Climate & the NE Seasons

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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"**
- **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?

- **Pictorial strategy, 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*

Spring transition

- Warm dry week to ten days in Spring, after snowmelt, past equinox
- 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 4/15/2008

- *Weather:*

  Sunny, dry week

- *Climate:*

  After snowmelt before leaf-out 'warm & dry' (little evaporation)

- *Climate change:*

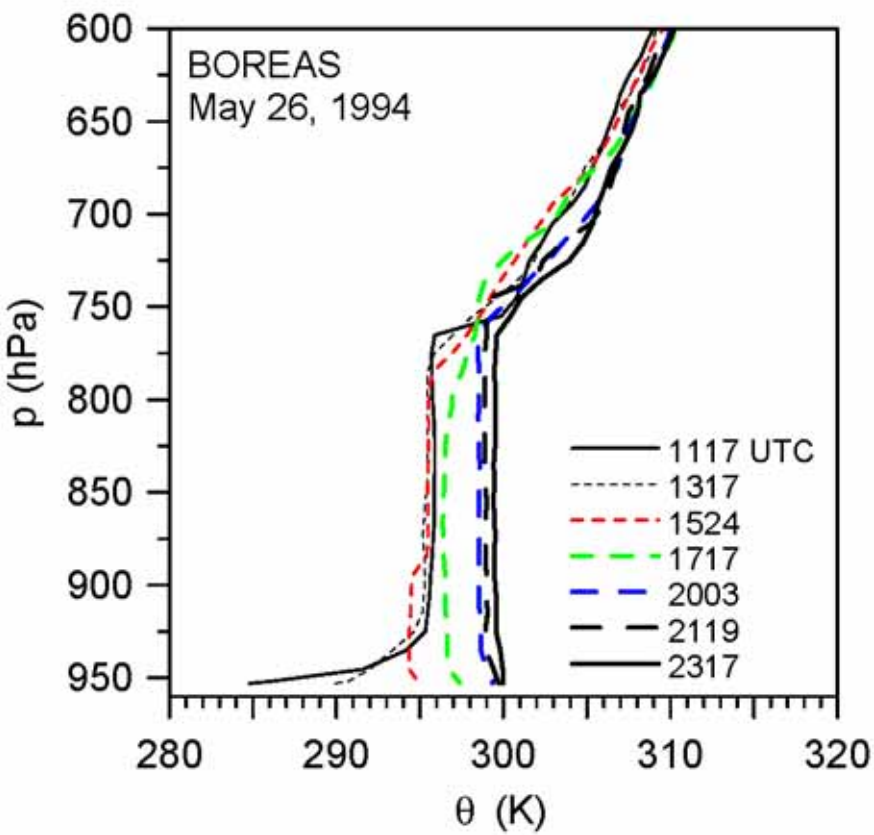
  'Spring' earlier than 30 years ago

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

