Communicating Climate Science

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Vermont Weather and Climate Data and Research Working Group

March 10, 2011

(2 talks from Annual meeting American Meteorological Society)

1. How can we explain climate processes to the Public?

- **Pictorial strategy, using 'seasonal climate transitions' that are familiar**

- **Seasonal climate transitions**

- *Spring, Summer, Autumn and Winter*
- *Familiar to farmers, gardeners and foresters*

- **Betts, A. K. (2011), Seasonal Climate Transitions in New England. *Weather*, (in press). DOI: 10.1002/wea.754.** ***http://alanbetts.com/research***

Two Spring transitions

1) Warm dry week to ten days in Spring, after snowmelt, past the equinox

2) Followed by drop of temperature of 3-5C 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 transition-1 4/15/2008

- *Weather:*

  Sunny, dry week

- *Climate:*
  After snowmelt before leaf-out 'warm & dry' (little evaporation). Large diurnal temp. range. **Frost likely.**

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

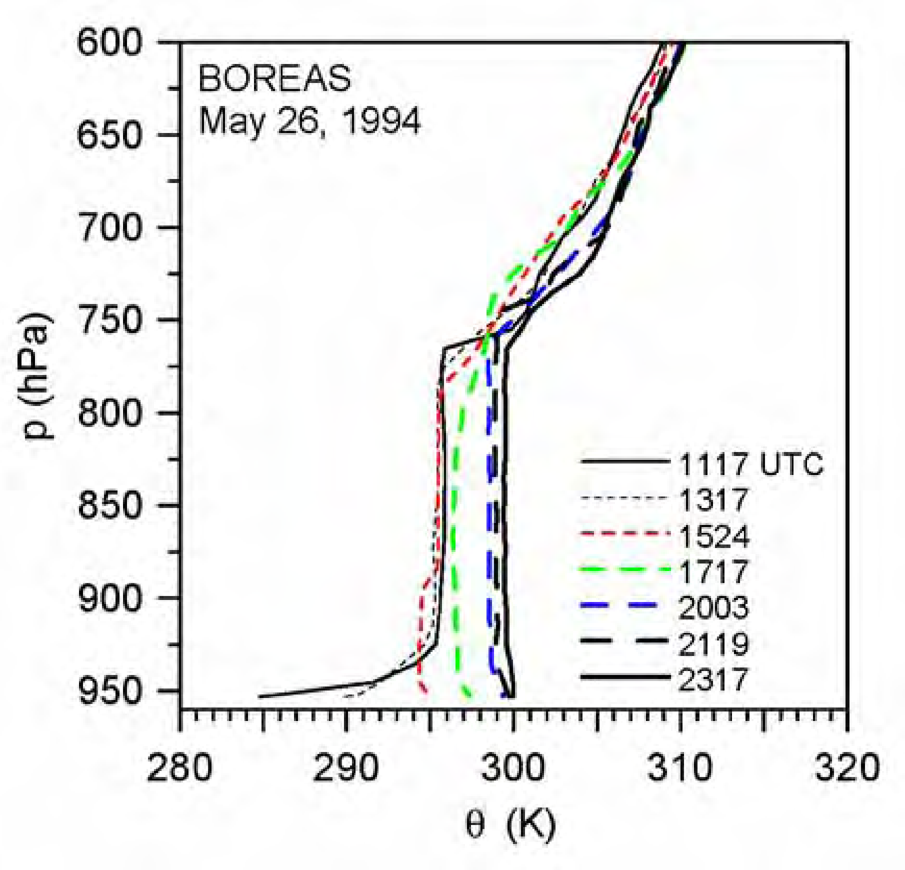
Pittsford, Vermont

More extreme at boreal latitudes

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

– too cold to evaporate

- Longer seasonal lag than New England



Spring transition-2 5/15/2010

- *Weather:*

Cooler, humid, cloudy week

- *Climate:* After leaf-out, large evaporation, temp. falls 3-5C. Low cloud-base. Smaller diurnal temp. range. **Frost unlikely.**

- *Climate change:* ‘Leaf-out’ earlier than 30 years ago

Pittsford, Vermont

Key model question: Are spring transitions correct?

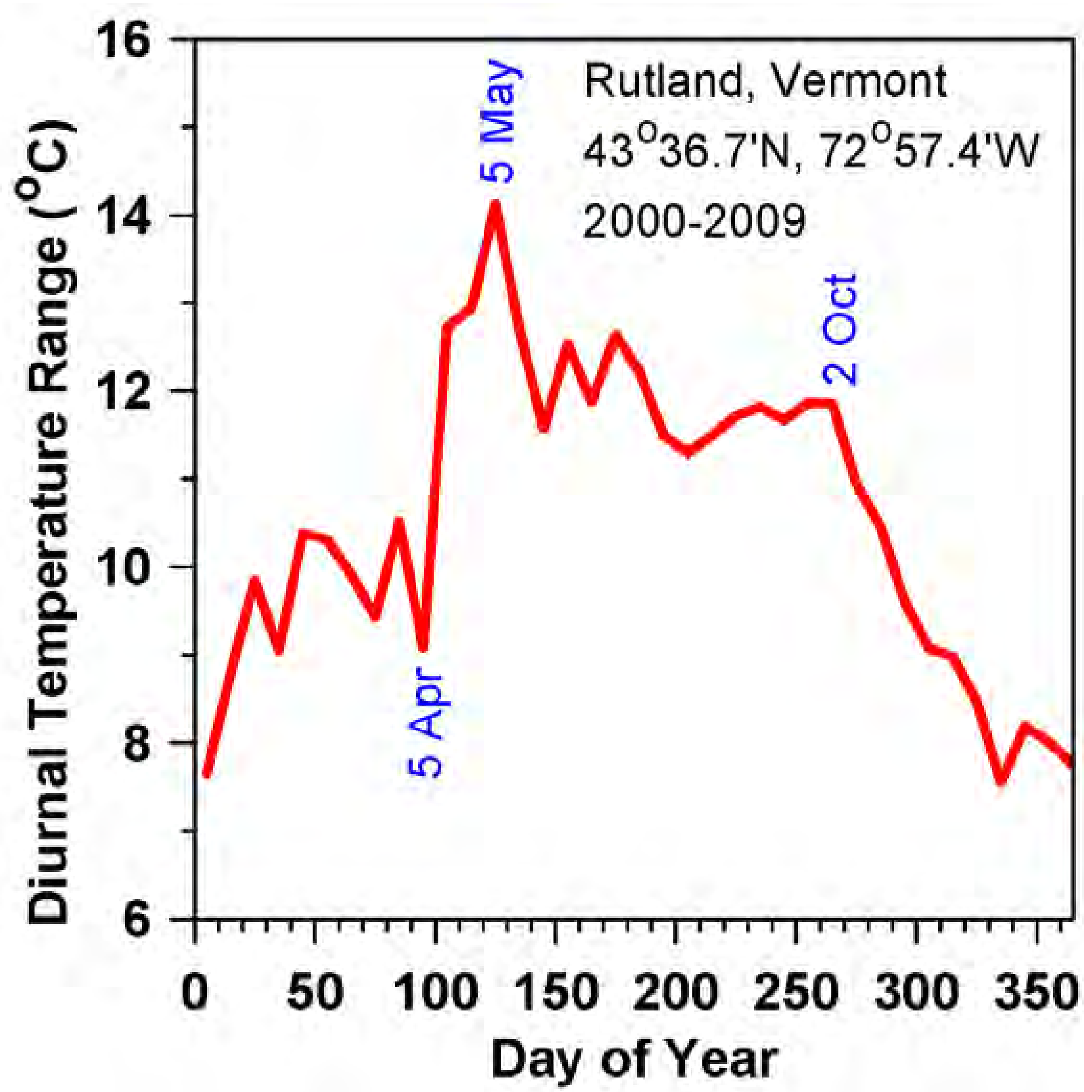
- 15 April after melt
- Low transpiration
- Dry atmosphere
- Larger DTR

15 May after leafout
Large transpiration
Moist atmos., clouds
DTR reduced

Mean Diurnal Temperature Range

- Water vapor & cloud greenhouse effect linked to LW_{dn}, LW_{net} and DTR
- Coupled to transpiration

[Betts, JGR, 2006]



Summer transitions

- 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
- 2010 we had a summer dry-down

Wet summers

- Both 2008 and 2009 were wet
- Direct fast evaporation off wet canopies
- Positive evaporation-precipitation feedback

Summer dry-down

- Wet in spring
- Soil moisture falls: summer dry-down
- Low RH & no rain

- Hay dries fast!

