How can we explain Climate Change?

- *what are scientists' responsibilities?*

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August 4 & 5, 2010


NASA/JPL

Climate Change

- **One of several challenges this century**
- **Dec 7-18, 2009: COP-15, Copenhagen**
  - UN Framework Convention on Climate Change, 1992
- **Action was postponed: "Agreed they needed to act, and that what they could agree on now was not nearly enough"**
- **US can't agree to anything till Congress does - and Congress did nothing this year**
- **We are already decades late in taking action**
  - Sawyer, Nature, 1972, Man-made CO_2 and the "greenhouse" effect

- ***Global issue & local issue; societal & personal issue!***

How can we explain it to Public?

Blend big picture issues and local issues

1) Explain concepts pictorially, using seasonal climate

- **What is seasonal climate?**

- *Does a forecaster see the climate or only the synoptic weather? Time-horizon*

- **Seasonal transitions**

- *Spring, Summer, Autumn and Winter*
- *Poorly understood by many – but familiar*

Spring transition

- Warm dry week to ten days in Spring, after snowmelt, past equinox
- Followed by drop of temperature of ≈3C with leaf-out – in a wave up the eastern seaboard
- **Many key climate processes:**

- Seasonal lags-melt of frozen soils
- Vegetation-evaporation coupling
- Latent heat of evaporation reduces surface T
- Evaporation-RH-cloud-WV greenhouse
- RH- LW_{net}-diurnal temperature range-frost

Spring 4/15/2008

- *Weather:*

  Sunny, dry week

- *Climate:*
  After snowmelt before leaf-out
  'warm & dry'
  (little evaporation; RH minimum)

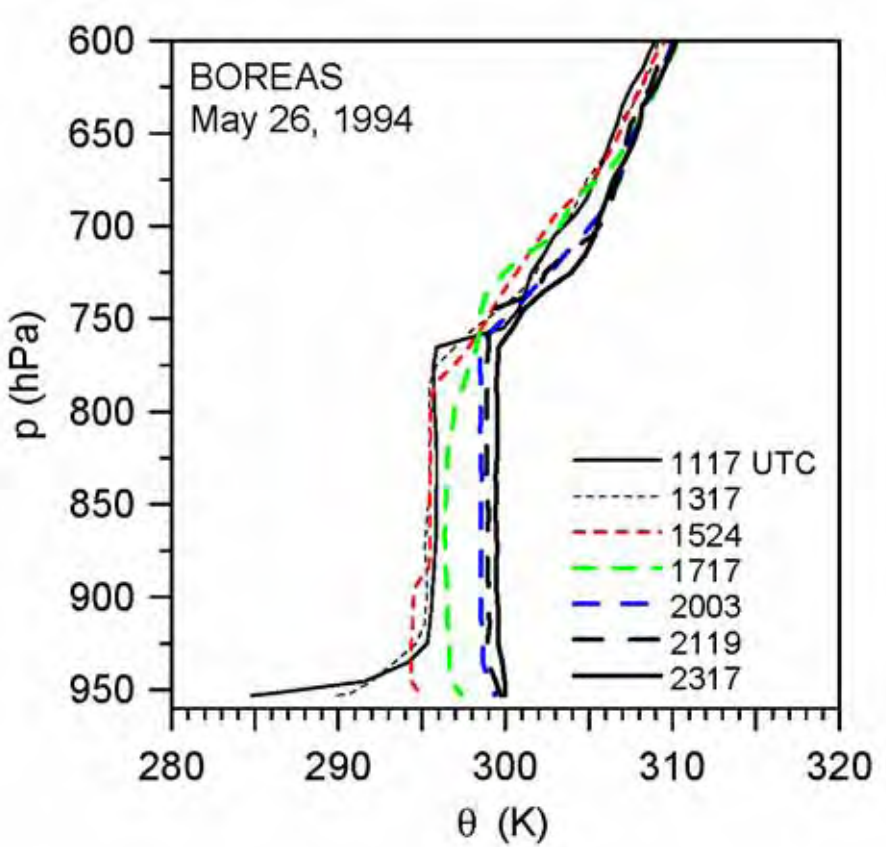
- *Climate change:*
  'Spring' is week earlier than 30 years ago

More extreme at boreal latitudes

- Mid-May frozen roots; conifer canopy at 23ºC
- Surface pools everywhere but no evaporation and afternoon RH = 27%;
- Cloud-base 2000m
- A ‘green desert’

– too cold to evaporate

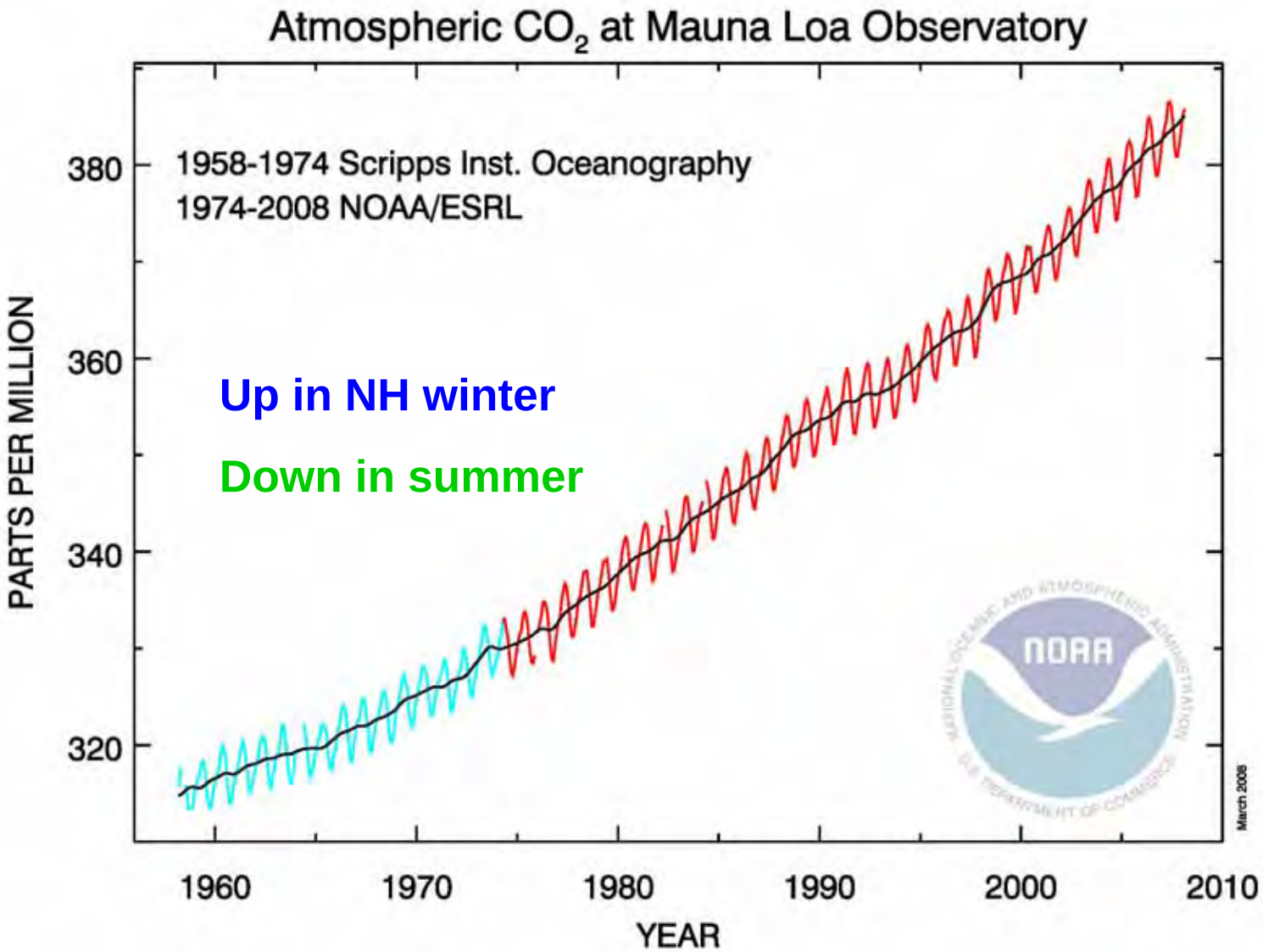
- Longer seasonal lag than NE



Spring green-photosynthesis:

- **Leaves use red light to soak up carbon dioxide and grow. They give off oxygen.**

Carbon dioxide is increasing – fossil fuel imbalance



Summer transition

- Summer dry-down; soil moisture falls, evaporation falls, BL drier, θ_E falls, no precipitation
- May lock into a dry spell, a ‘drought’ till upset by strong weather system
- But it can go either way…
- 2008 and 2009, we had wet VT summers with + evaporation-precipitation feedback

Wet summer – Dry summer

- *feedback can go either way*

- Direct fast evaporation off wet canopies & more rain
- Dry-down of soil and less evaporation & less rain
- **Depends on weather systems**

Fall transition

- ***Mirror of Spring transition***
- **Vegetation tries to postpone first killing frost**
- By October 1, sun is past equinox and sinking
- Deciduous trees still evaporating, BL moist, BL cloud
- WV & cloud greenhouse reduces outgoing LW, reduces drop of T at night and prevents frost
- Till one night, dry air advection from north gives first frost, vegetation shuts down, frosts become frequent
- Dry atmos., large $LW_{net} \rightarrow$ large diurnal cycle
- Warm days and cool nights: 'Indian summer'
- Didn't happen in 2009 – wet soils and rain!

