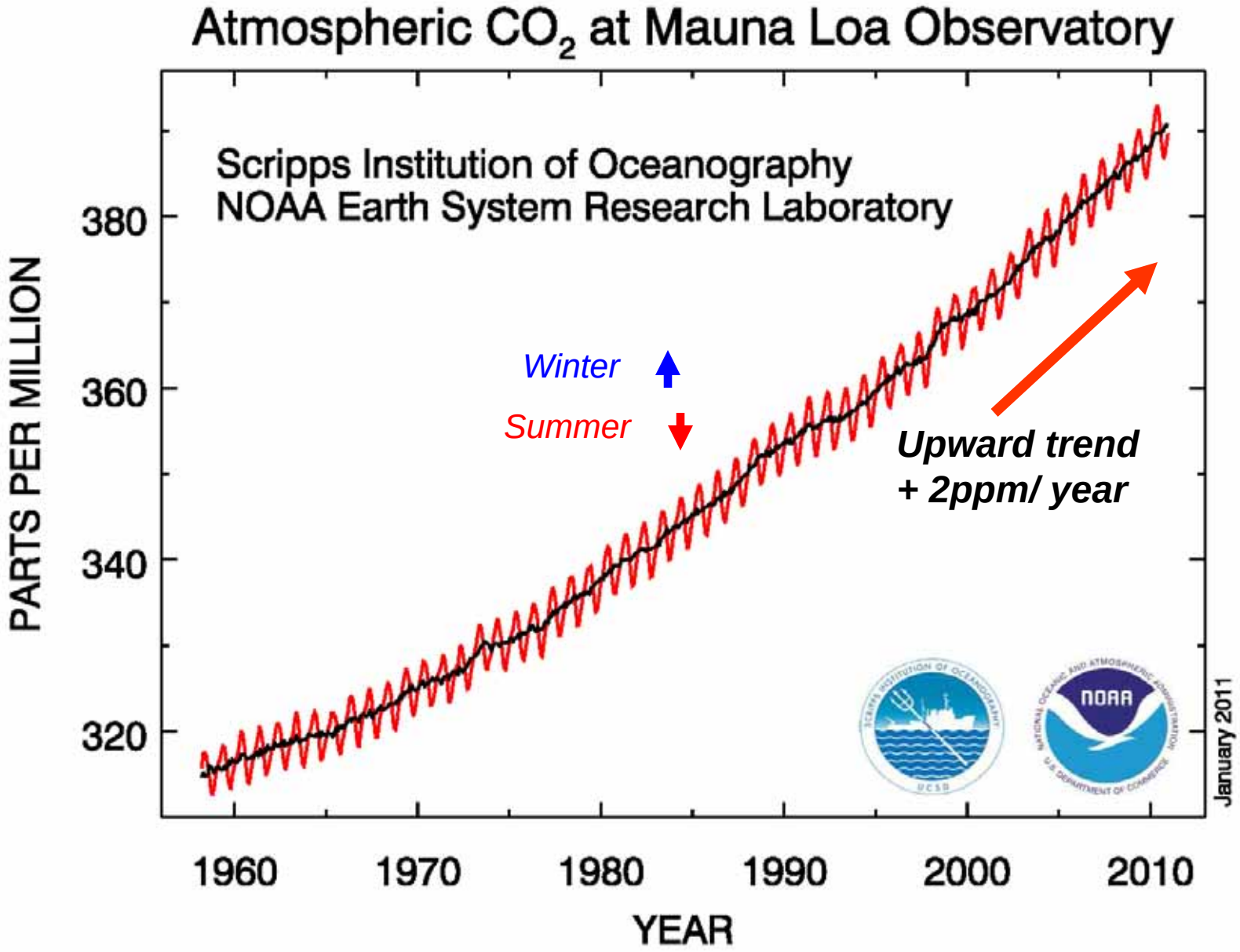
- **Spring is coming earlier by 3 days each decade**

Why is the climate getting warmer and ice melting?

Why is the climate getting warmer and ice melting?

- **We are burning so much fossil fuel for our energy**
- **Fossil fuel contains carbon from ancient shrubs and trees**
- **Burning coal, oil and gas converts this “fossil” carbon to carbon dioxide in the air**

Carbon Dioxide Is Increasing



Why Is More Carbon Dioxide in the Air a Problem?