Fall transition

- ***Mirror of Spring transition (2)***
- **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

Energetics of ground & snow melt

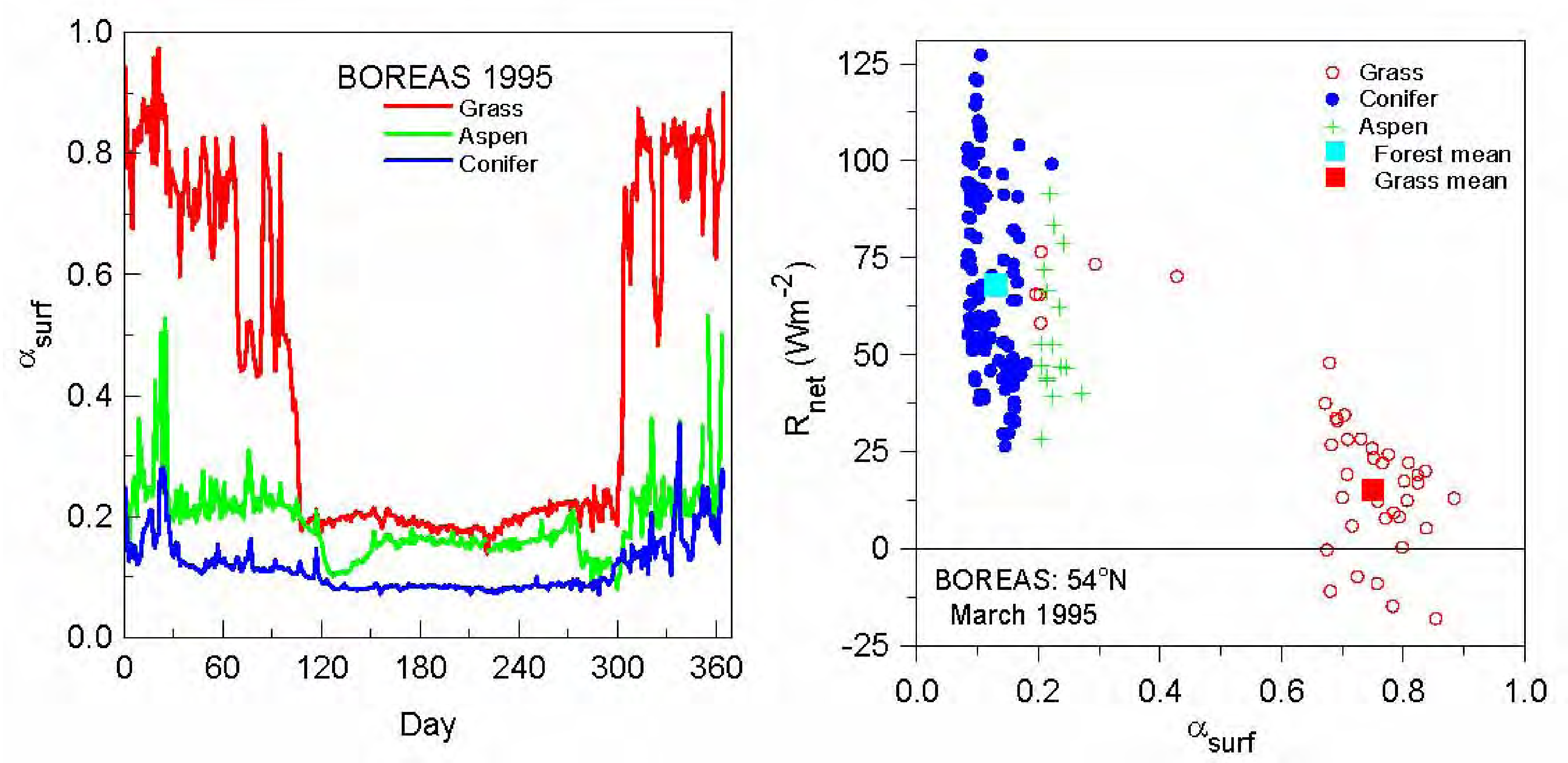
- 1 meter frozen soil = 300mm water
- 1 meter snow = 100mm water
- 25 Wm^{-2} melts 6.5 mm/day
- Soil phase change gives 'sink' of 25 Wm^{-2} for 45 days in spring and smaller 'source' over longer time period in fall
- As climate warms, frozen period shrinks at mid- and high latitudes – *Model must be accurate as freezing point matters!*

Winter transition: T falls sharply

- Snow reflects sunlight
- Sublimation low
- Dry atmosphere
- Large outgoing LW_{net} (*reduced water vapor greenhouse*)
- Snow uncouples ground
- Temperature falls

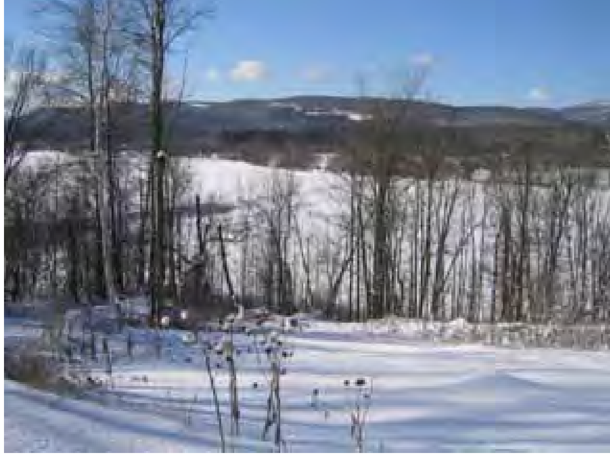
Note trees shade snow: low forest albedo

Boreal forest example



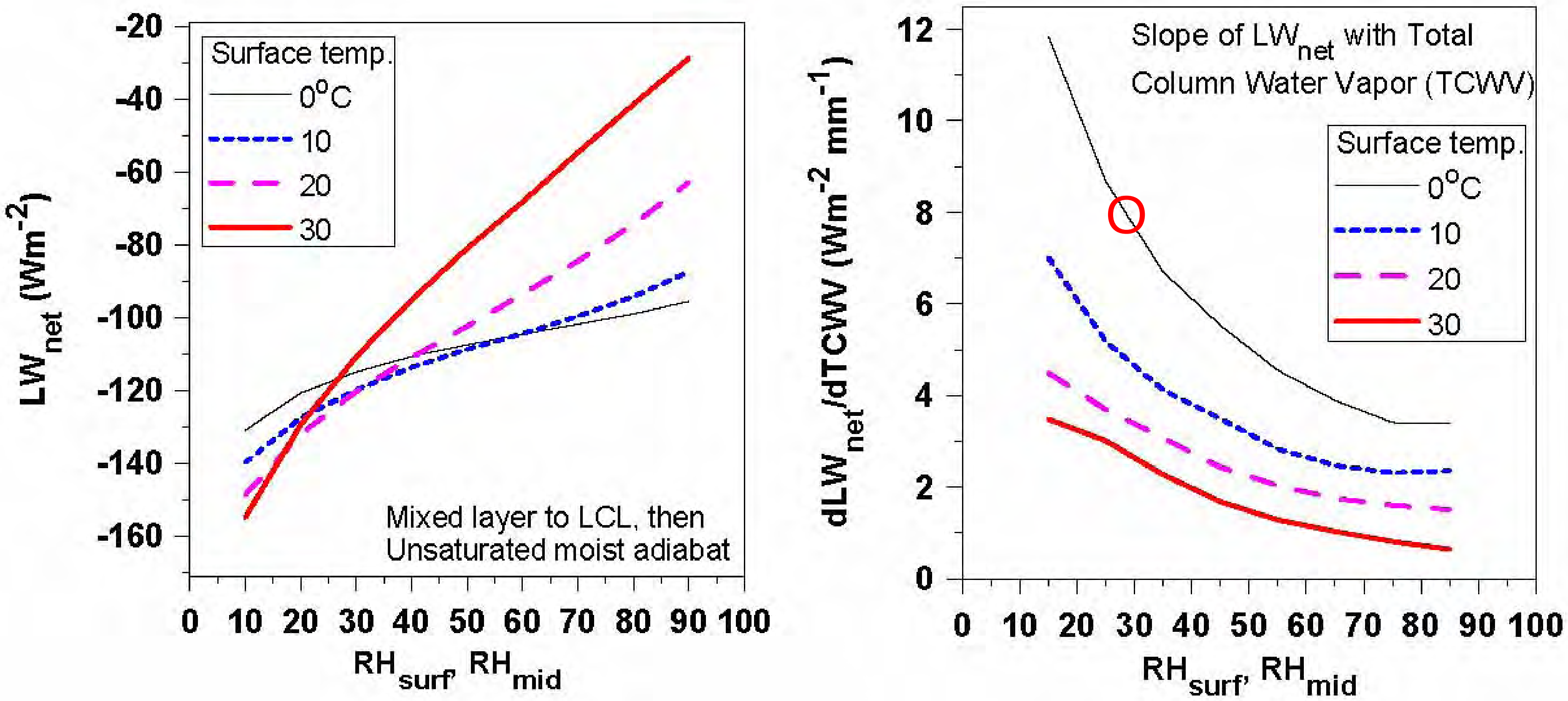
- High albedo in March: $R_{net} \approx$ zero