Fall colors

- Fall color after killing frost
- If delayed then less color as leaves die slowly
- Note blue sky – dry atmosphere
- First frost in VT getting later [few days per decade]

Atmosphere is transparent to 'light' but not to 'infrared' radiation

- **The earth cools by emitting infrared or heat radiation, but molecules H_2O, CO_2, CH_4 and O_3 vibrate and absorb it:** 'Greenhouse gases'

- Atmosphere blankets the earth and keeps it about 59^oF warmer - so oceans don't freeze
- Increasing greenhouse gases are warming earth further: $\approx 5^oF$ this century, unless emissions reduced

Winter transition

- First heavy snow brings plunge of Temp. because reflection of sunlight drops net radiation below zero – *[plus reduced water vapor greenhouse]*
- Related to **snow/ice-albedo feedback** in climate system
- Related to accelerated warming & melting in the Arctic
- *Sublimation of snow by residual SW_{net} reduces surface solar heating to zero [& evaporation is reduced]*
- **Coupled to water vapor greenhouse feedback:** *evaporation falls with frozen temperatures & cloud decreases. Clear sky outgoing LW_{net} increases and locks in colder temperatures*

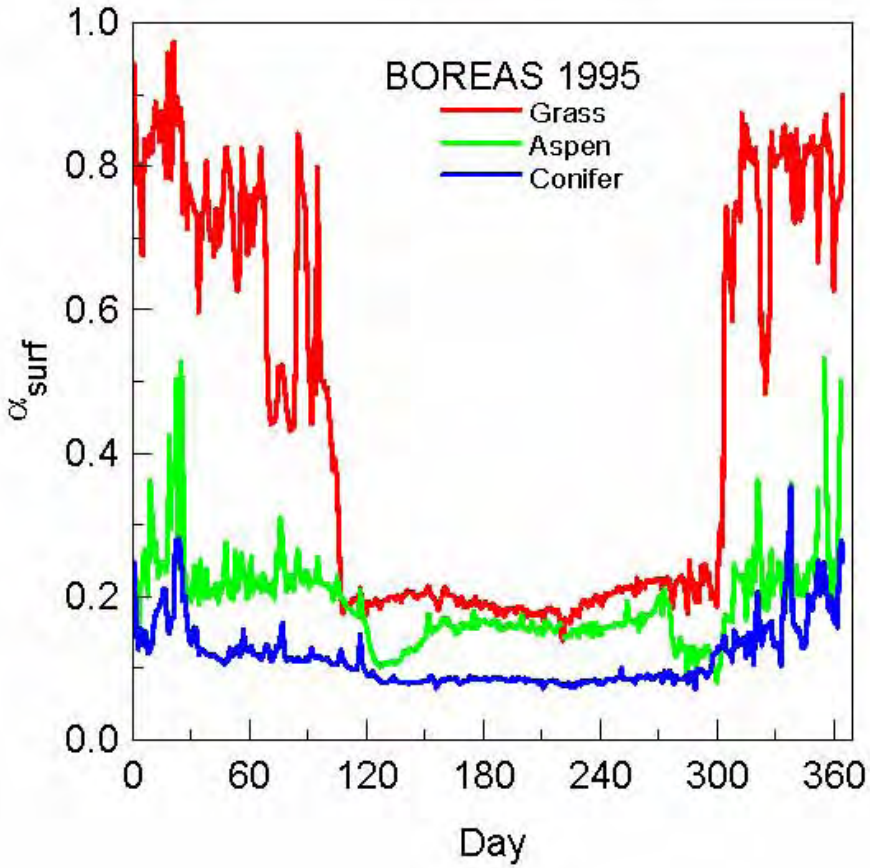
Vermont winter, 2006

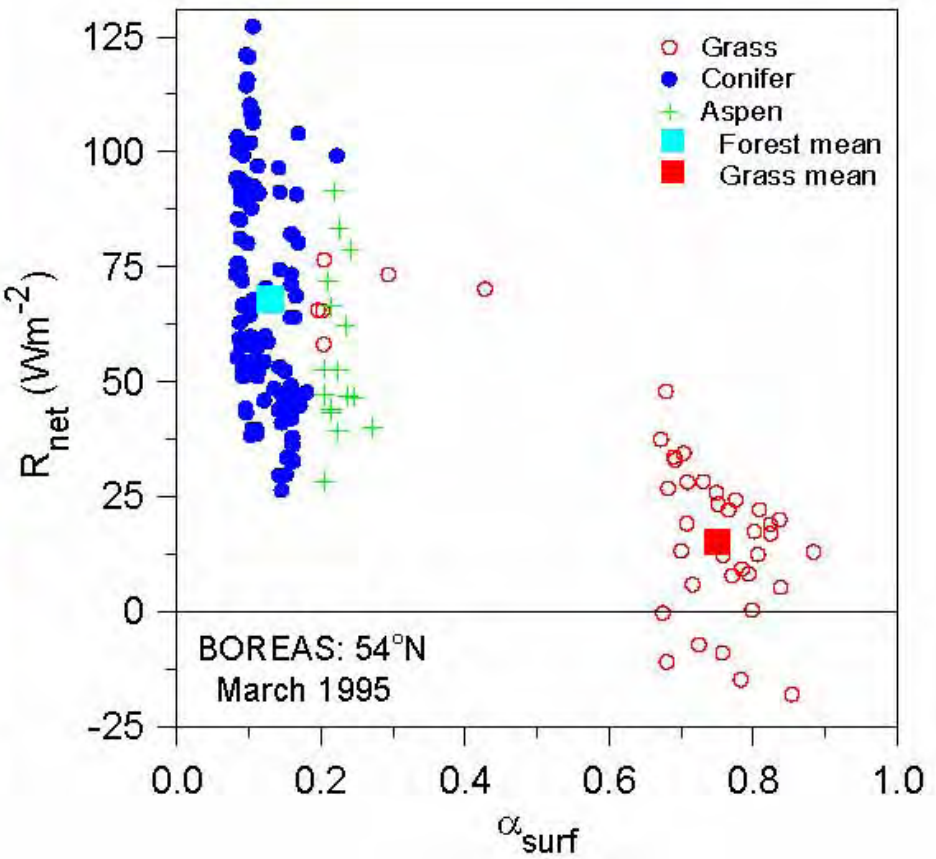
- **Sun is low; and snow reflects sunlight, except where trees!**
- **Sunlight reflected, stays colder; little evaporation, clear sky**

Rough Energetics

- Winter SW_{down}(clear) ≈ 130 Wm^{-2}
- 10cm fresh snow changes albedo from 0.15 to 0.75 & drops SW_{net} from 110 to 30 Wm^{-2}
- Residual 30 Wm^{-2} sublimes 1cm snow/day
- Snow loss increases as snow ages
  - snow lasts ≈ 5 days,
  - reducing solar heating to ≈ zero

Boreal forest example





- High albedo in March: $R_{net} \approx$ zero
- Difference between snow on grass and under trees is huge: snow-albedo feedback gives cold surface temperature

January 7, 2007

- Rain, not snow; grass still green, evaporation continues
- Sunlight absorbed, not reflected; stays warmer, sky cloudy

Warmer winters
Gardening in Vermont in January!

Jan 7, 2007

December, 2006, *warmest on record*

[since 1894]

Jan 10, 2008

Warm Fall, *record Arctic sea-ice melt*

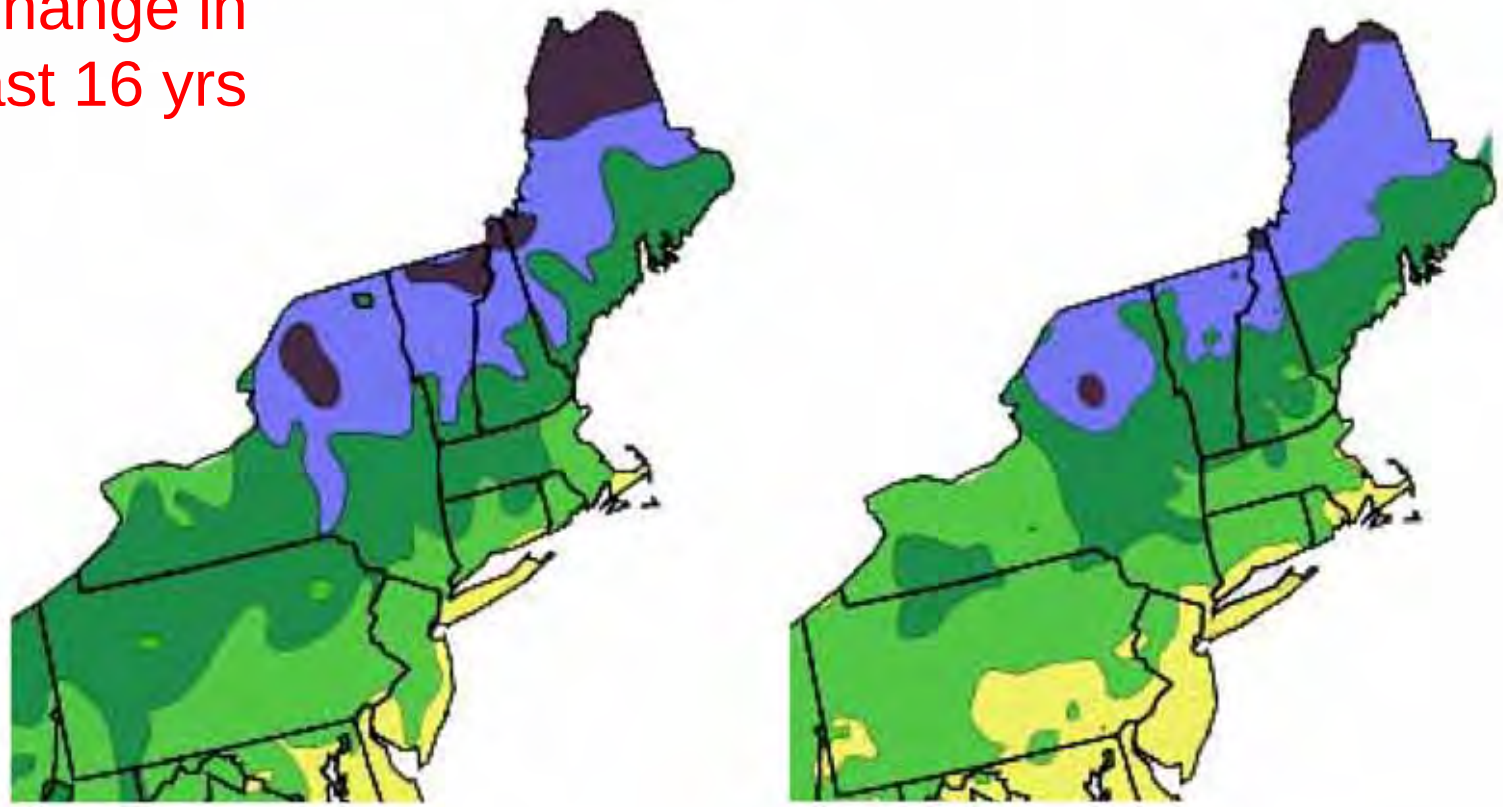
Snow cover in December, ground unfrozen

Brussel sprouts can now survive VT winter [protected by leaves & snow]