- **The air is transparent to sunlight, which warms the Earth**
- **But some gases in the air trap the Earth's heat and keep the Earth warm**
- **These are "Greenhouse gases"- water vapor, carbon dioxide, ozone, methane**

  (symbols are H_2O, CO_2, O_3, CH_4)
- **They are needed to keep the Earth from freezing**
- **CO_2 is rising fast: by itself only a small effect**

But as CO_2 increases…

- **Earth warms, and evaporation and water vapor in the air increases and this triples the warming**
- **As Earth warms, snow and ice decrease, so less sunlight is reflected, so winters and the Arctic are warming faster**
- **Doubling CO_2 will warm Earth about 5°F**
  - **And much more in the North and over land**
  - **So the climate change we are seeing in Vermont will continue**

So what can we do?

- **Understand what is happening to climate where you live, so you can be prepared for changes to come**

- **Study how we use energy and how changes can reduce climate change in the future**

Understand what is happening to climate where you live

- How is the climate different today than 10, 20, 30 years ago? Find out by talking to local farmers, your parents and grand-parents, others who have lived here for a long time
- Ask farmers about the seasons. Have they changed? When did they plant and harvest and what crops did they grow?
- When did lakes, rivers and the ground freeze – 30 years ago and in recent winters?
- How often could you skate on the ponds and rivers? And snowmobile through the woods. How long could you ice-fish in winter, and how thick was the ice?
- When were the last frosts in spring and the first frost in the Fall?
- When did maple sap flow? When did trees and shrubs leaf out in spring? When did the leaves turn in Fall?
- What were the summers like? Were they wet or dry?
- Try to find out how the climate has changed!

What do we use energy for? Where does energy come from?

- We use energy for electricity, heating and transport
- Where does it come from?

- How much does your school use?
- How much do you use at home?
- How much does it cost?
- Can we reduce energy use by making things more efficient?

This is why we are seeing

- **Houses, basements and attics, are being insulated more with better windows**
- **Solar panels that generate electricity from sunlight**
- **Wind farms that make electricity from the wind**
- **More wood being burnt in homes, schools and power plants, because trees grow back and take CO_2 from the air**

This is why

- **We need more efficient cars that burn less gasoline**
- **Like hybrid cars that have gas and electric motors - and batteries that store energy when the car slows down**

55 miles per gallon at 50 mph
45 miles per gallon at 70 mph

What Will This Mean For You?

- **Our fossil fuel energy use is changing the climate of the Earth and Vermont – we need to slow down the changes**
- **This is a challenge for society, because we have used fossil fuel for the past 100-200 years**
- **So there is a lot to explore about what is happening and what we can do about it!**

Discussion

- **http://alanbetts.com**

  - this talk http://alanbetts.com/talks

  - newspaper articles at http://alanbetts.com/writings

- ***Seasonal Climate Transitions in New England***

When Will We Get First Frost?

- **Usually by end of Sept (getting later)**
- **What kind of night?**

When Will We Get First Frost?