Rough energetics: snow-on-grass



- Winter SW_{down}(clear) ≈ 130 Wm^{-2} (Vermont in Feb.)
- 10cm fresh snow changes albedo from 0.15 to 0.75 & drops SW_{net} from 110 to 30 Wm^{-2}
- SW_{net} impact = -80 Wm^{-2} while snow lasts
- Residual 30 Wm^{-2} sublimes 1cm snow/day [1mm ice]
- Snow loss increases as snow ages
  - snow lasts ≈ 5 days,
  - reducing solar heating to ≈ zero

LW impact of water vapor



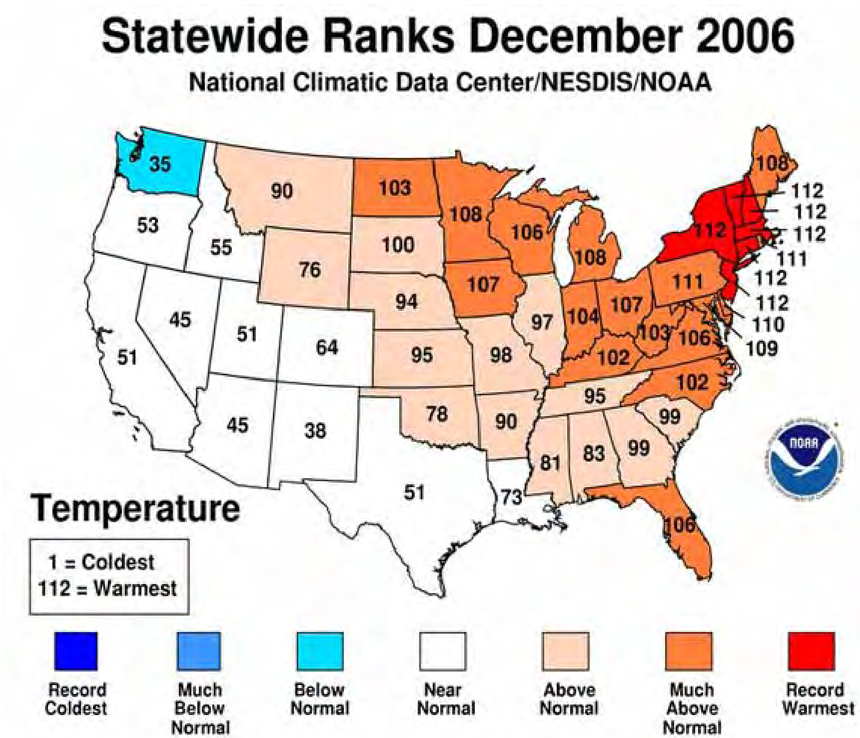
- When cold, removing 1mm water vapor in 30% RH atmosphere increases outgoing LW_{net} by 8 Wm^{-2}

Betts & Chiu, 2010, unpublished

What are key observables?

- Surface albedo, effective cloud albedo
- **Frozen** ground, snow cover, frozen lakes
  - total frozen water and SW reflection
- Seasonal transitions are good integrated markers of climate system: **ice and vegetation**
- Surface RH and LCL: linked to availability of water and vegetation
- DTR coupled to surface LW_{net} coupled to WV and cloud greenhouse effect

After warmest December on record: transition delayed into mid-January.



Gardening in Pittsford, VT
Jan 7, 2007

1. Conclusions

- Understanding seasonal climate transitions helps us understand key climate processes
- These can be seen locally and understood in terms of personal experience
- *Easier then to grasp some of the water cycle processes that are accelerating the warming of northern latitudes*

2. Vermont Climate Change Indicators

- Betts, A. K. (2011), Vermont Climate Change Indicators. *Weather, Climate and Society* (in revision).
  http://alanbetts.com/research

2. Strategy

Issues for the public :

- ***Global changes are beyond direct experience***
- ***Complex models for future - limited credibility***
- ***Scientific literature is unintelligible jargon***

Instead

- **Identify and describe what is happening locally, to link direct perception & collective experience of local communities with global picture**

- **Deepens community understanding and acceptance of the reality of climate change**
- **Provides conceptual basis for adaptation planning (along with model projections)**

What is happening to New England? –*Vermont!*

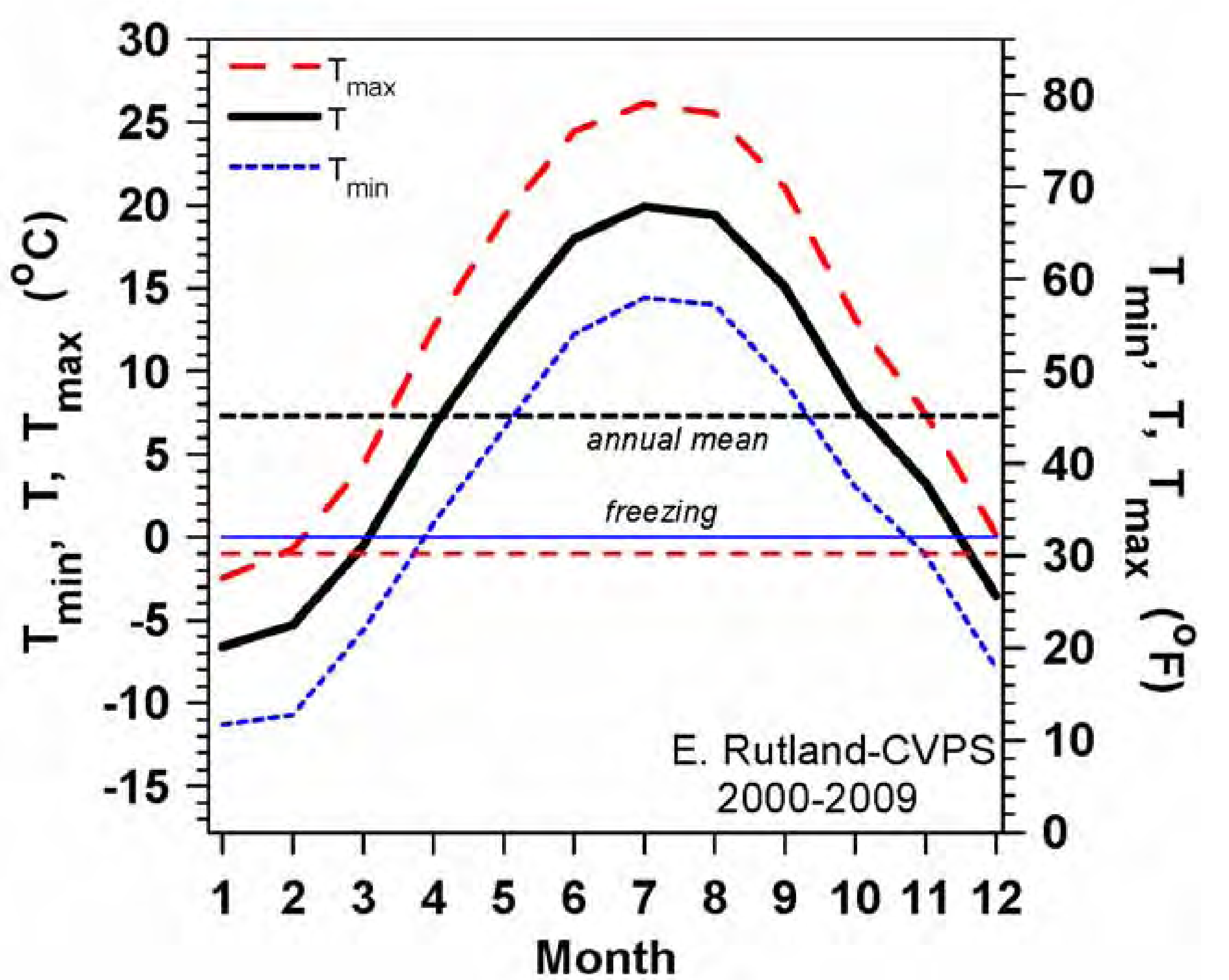
- Local climate change indicators
- Easier to grasp than global view

- *Warming twice as fast in winter than summer*
- *Winter severity decreasing*
- ***Lakes frozen less by 7 days/decade***
- ***Growing season longer 3.7 days/decade***
- ***Spring earlier by 2-3 days per decade***