Picked February 10, 2008, Pittsford, VT

USDA Hardiness Zones - Northeast

Change in
last 16 yrs



1990

2006

Zone

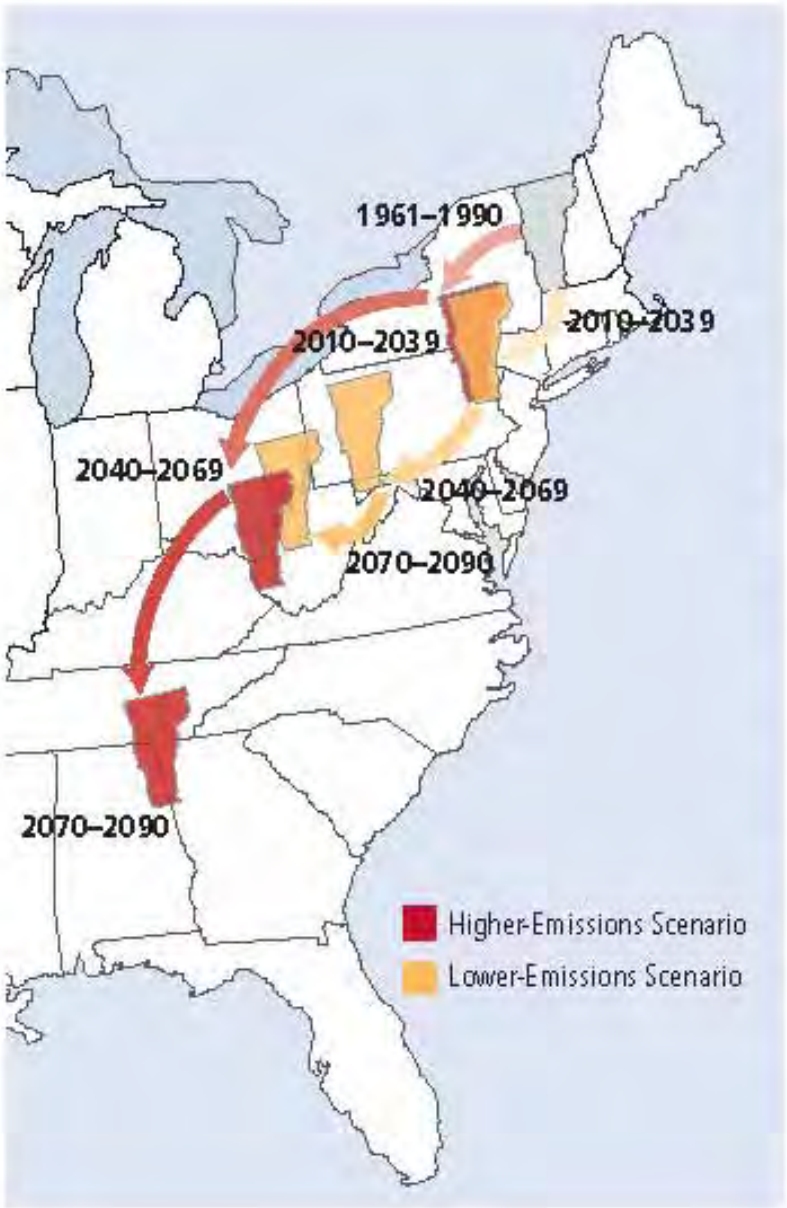
2 3 4 5 6 7 8 9 10

USDA Hardiness Zones

Vermont's future with high and low GHG emissions

Red is high emissions

What about the tropics?

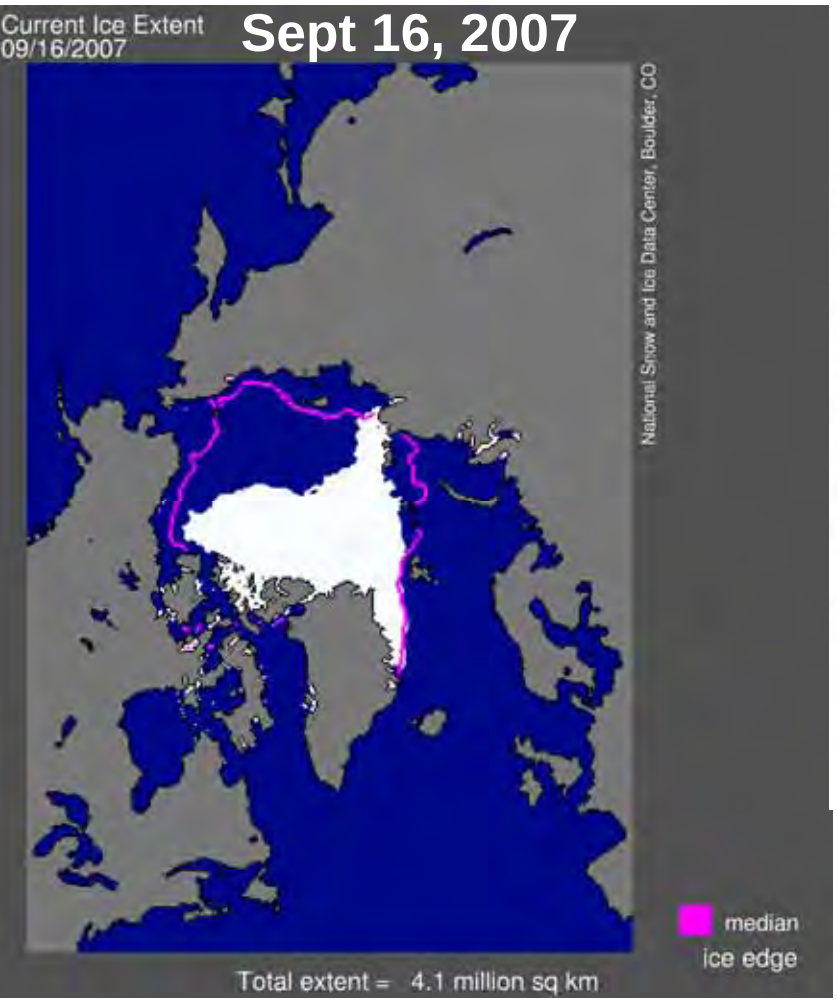


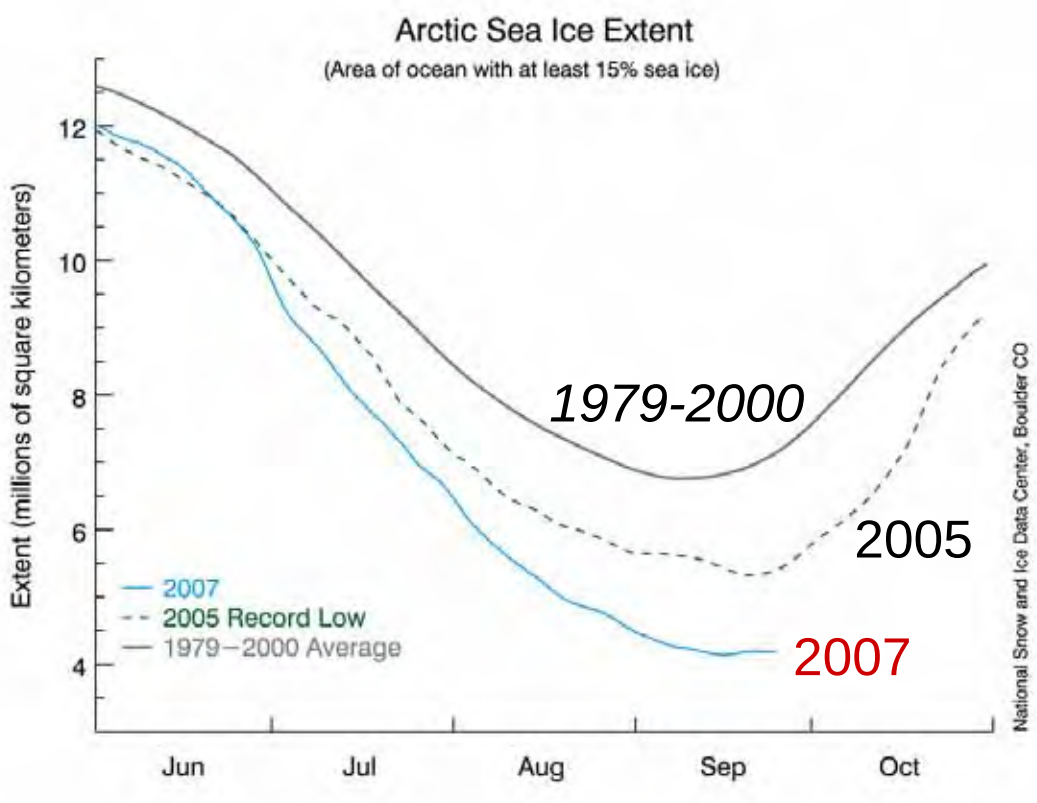
Migrating State Climate

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

Arctic sea-ice loss is accelerating

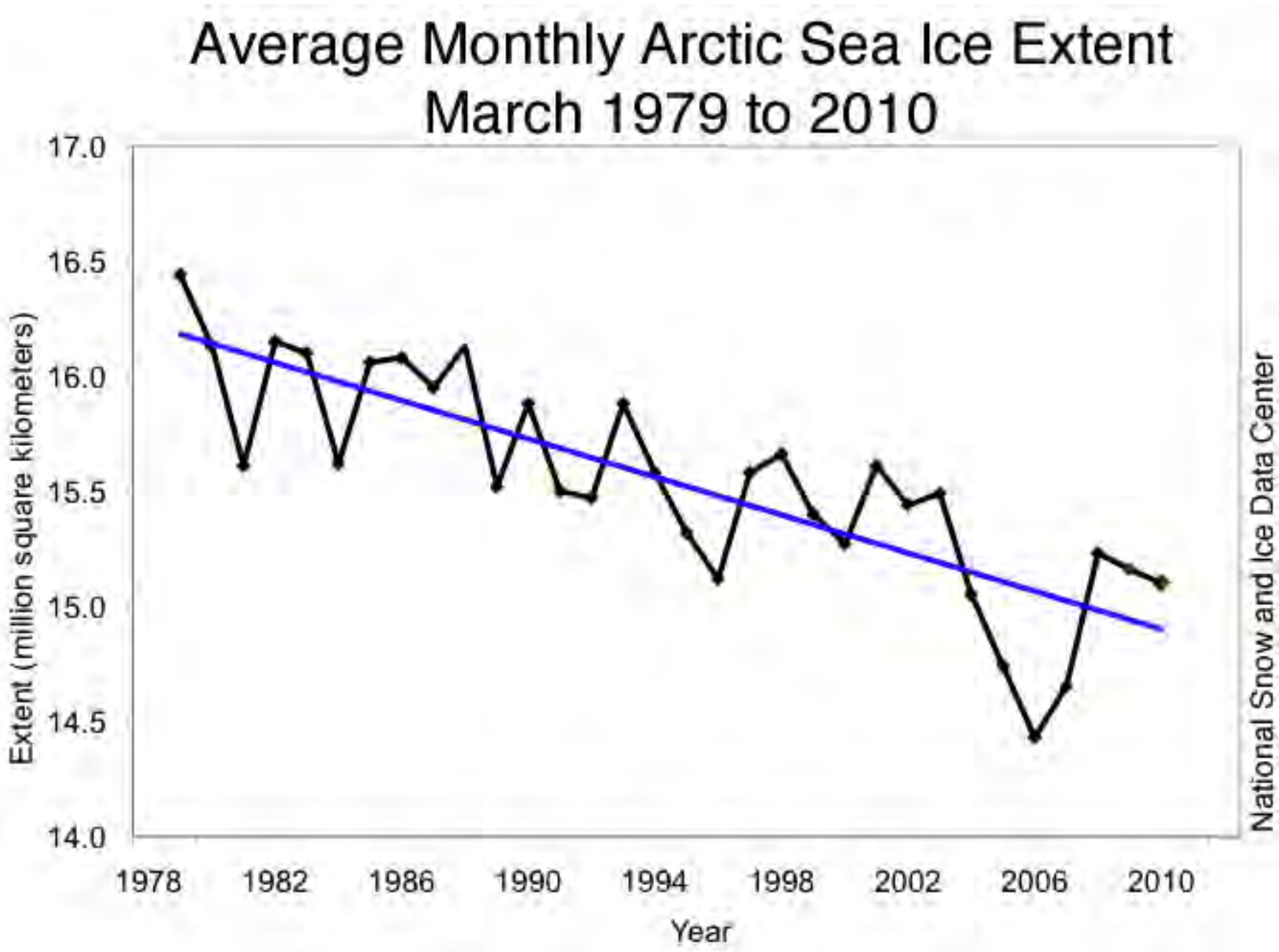




Double feedback: loss of reflective ice and increased water vapor greenhouse from more evaporation