- **Usually by end of Sept: getting later**
- **What kind of night?**

- **When the sky is clear and Earth can cool quickly to space at night**

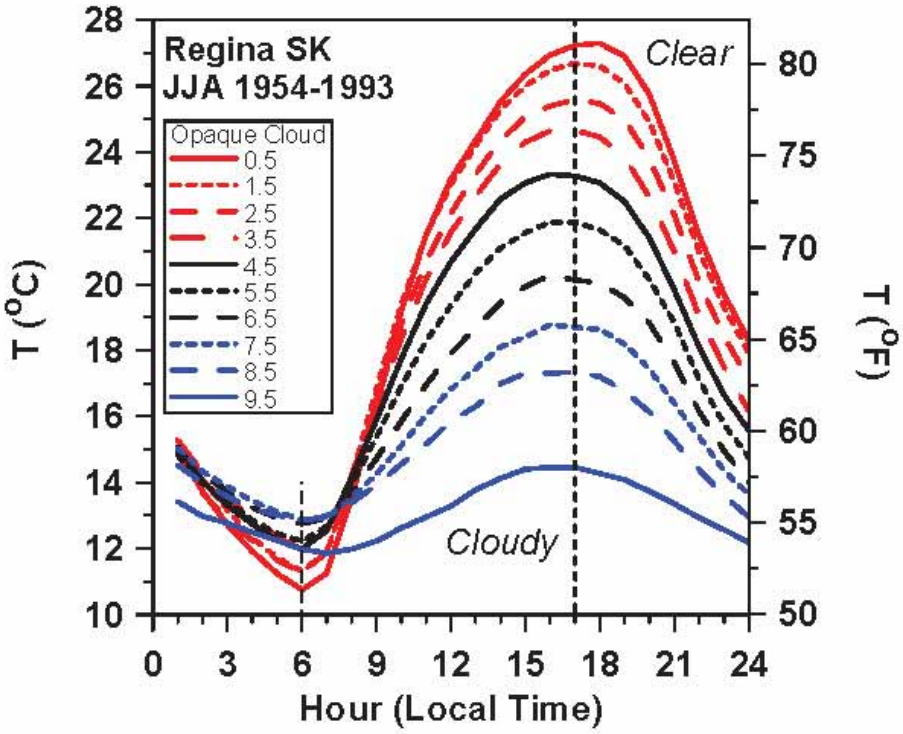
- **The sky is “cold”**

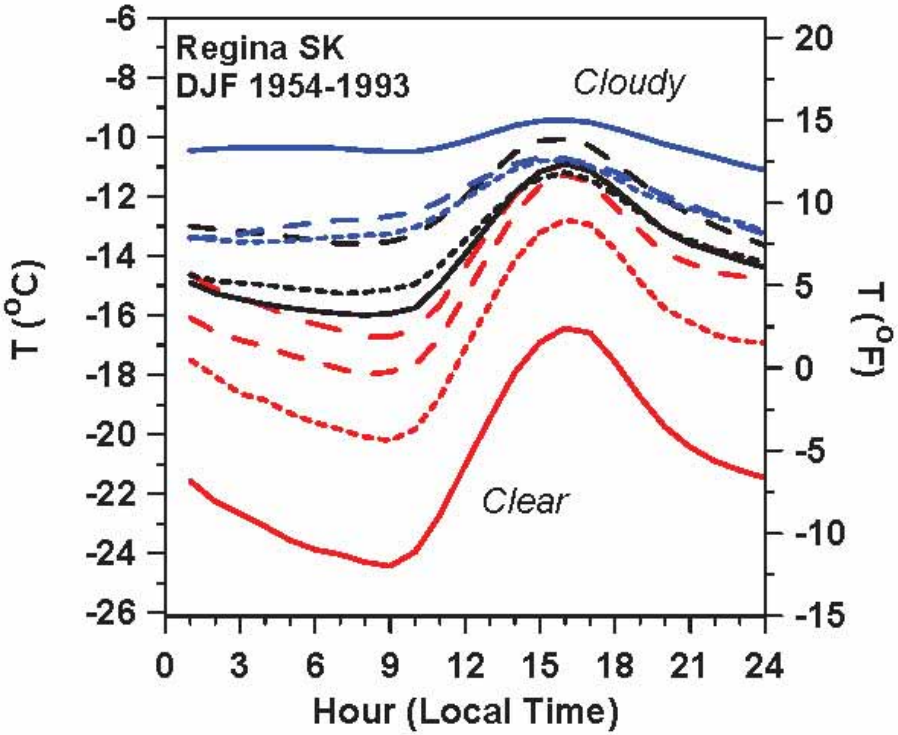
What is the temperature of the sky?

- **Earth is heated by the sun and cools to space through the atmosphere**
- **The temperature of the sky depends on the greenhouse gases: mostly water vapor and CO_2; and clouds.**
- ***Water vapor and clouds vary a lot – we can measure them with an infrared thermometer***

- ***Estimate temperatures first…. Ground, grass, walls, pavement… SKY…***

Clouds: Summer & Winter Climate





- **Summer:** **Clouds reflect sunlight (soil absorbs sun)**
  - **no cloud, hot days; only slightly cooler at night**
- **Winter:** **Clouds are greenhouse (snow reflects sun)**
  - **clear & dry sky, cold days and very cold nights**