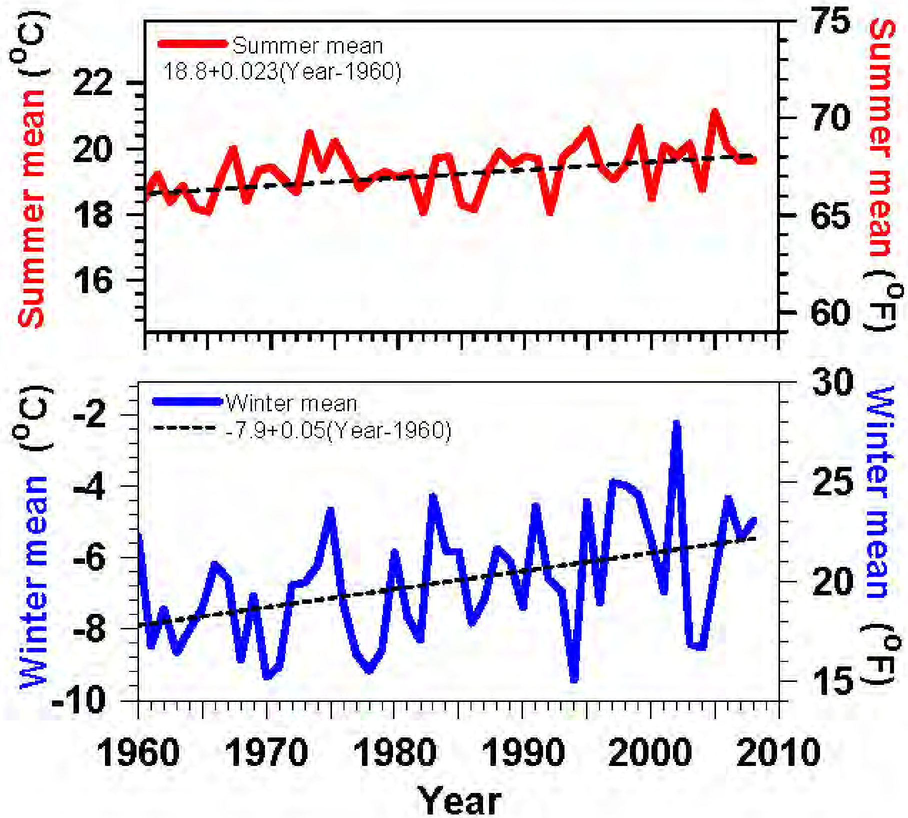
Annual Cycle of Temperature

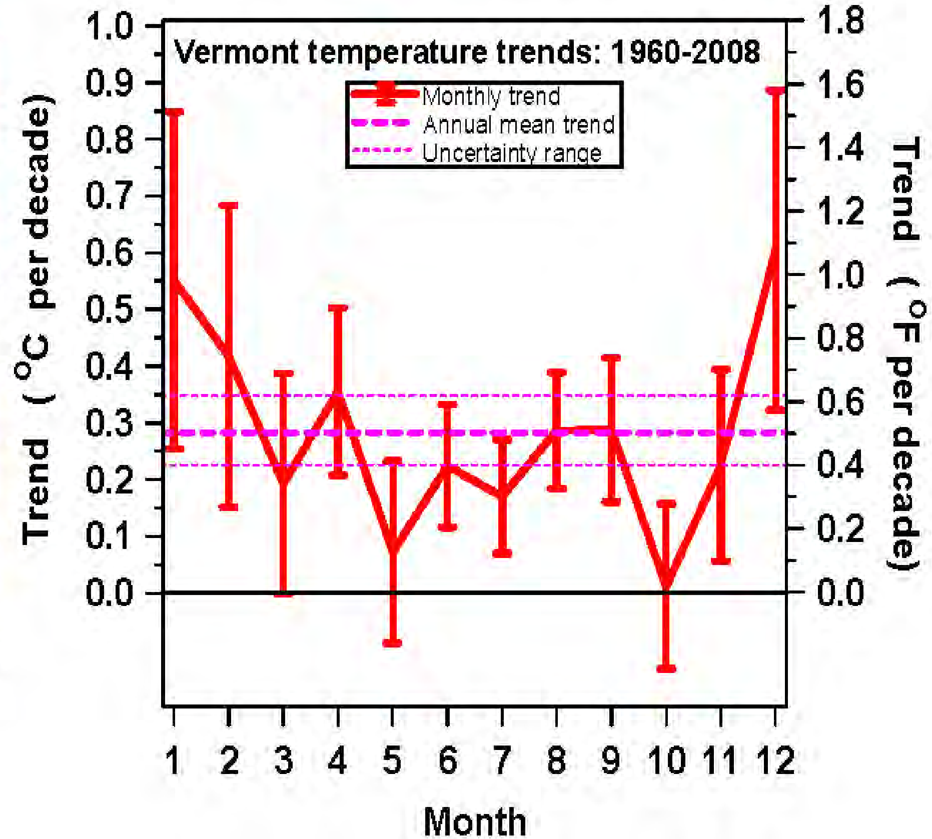
- Warm and cold seasons (frost) comparable in length