(www.nsidc.org)

- 2007 saw new record ice-loss by huge margin
- 40% melted by September → warm Fall

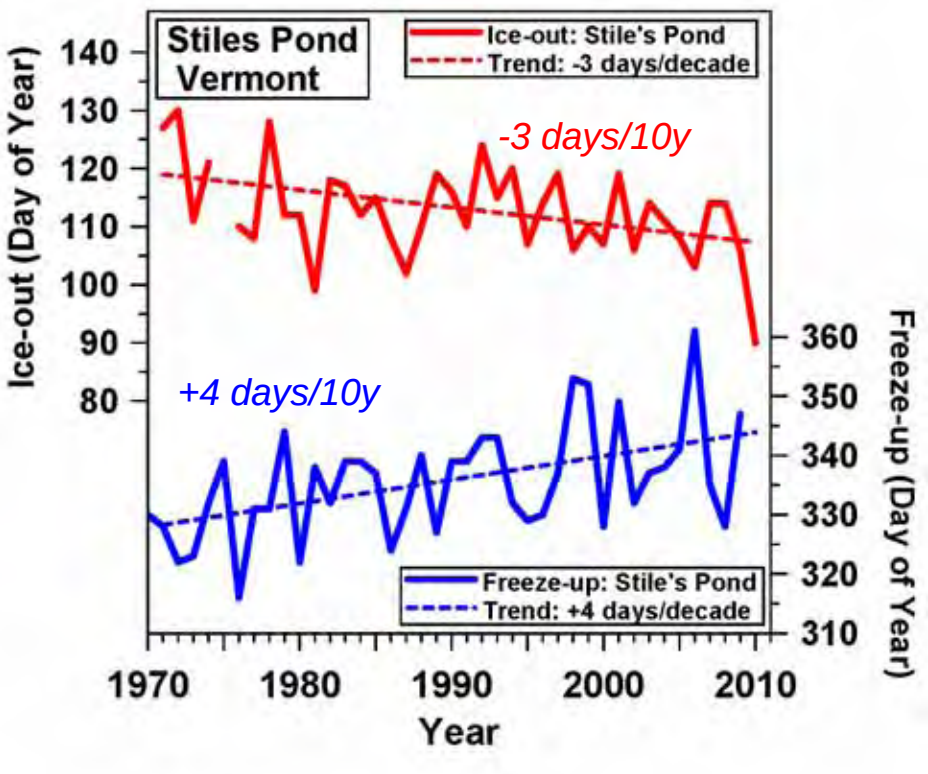

Average Monthly Arctic Sea Ice Extent
March 1979 to 2010
17.0
16.5
16.0
15.5
15.0
14.5
14.0
Extent (million square kilometers)
1978
1982
1986
1990
1994
1998
2002
2006
2010
Year
National Snow and Ice Data Center

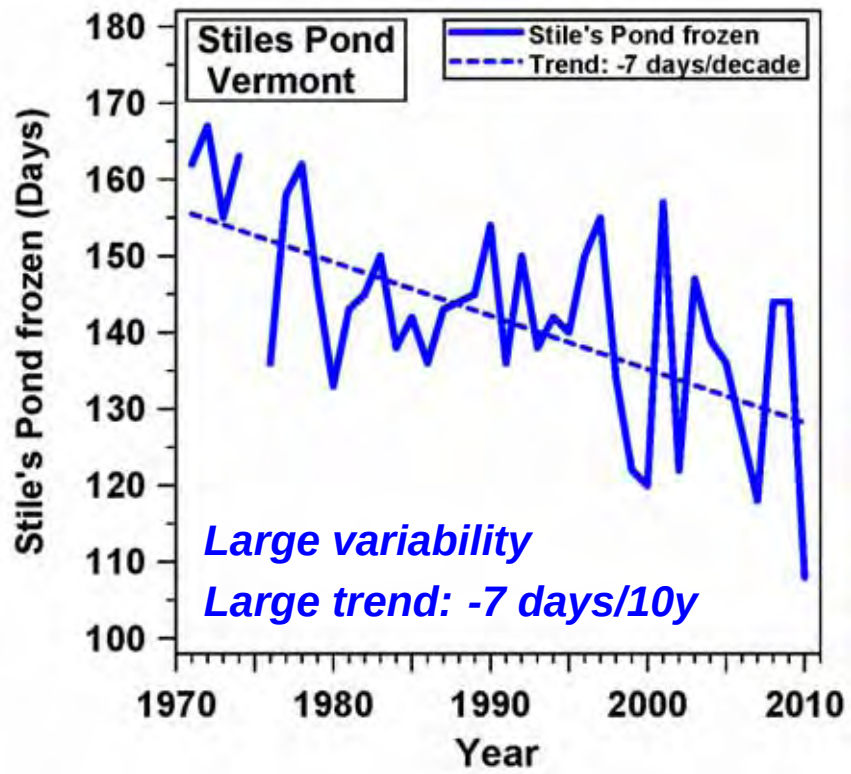
Relate big picture to what is happening locally

2) Local climate change indicators: Vermont

- Frozen period for lakes
- Growing season for frost-hardy and frost-sensitive plants
- Spring phenology

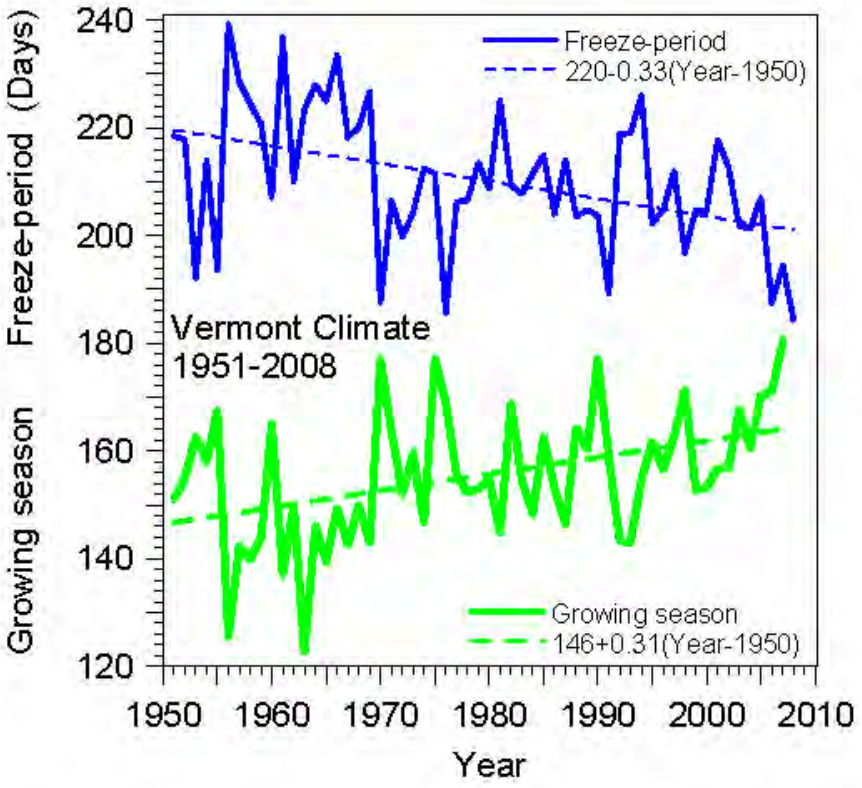
Small lake freeze-up & ice-out

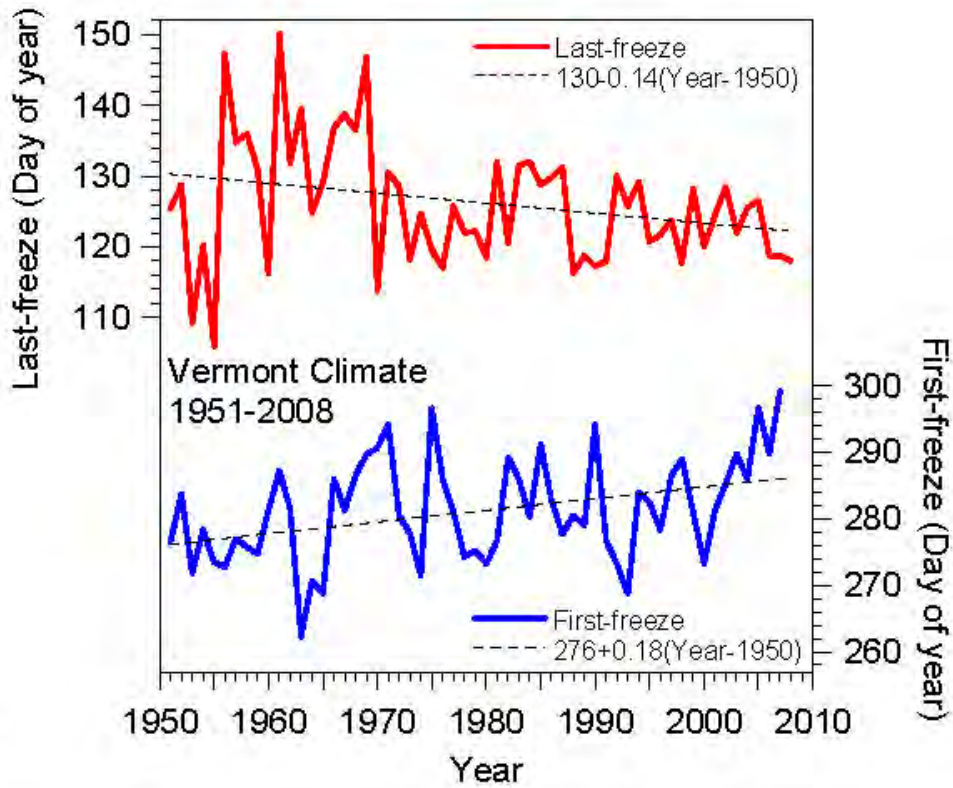




- **Small lakes are *climate indicators for the cold season* in Vermont.**
- Freeze-up depends on lake and air temperatures in the fall
- Ice thickness depends on the severity of the winter
- Spring ice-out depends on ice thickness and air temperatures in spring
- *Public (ice-fishermen & winter recreation) know what is happening*