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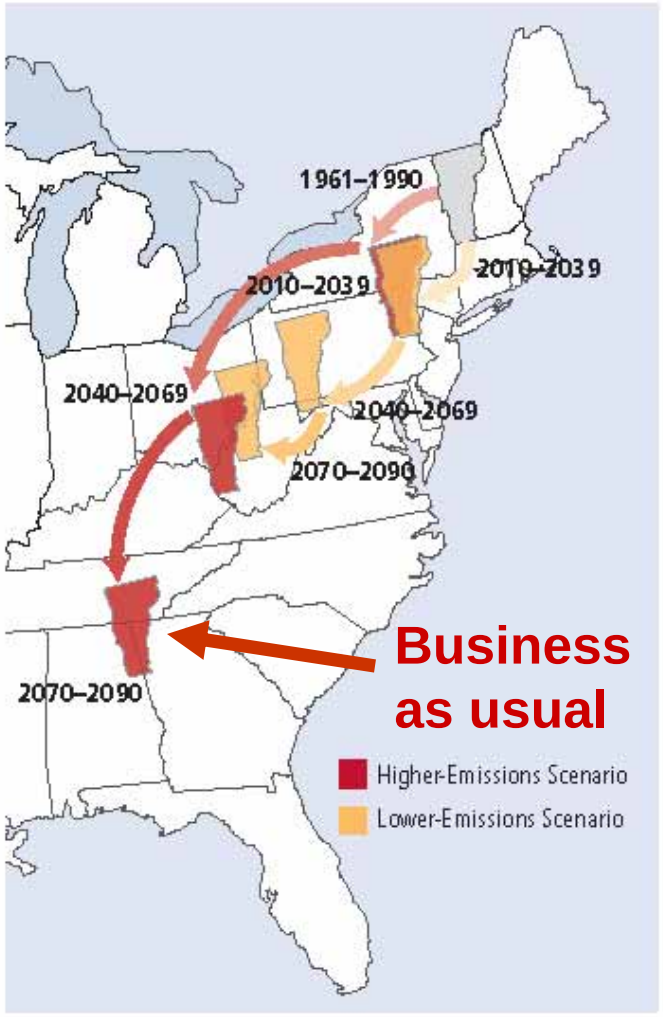
Additional Slides

Vermont's Future with High and Low GHG Emissions

What about skiing?

What about tropics?



Migrating State Climate

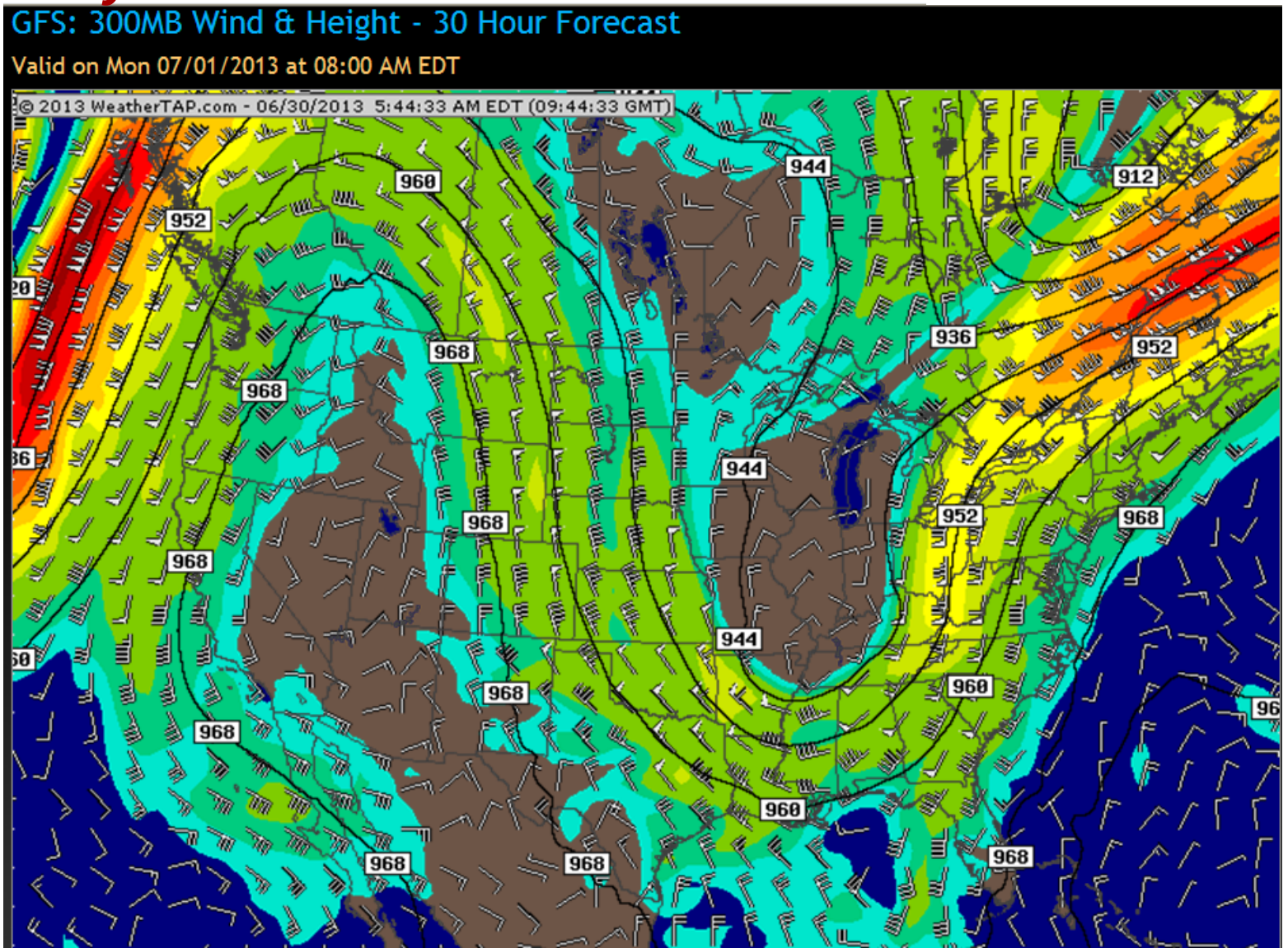
Changes in average summer heat index—a measure of how hot it actually feels, given temperature and humidity—could strongly affect quality of life in the future for residents of Vermont. Red arrows track what summers in Vermont could feel like over the course of the century under the higher-emissions scenario. Yellow arrows track what summers in the state could feel like under the lower-emissions scenario.