- Shift of +1°C relative to freezing is significant



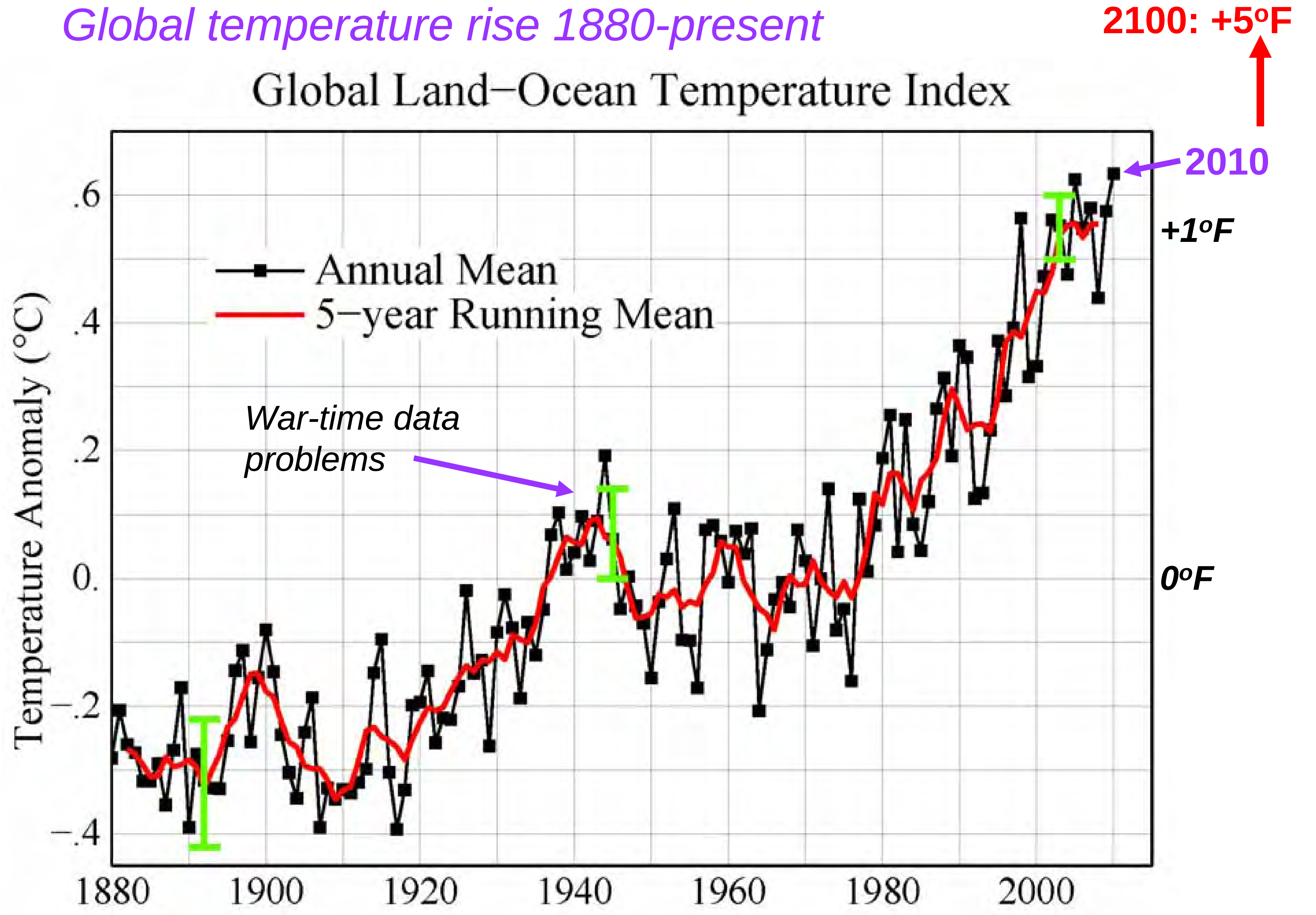
Vermont temperature trends





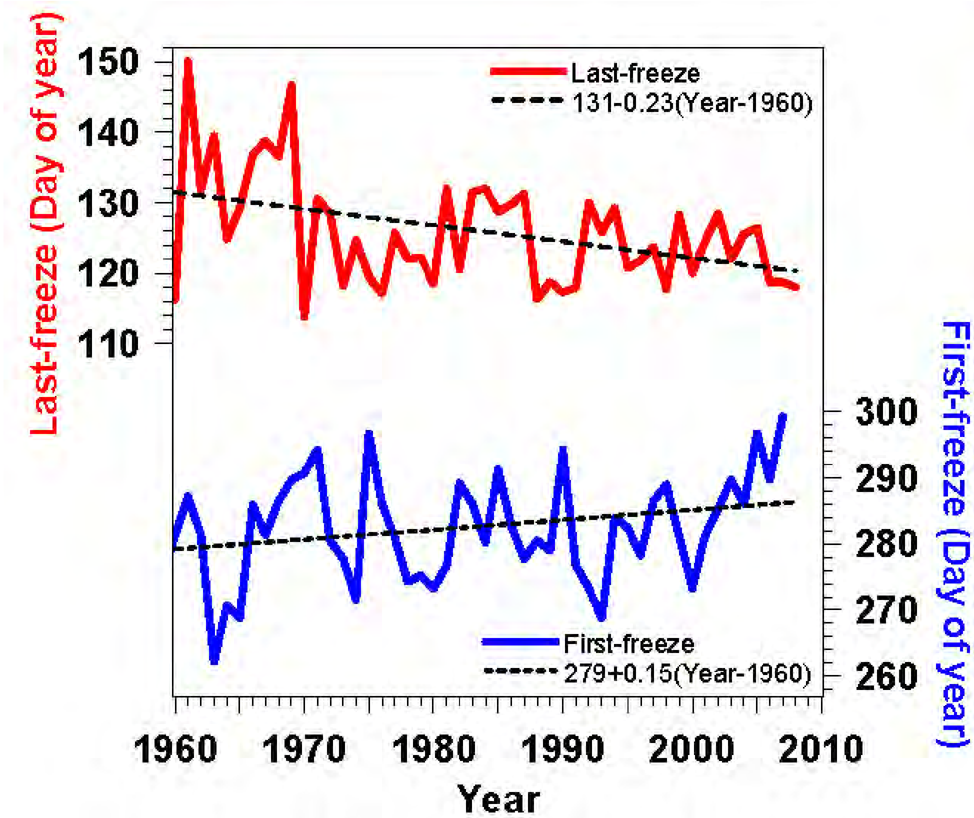
- ***Warming twice as fast in winter than summer***
- summer +0.23^{o}C (0.4^{o}F)/decade
- winter +0.5^{o}C (0.9^{o}F)/decade (note larger variability)

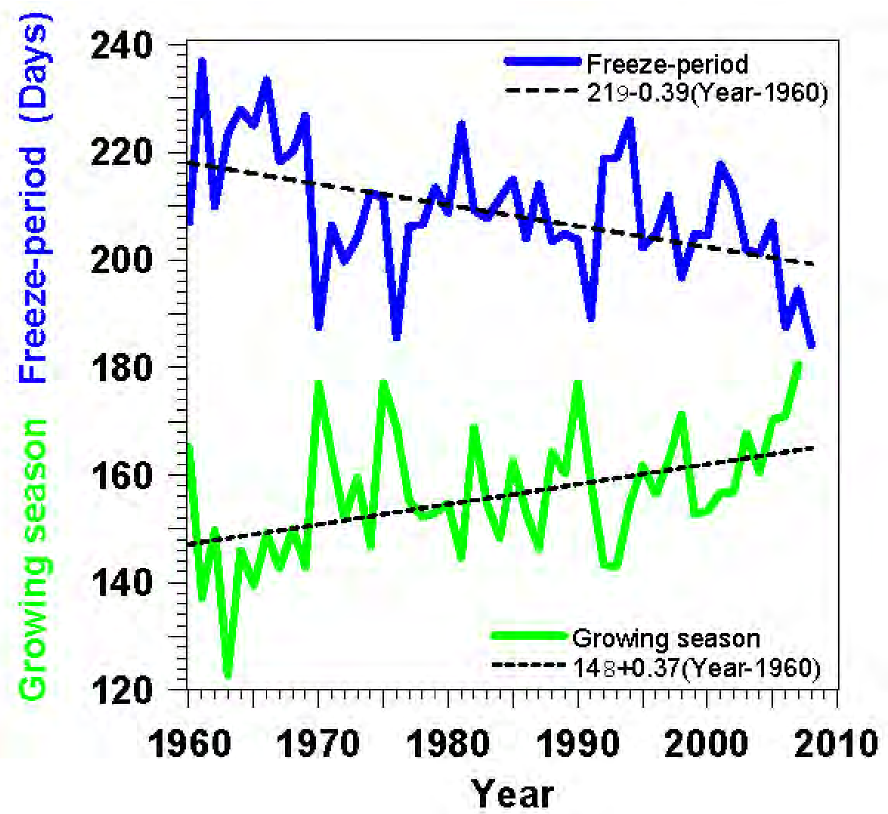
Global temperature rise 1880-present



NASA-GISS, 2011

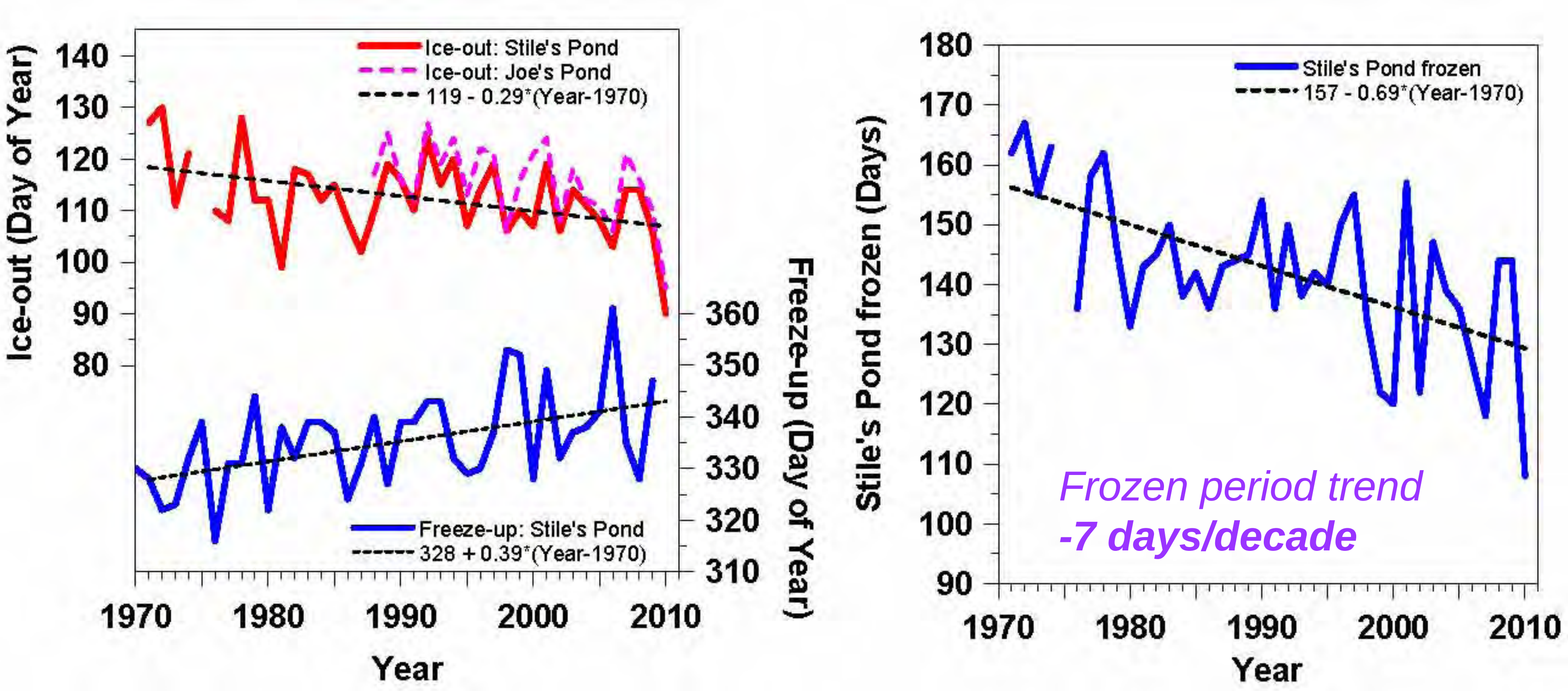
First & last frosts changing





- *Growing season for frost-sensitive plants increasing 3.7 days/decade*
- *Large interannual variability*