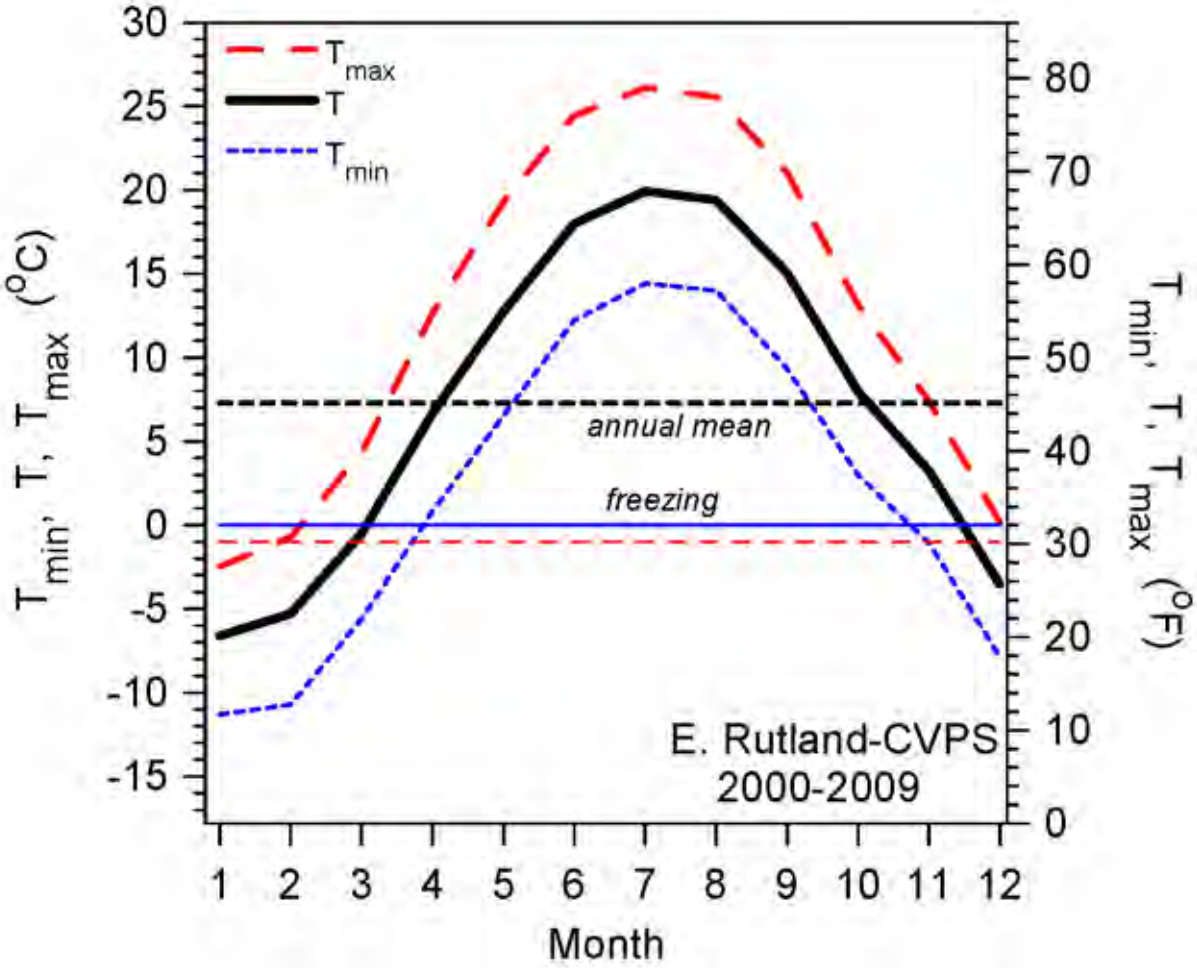
Growing season trends





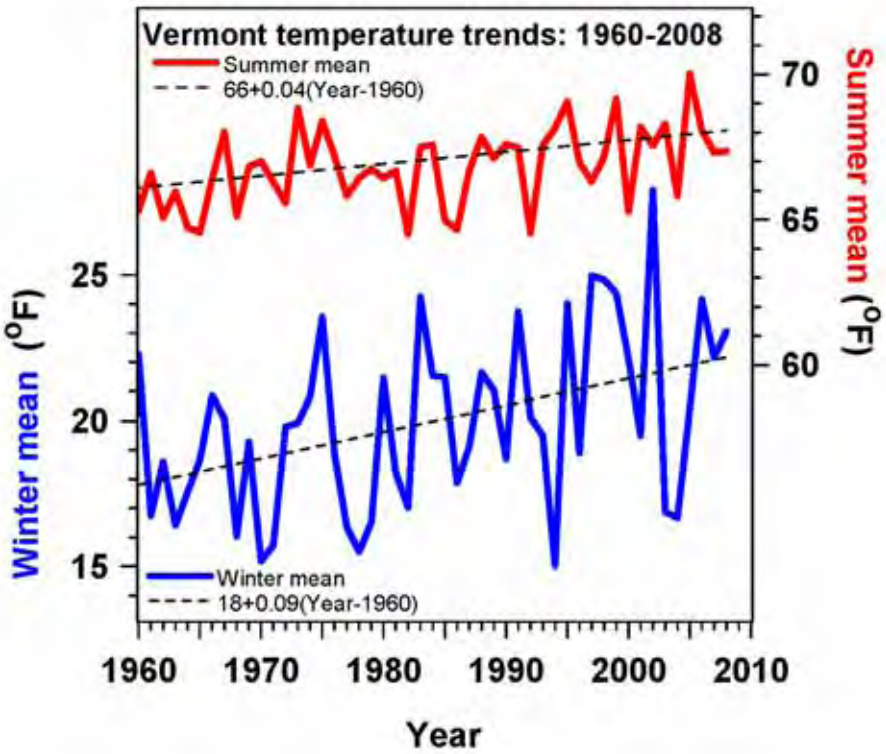
- ***Lot of variability as well as trends***
- **Last spring frost earlier by 1.4 days/decade**
- **First fall frost later by 1.8 days/decade**
- **Growing season longer by 3.1 days/decade**

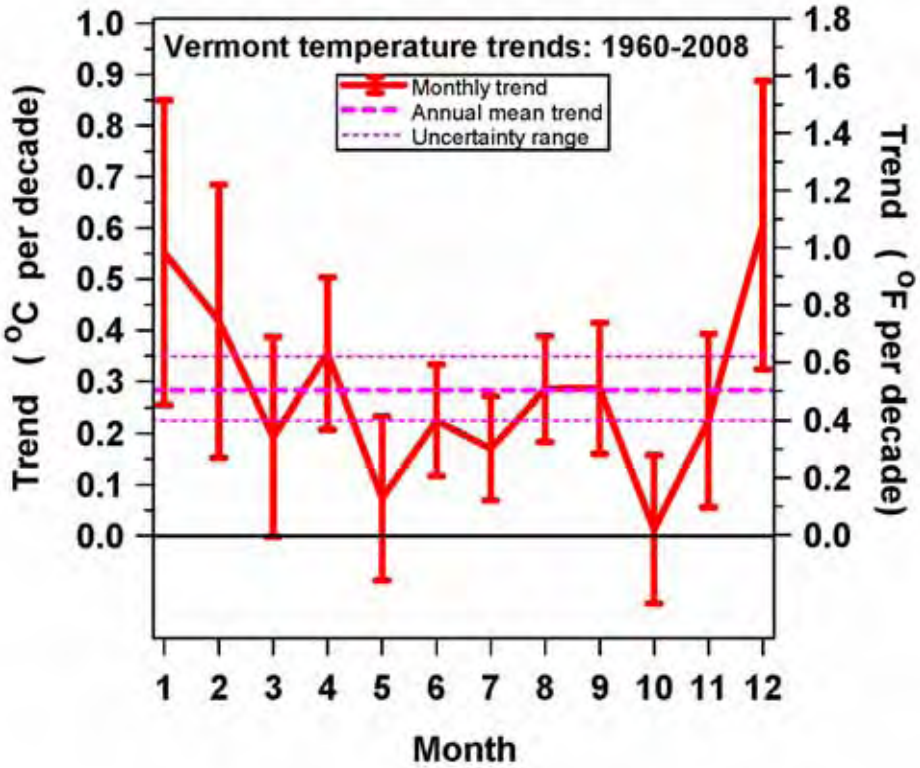
What is happening to Vermont?



- **Shift of cold season T_{mean} in relation to freezing: 0°C**

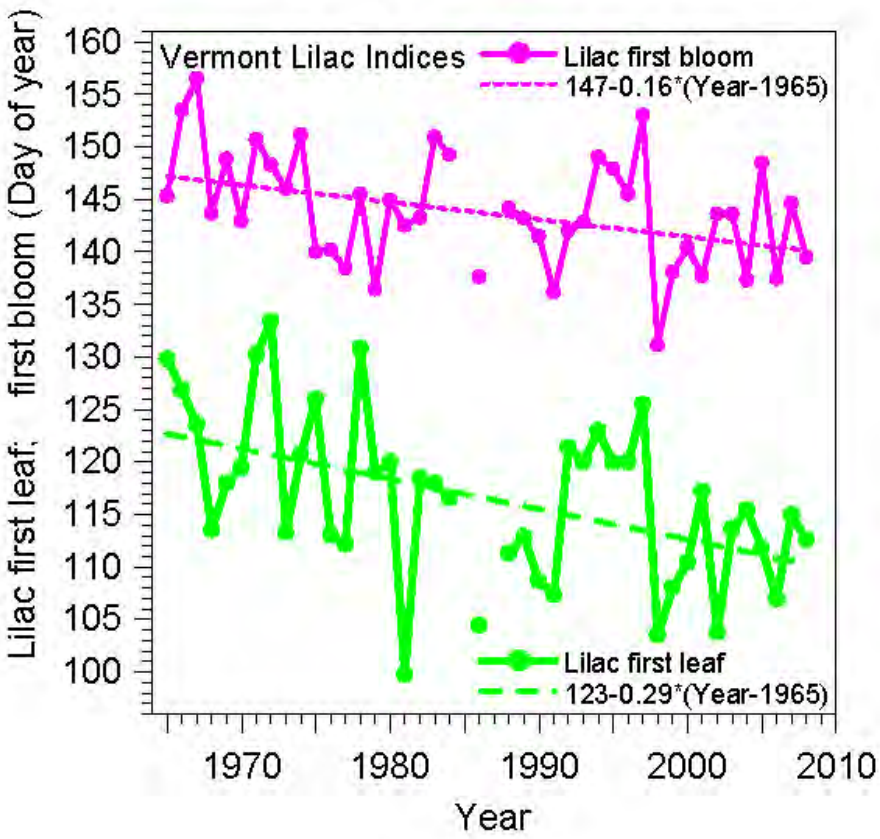
What is happening to the temperature in Vermont?