NECIA, 2007

Jet Stream Patterns Slowing Down and Amplifying, Giving More Extreme Weather

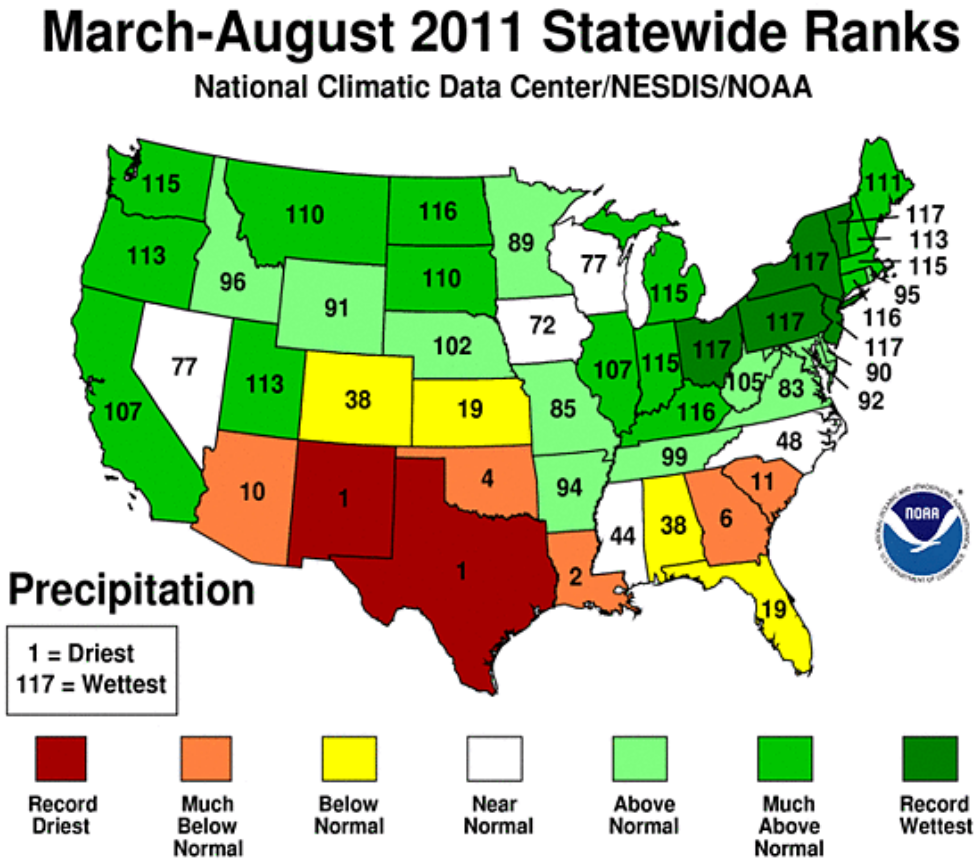
Very wet June in VT

(Francis and Vavrus, 2012)



2011 Floods: VT and NY

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



March-August, 2011

- **Record wet : OH to VT**
- **Record drought: TX & NM**
- **'Quasi-stationary' pattern**