Lake freeze-up & Ice-out changing – *frozen period shrinking fast*

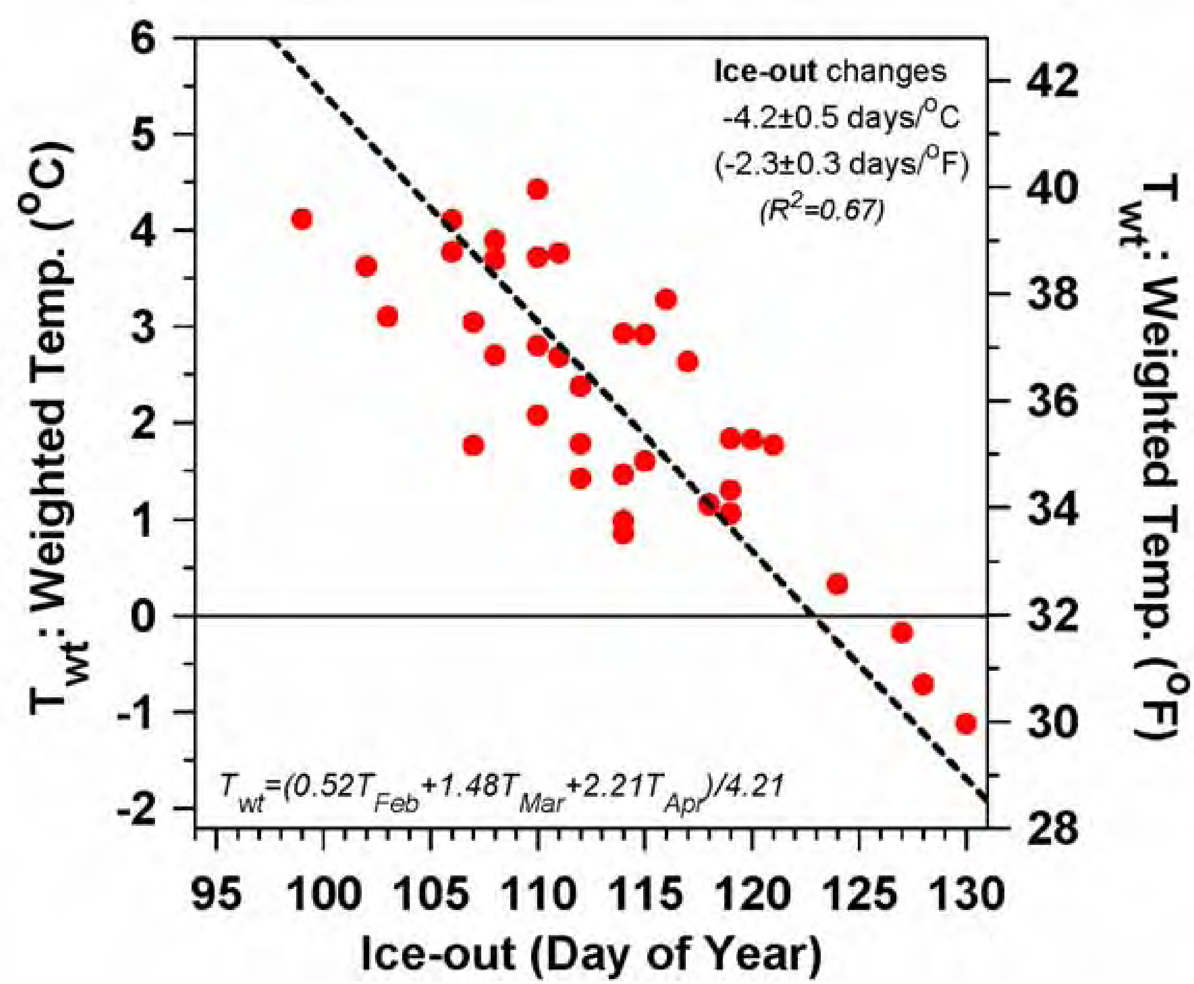


- *Ice-out earlier 3 days/decade*
- *Freeze-up later 4 days/decade*

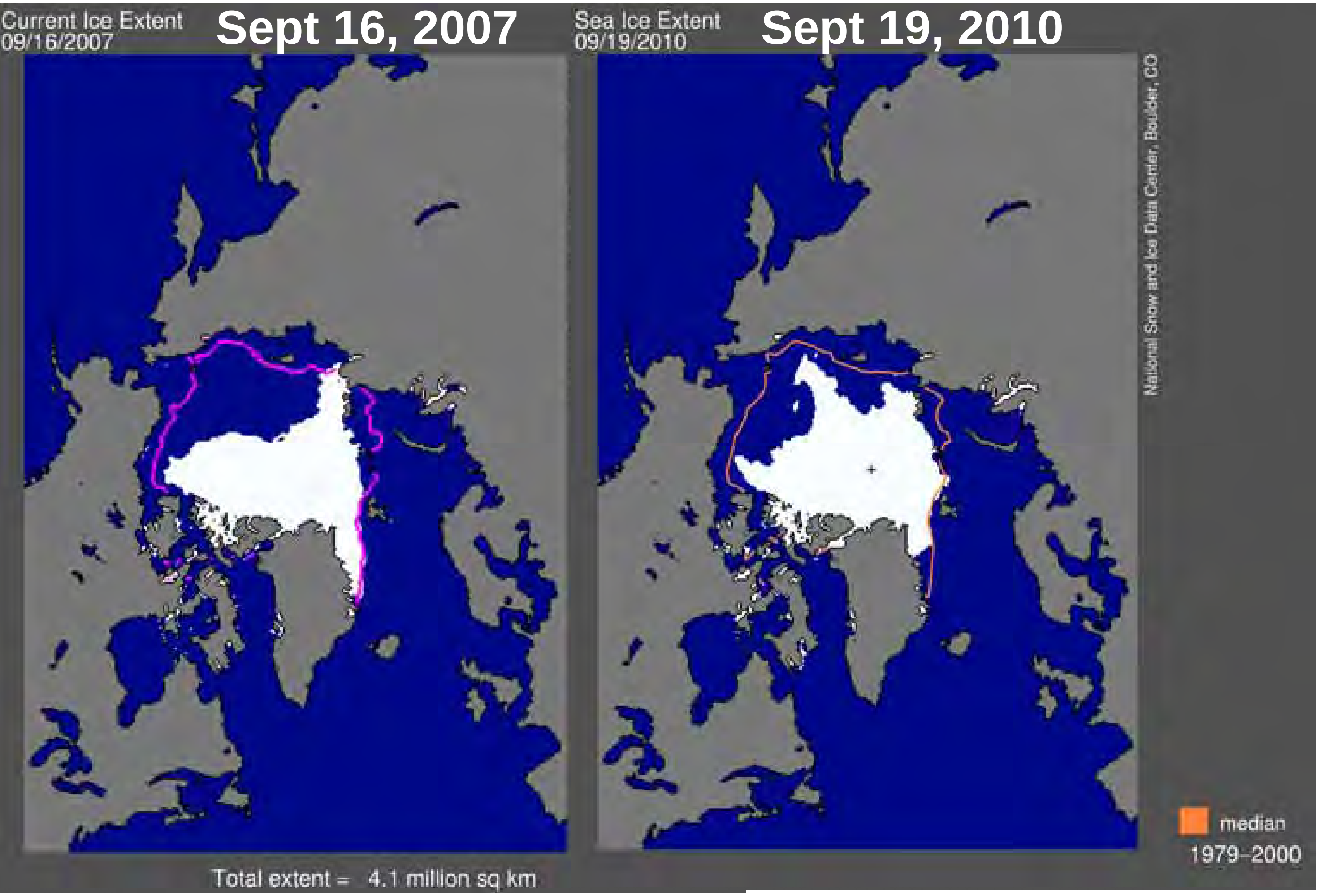
Interannual variability of Ice-out related to Feb-Mar-Apr temperatures

- Ice-out changes by -4.2±0.5 days/°C

- *T_{wt} is weighted Feb-Mar-Apr temperature derived from multiple linear regression*



Feedbacks are accelerating Arctic sea-ice loss



Feedbacks - speed melting

-less ice, less sunlight reflected

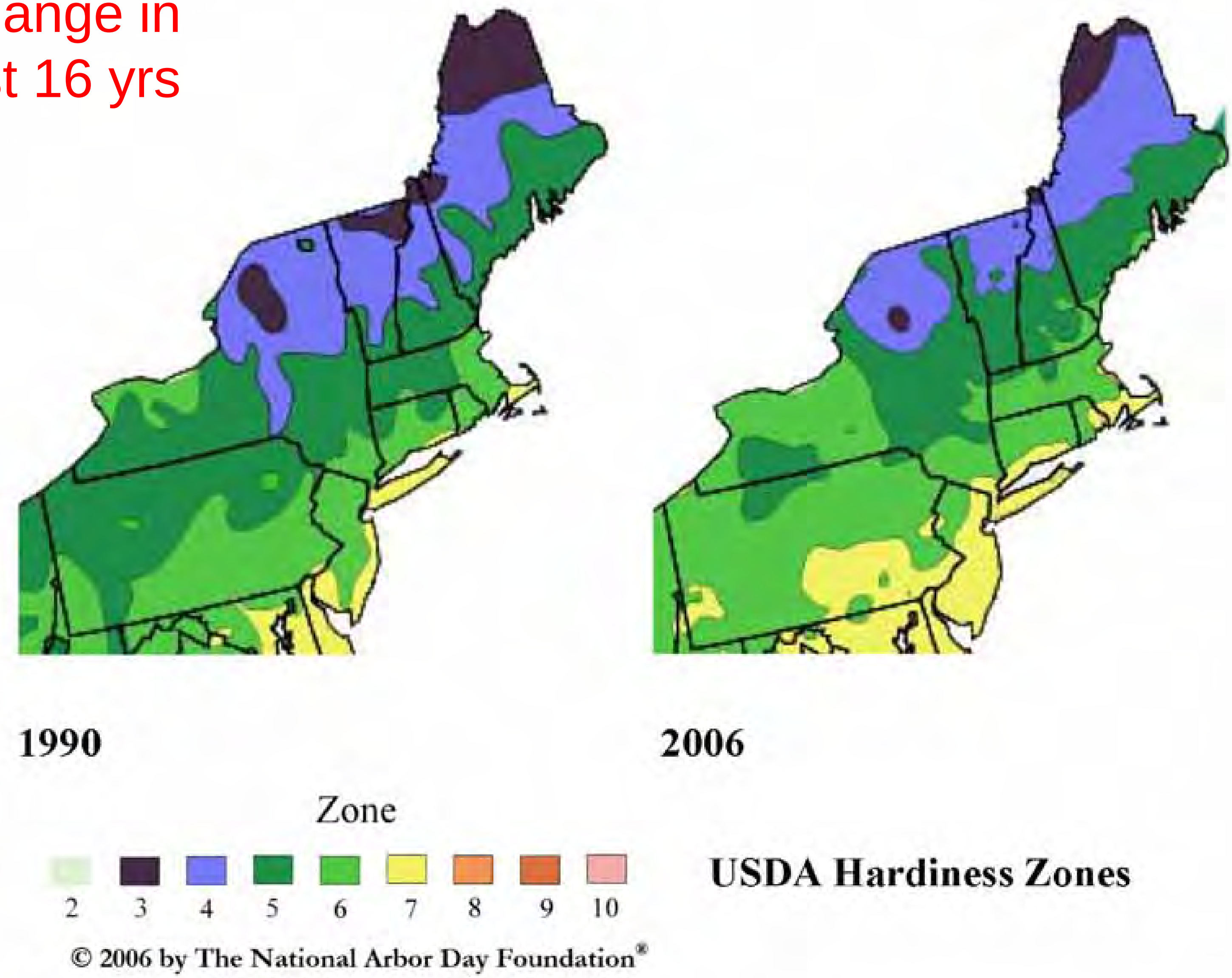
-more evaporation, larger water vapor greenhouse