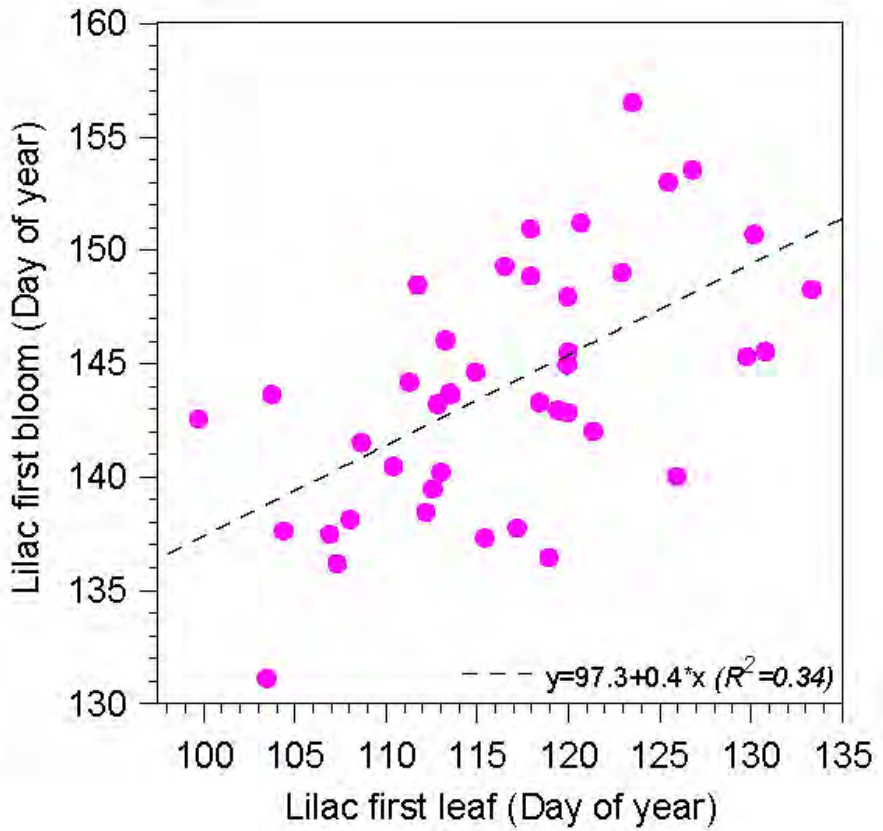




- **Summer trend** is 0.4 ◦F (0.23◦C) per decade
- **Winter trend** is 0.9 ◦F (0.5 ◦C) per decade
- *Note large variability from year-to-year*

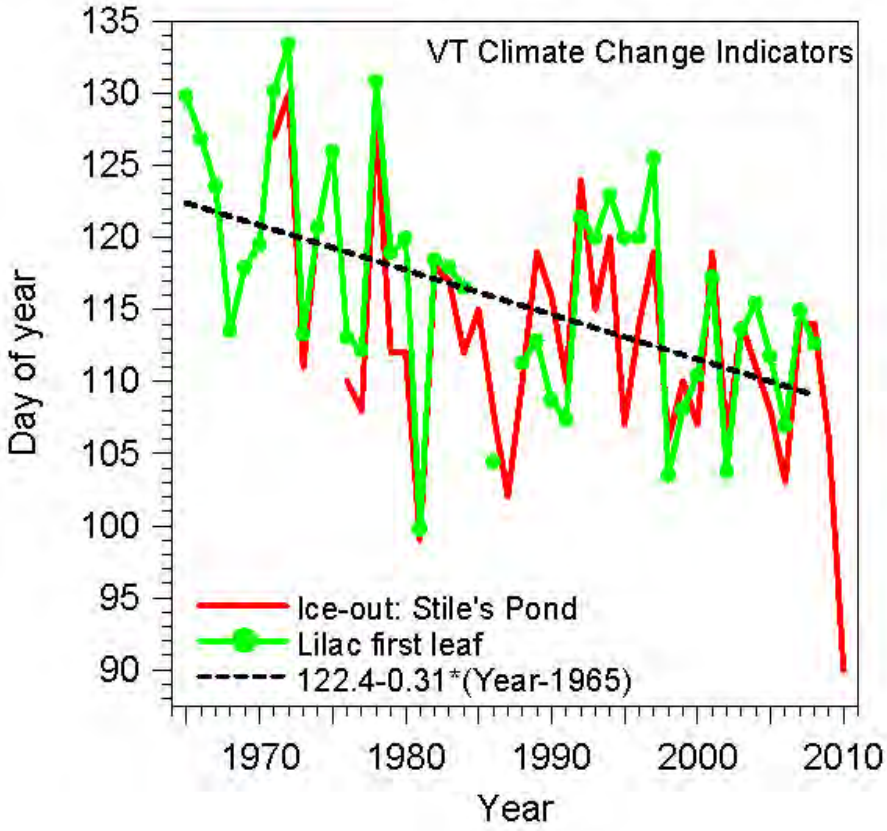
Do plants show trends in spring?

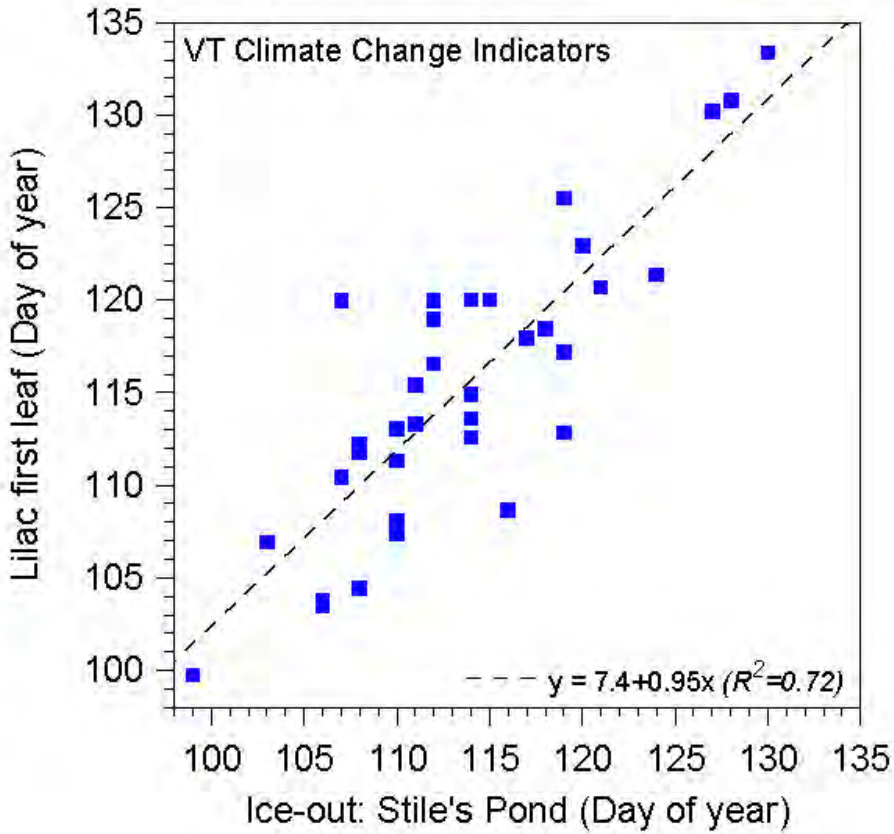




- Spring trend of first leaf - 2.9 days/decade
- Spring trend of first bloom -1.6 days/decade

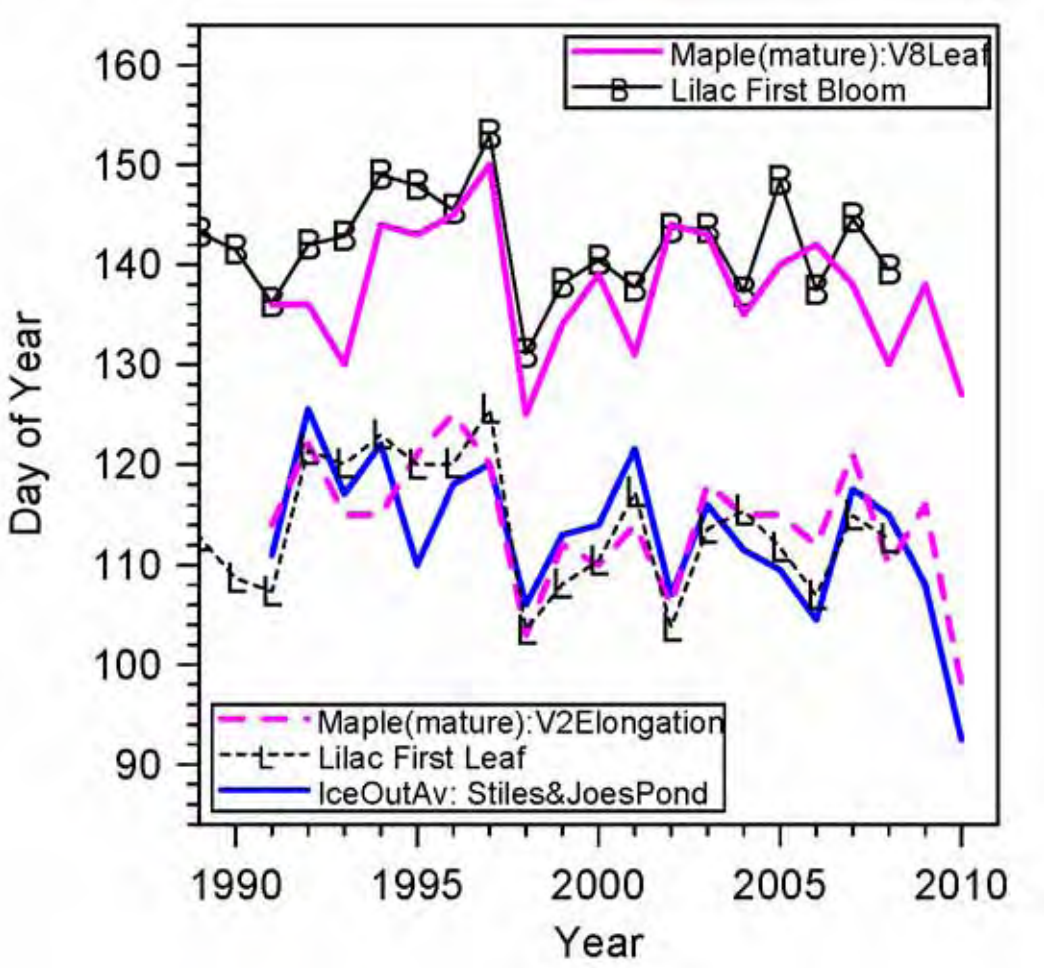
Lilac first leaf matches ice-out!





- **Lilac first leaf correlated with spring ice-out**
- **Trend for both is -3 days/decade**
- **Frost-hardy plants are following ice-out trend**

What about the sugar maples?



- Ice-out, lilac leaf, and maple bud elongation correlated
- Lilac bloom and maple leaf-out correlated

Conclusions -1

- Understanding seasonal climate transitions helps us understand key climate processes & grasp the local and global nature of what is happening to the Earth

- Local climate change indicators provide a clear framework for communities – for understanding, acceptance and adaptation planning

How do we manage the Earth?

(When there is so much we don't know)

- ***Long time horizon*: generational to century**

- All *waste products* must have short lifetime in biosphere [think CFCs, CO_2, Pu-239]
- Minimize use of raw materials by *remanufacturing*
- Maximize efficiency of use of *energy and water*

- *Relocalize* to regain control/responsibility and minimize transport

Examples of long-lived ‘waste’

- CFCs – refrigerants – very stable – lifetime centuries - broken down by sunlight in stratosphere – catalyze **ozone** destruction, which protects earth from UV
- CO_2 from fossil fuels – lifetime centuries – a **greenhouse gas** that traps earth’s heat radiation – pushing earth to warmer climate
- Nuclear waste – radioactive – plutonium-239 half-life, 24000 years – **nuclear weapons**

(Self)-deception is still an issue

- ***Three pillars of American dream are crumbling***
- "Economic growth" based on **fossil fuels, debt and consumerism** is **unsustainable**

  - and a disaster for the planet!

- **Individual "rights"** & needs of humanity must be balanced against the needs of the **earth's ecosystem**
- **We have no workable paradigm to guide and manage technology** – so result is tremendous successes and catastrophic failures

What are scientists' responsibilities?

- Climate science is under attack because it is politically and economically relevant
- ***Traditionally scientists "stuck to science"***
- How do we proactively defend the science and maintain trust and integrity of science?

- **Needs deeper ethical/historical understanding**

Climate Change is a huge challenge for humanity

- **We haven't integrated our science/technology and our moral responsibility for the earth**
- **We have a large investment in a fossil fuel infrastructure, that must be replaced**
- **We have major political problems finding consensus**

- ***We are already decades late in taking action and the lags in the earth system are long***

Climate Neutrality?

- **We know what we need**
  - **Energy-efficient society**
  - **Energy sources renewable: not fossil**

- **What are the obstacles?**
- **Why are we taking such a huge risk for this planet?**

Efficiency comes first

- **Need to double or triple our energy efficiency**
- **Cannot replace current fossil fuel use with biofuels & renewable energy**
- **Oil and gas reserves are limited, but coal reserves are sufficient to push CO_2 well above 1000ppm *[and in time melt ice-caps]*. Can we "sequester" CO_2 [put it back in the earth]?**

- **Strengths of science**:

  - integrity, honesty and communication

  - *particularly valuable in a society lost in ignorance and deceit*

- **Limits of science**:

  - tangible, measurable and communicable

  - *hard to deal with the complexity and interconnectedness of the living natural world*

Does the distinction between the human-made world and the natural-world matter?

- We understand the human-made world, the world of computers & technology – because we made it – *predictable*, *controllable*.
- The same is not true of the natural world – which is far more complex and alive. Our understanding is limited; *prediction & control not possible*
- *E. F. Schumacher* called it the ‘created’ world [speaking to faith groups]

Perspective for the 21st century

- Much of western political & theological belief systems formed when humanity had a limited understanding of its place on Earth; but the structures of belief didn't matter too much ***because our impact was small.*** **[US Constitution-Earth has no 'rights']**
- All this started to change with the industrial revolution powered by fossil fuels. Now humanity has a ***global impact on the natural world***, and understanding our place in it is paramount.
- ***Science and technology created this situation***, and must help us find a way out, by helping us understand the earth as a global system, now out-of-balance.

But science has become ‘valueless’

- Centuries-old split of science from ethics/religion
- Science preserved its factual integrity, but makes no value choices
- Political society & theology feel free to choose doctrine over understanding ‘reality’

- ***No-one accepts responsibility for the Earth***
- ***So collapse of our ‘human system’ is possible***
- ***Scientists cannot ignore their responsibility!***

The truth is critical: it takes honesty and understanding

- Industrialization, powered by fossil fuels
  has pushed the Earth out of balance
  and its time-scales are long

- It is more profitable in the short-term to spread
  uncertainty, confusion and delay
  than face the truth

Powerful but foolish

- In just 2 centuries, technology & fossil fuels have given us great power; and at first freedom from the mercy of the elements
- But with power has come *arrogance* and doctrinal beliefs that are incompatible with a sustainable Earth
- As Earth system responds, we are vulnerable to natural disasters – and ***we will have adapt.***

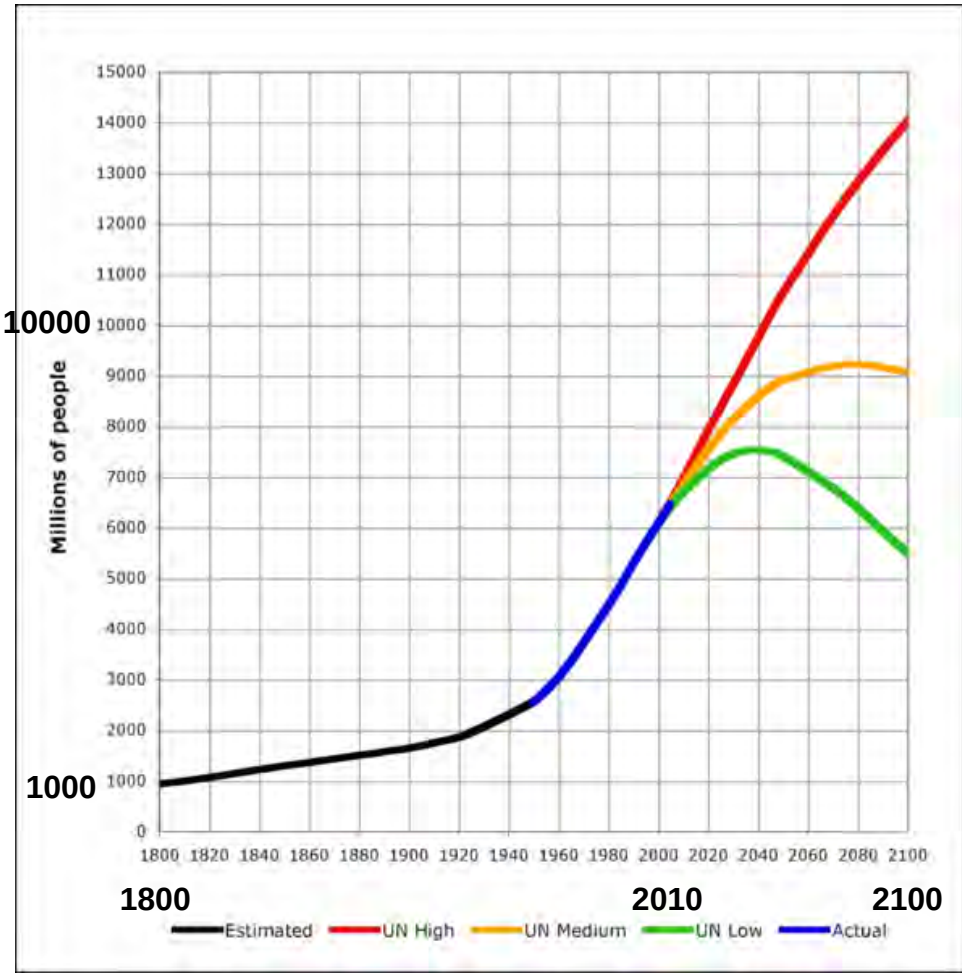
We passed the carrying capacity of the Earth in the 1980s**

- **Population is still rising**
- **Consumption is still rising**
- **Fossil energy use is still rising**

- ***We still 'believe' in Growth***

- ***Global poverty & suffering are still growing***

*** With a fair & equitable standard of living***



The future is not our past

- Faced with
  - climate change & limited oil
  - global population growth & ‘consumer growth’
  - past the carrying capacity of the Earth in 1980s

- What government can do is limited: too paralyzed by ideology/doctrine, bureaucracy & self-interest

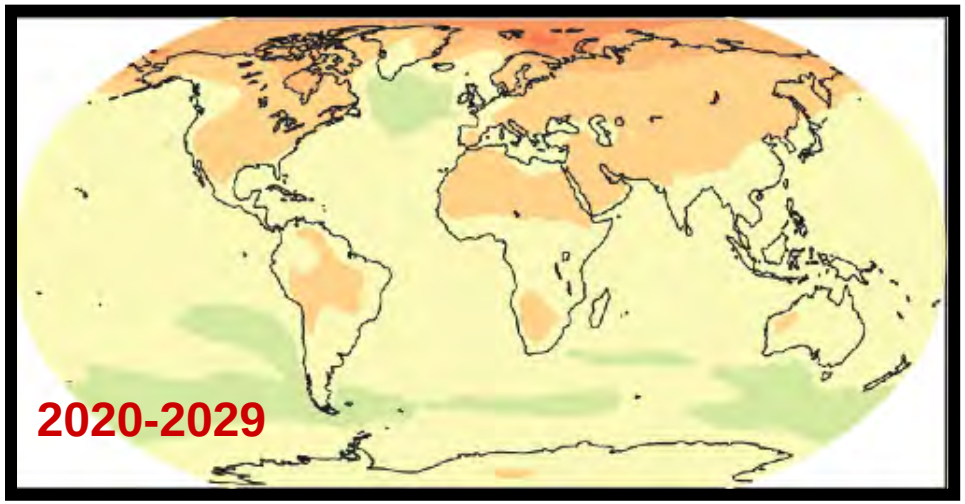
- **Communities are a key** *[transitiontowns.org]*

Conclusions -2

- **The issues humanity faces are deep**
- We are all part of the problem/solution
- *We have the tools & knowledge*
  - but not the wisdom!
- We need to look beyond our traditional silos and creatively accept our individual and collective responsibilities
- **We create the future – it is not a given!**