(www.nsidc.org)

- ***Open water in October contributes to warmer Fall in New England***

USDA Hardiness Zones - Northeast

Change in
last 16 yrs



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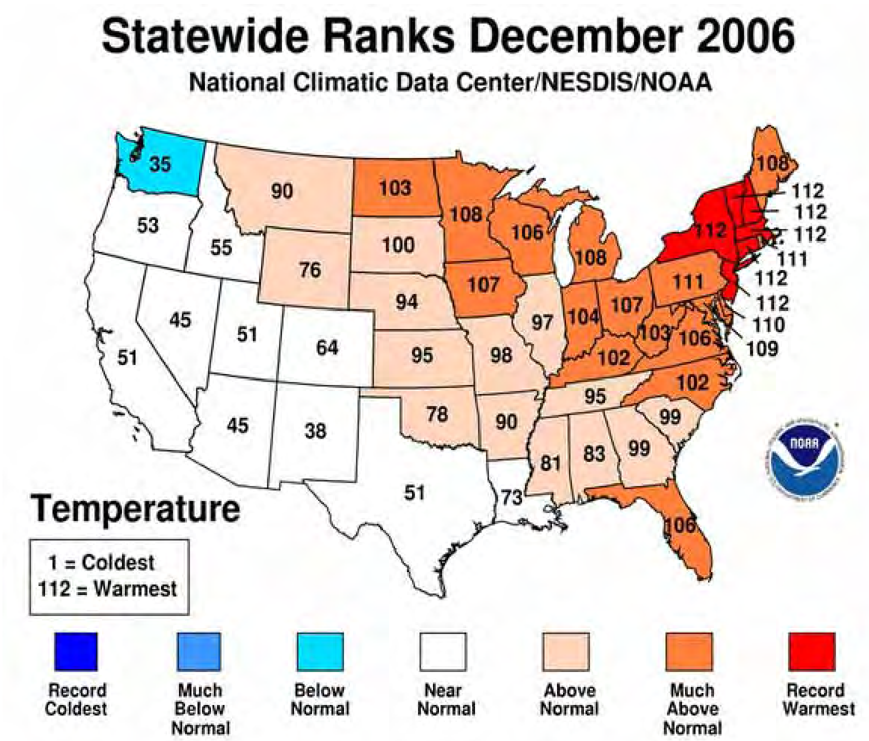

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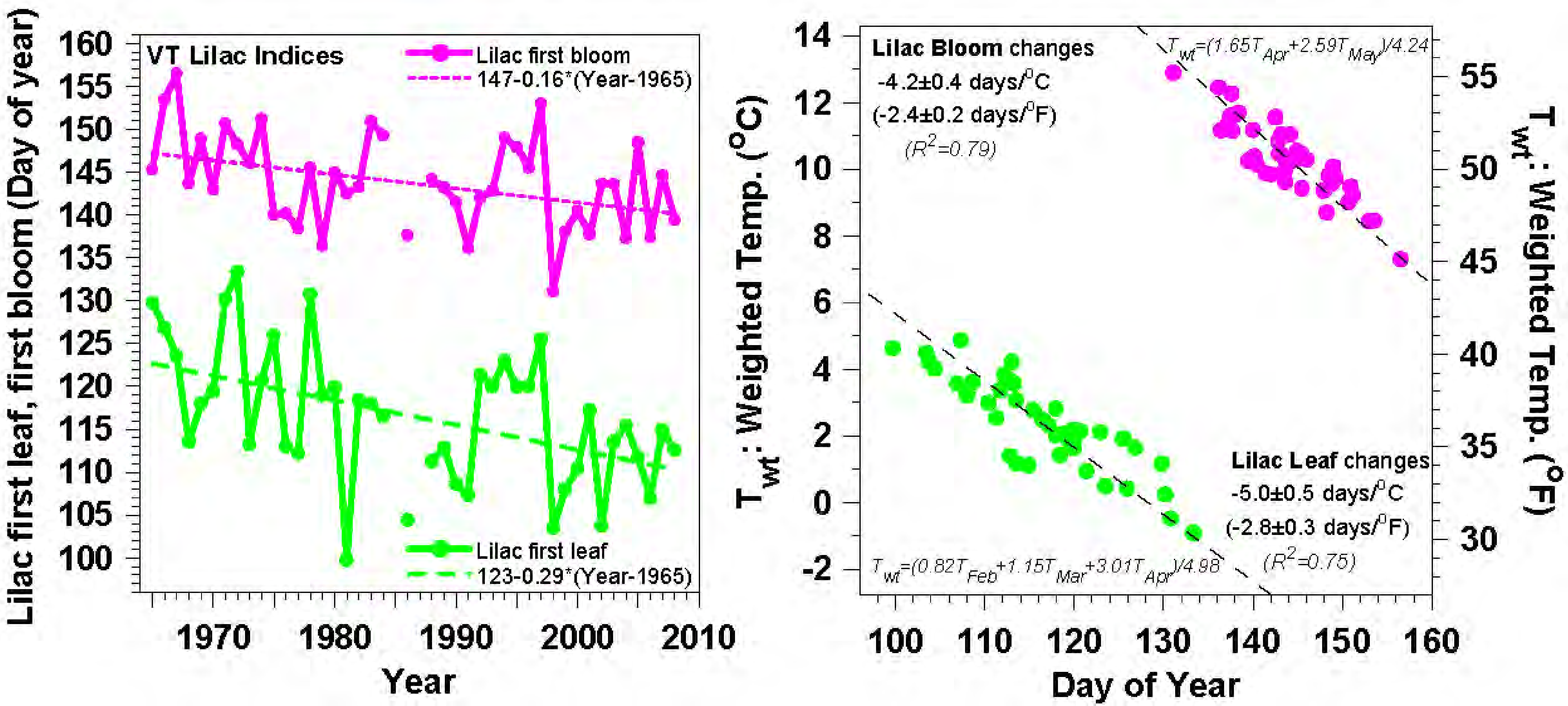
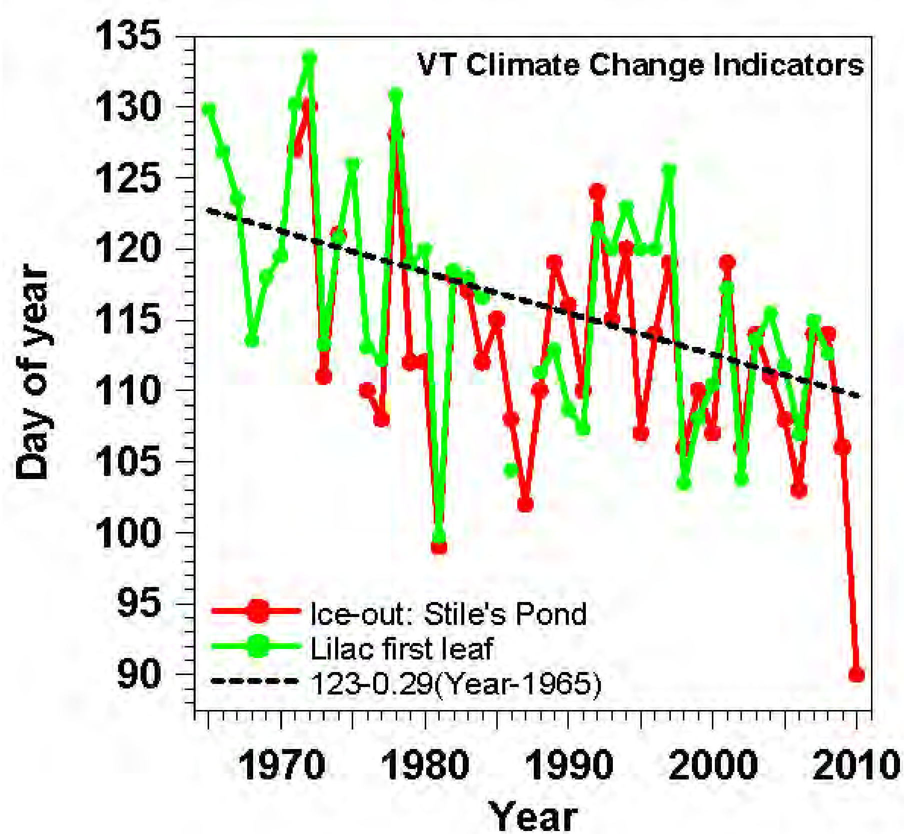
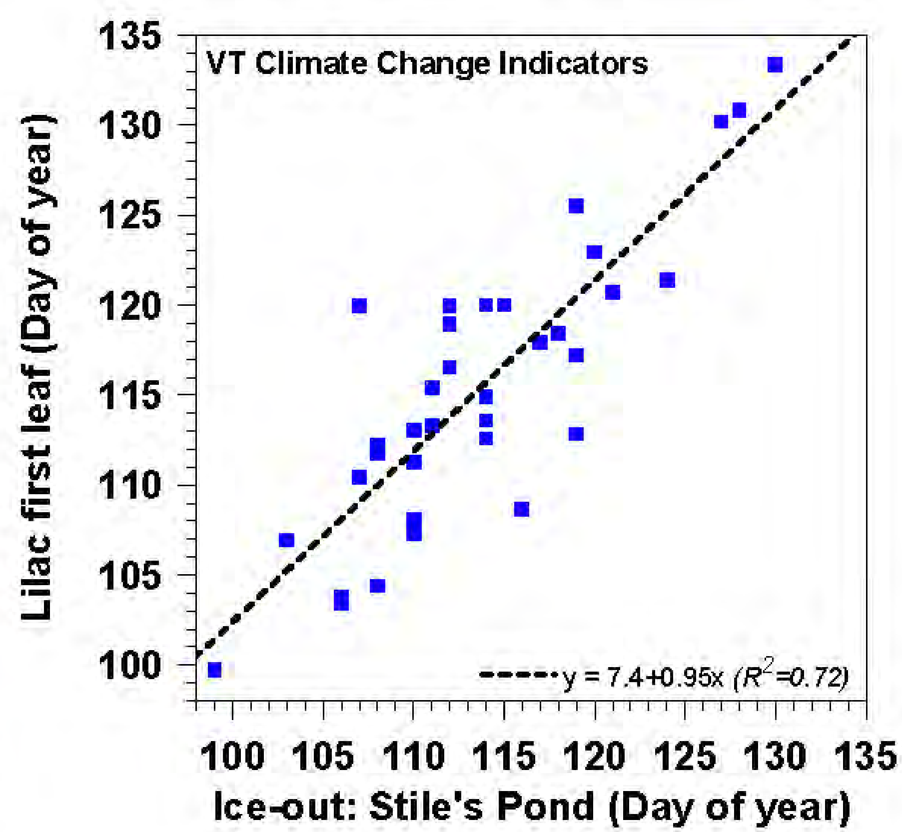
Lilac leaf and bloom in spring