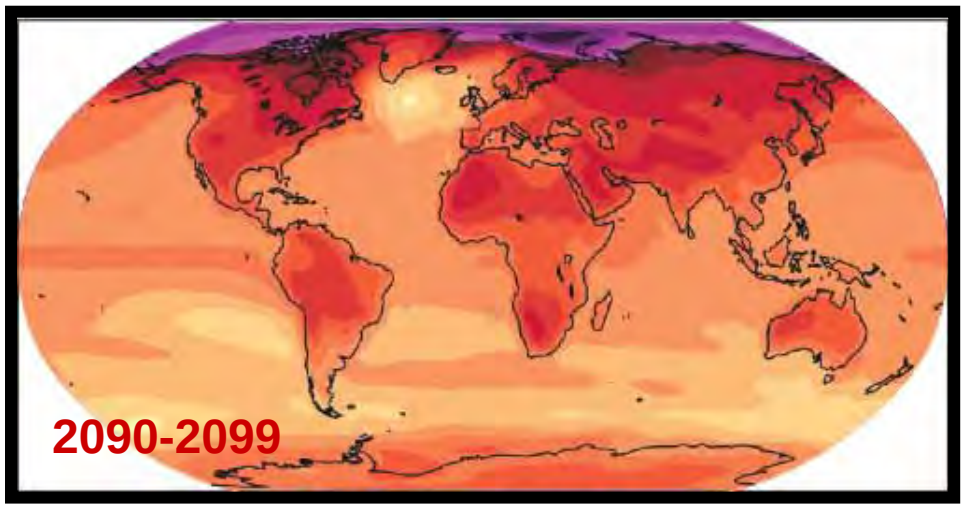
Multi-model Predicted Percent Change in Temperature (2020-2029 and 2090-2090 relative to 1980-1999) [^{o}C]

‘Committed’

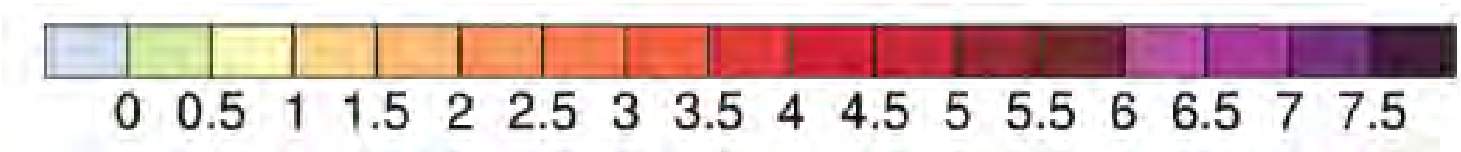


(We did nothing for the last 20 years)

Still up to us!



(We could halve this if we act now)



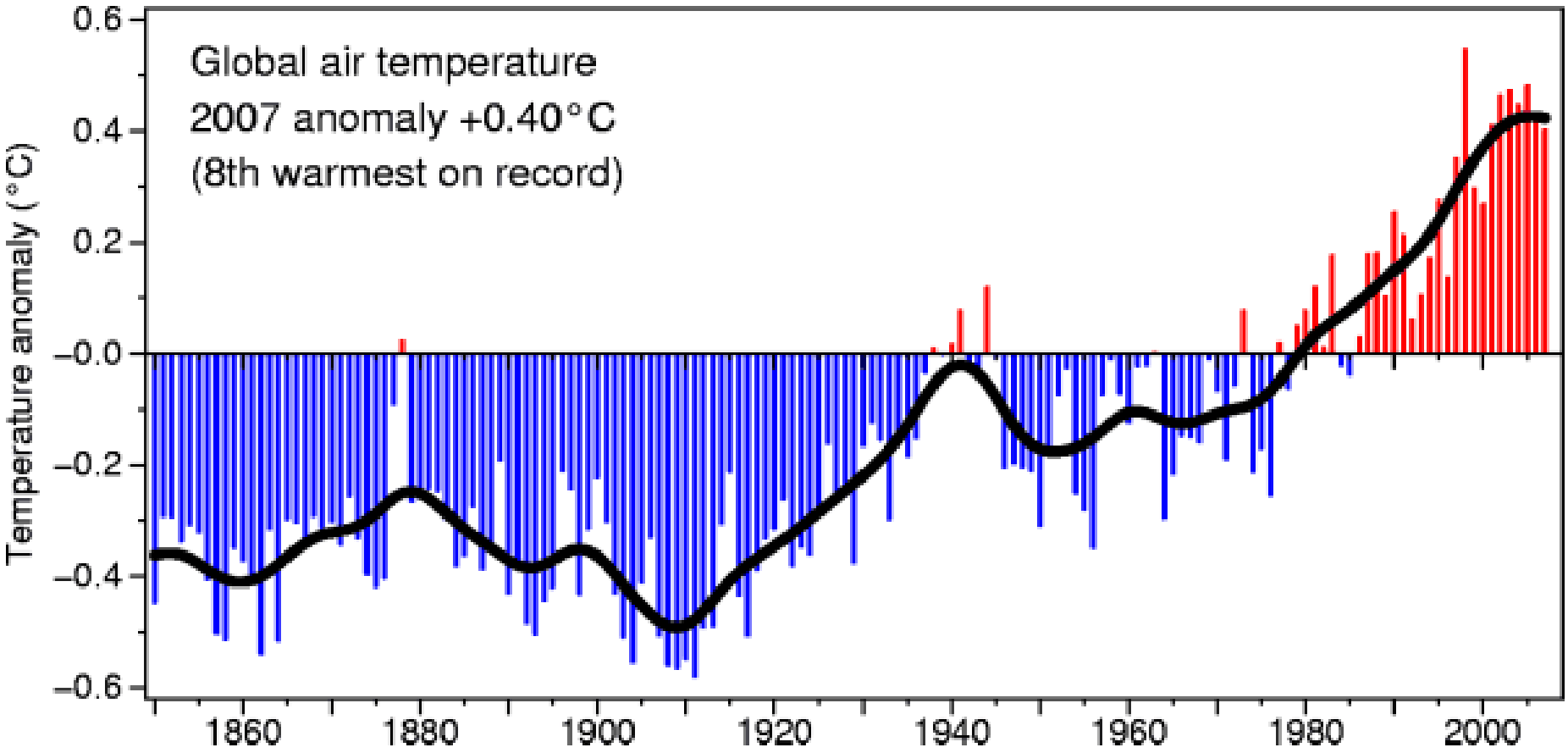
[^{o}C]

Earth system- critical issues

- **CO_2, H_2O, clouds & Greenhouse effect**
- **Ice-albedo feedback [sea-ice melt]**
- **Ice-melt and sea-level [rising faster]**
- **Ocean acidification [impacts severe]**
- **More extreme floods & droughts**
- Melting permafrost; CH_4, tundra regrowth
- Unstable feedbacks
- **Many unknowns**

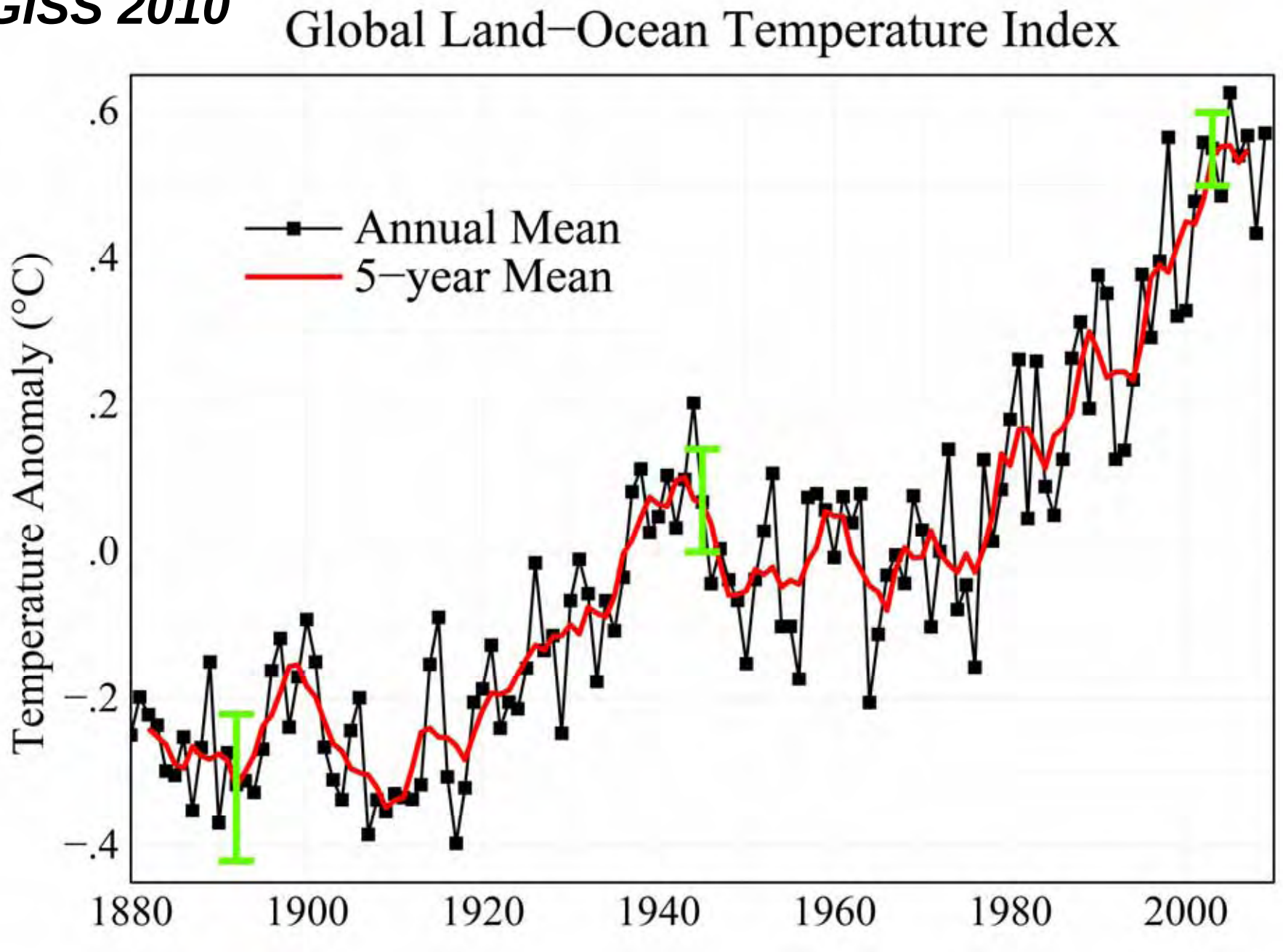
Last 150 years temperature record

- *Jones, 2008*



Warmest years: 1998 and 2001-2007

GISS 2010


Global Land−Ocean Temperature Index
Annual Mean
5−year Mean
Temperature Anomaly (°C)
.6
.4
.2
.0
−.2
−.4
1880
1900
1920
1940
1960
1980
2000