- Leaf-out trend: -3 days/decade
- Bloom trend: -1.5 days/decade
- Leaf & bloom dates change by 4 to 5 days/ºC

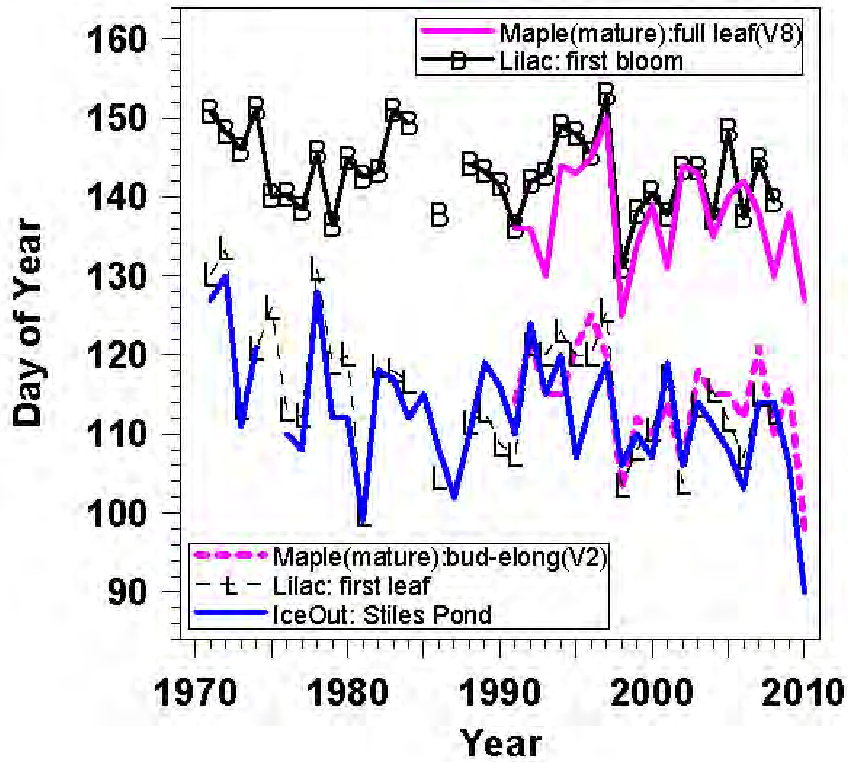
Lilac leaf-out and Ice-out coupled

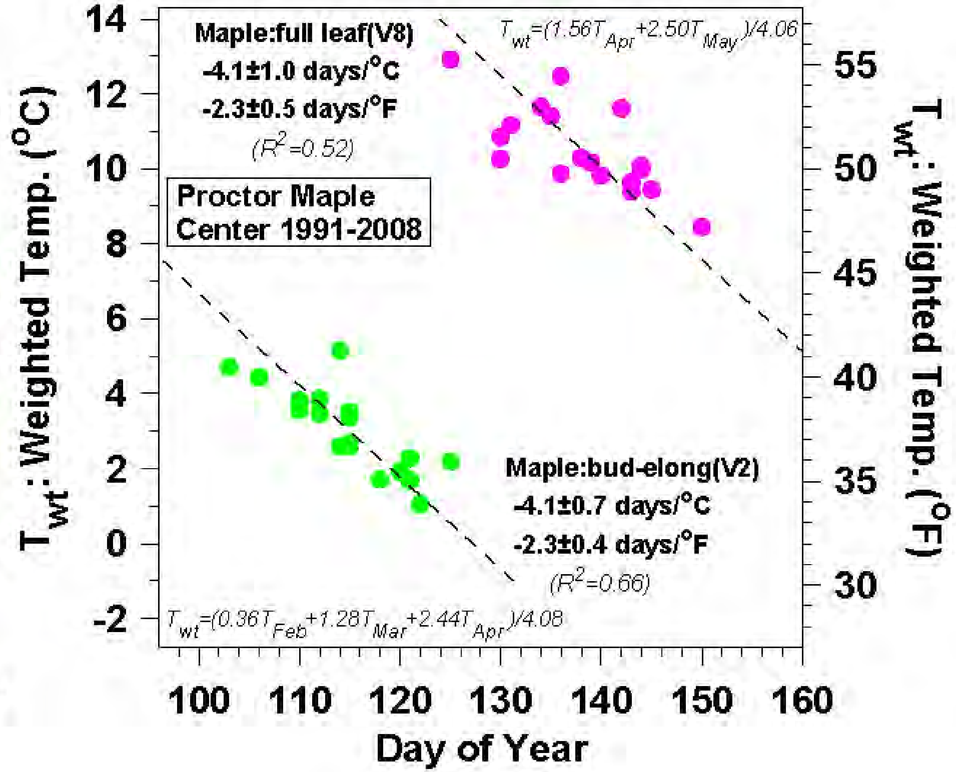




- *Lilac leaf and lake ice-out depend on Feb-Mar-Apr temperatures*
- *Both indicate trend to earlier spring*

Maples and Lilacs in spring





- ***Maple bud elongation mirrors lilac leaf-out***
- ***Maple leaf-out mirrors lilac bloom***

2. Conclusions

- **Coherent picture of shrinking of winter ‘frozen’ season by 7 days/decade and lengthening of growing season**
- **Ice-out and spring phenology linked**
- ***Observables familiar to VT communities deepen understanding and acceptance of the reality of climate change***
- **Provide a basis for community discussion and adaptation planning *[along with hydrologic indices and model projections]***