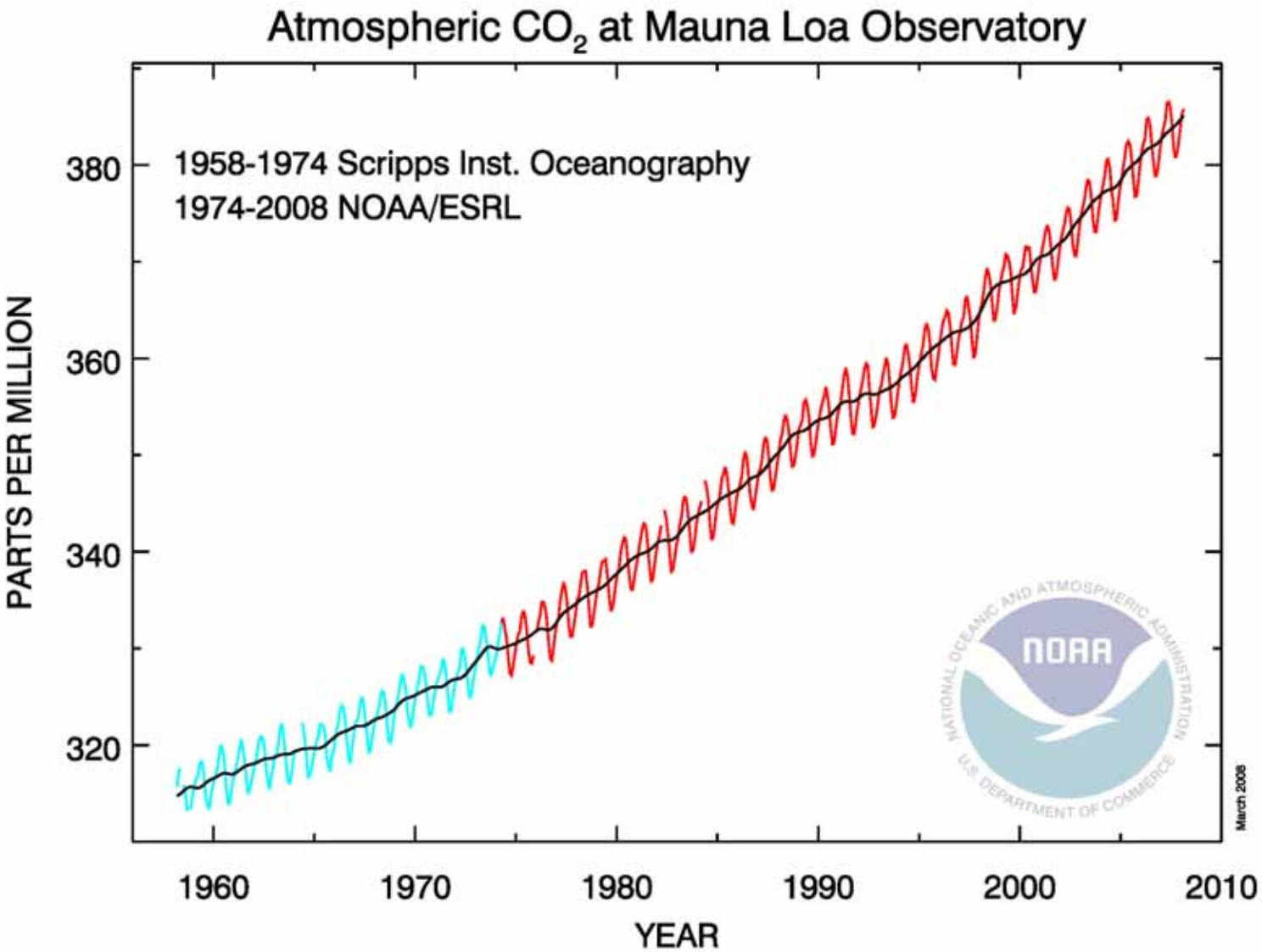
- Longer seasonal lag than NE



Photosynthesis: northern summer

- **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 summers

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

Farmer's delight

- Wet in spring
- Summer dry-down
- Low RH & no rain
- Hay dries fast!

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} → 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

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^{o}F warmer - so oceans don't freeze
- Increasing greenhouse gases are warming earth further: $\approx$ 5^{o}F this century, unless emissions reduced

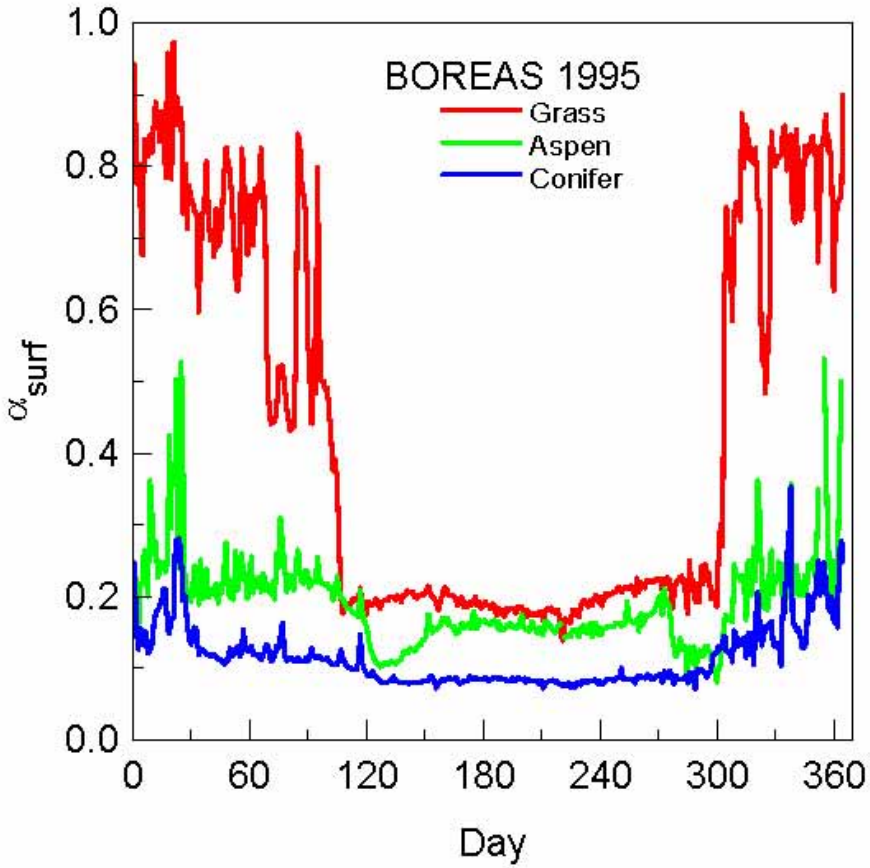
Winter transition

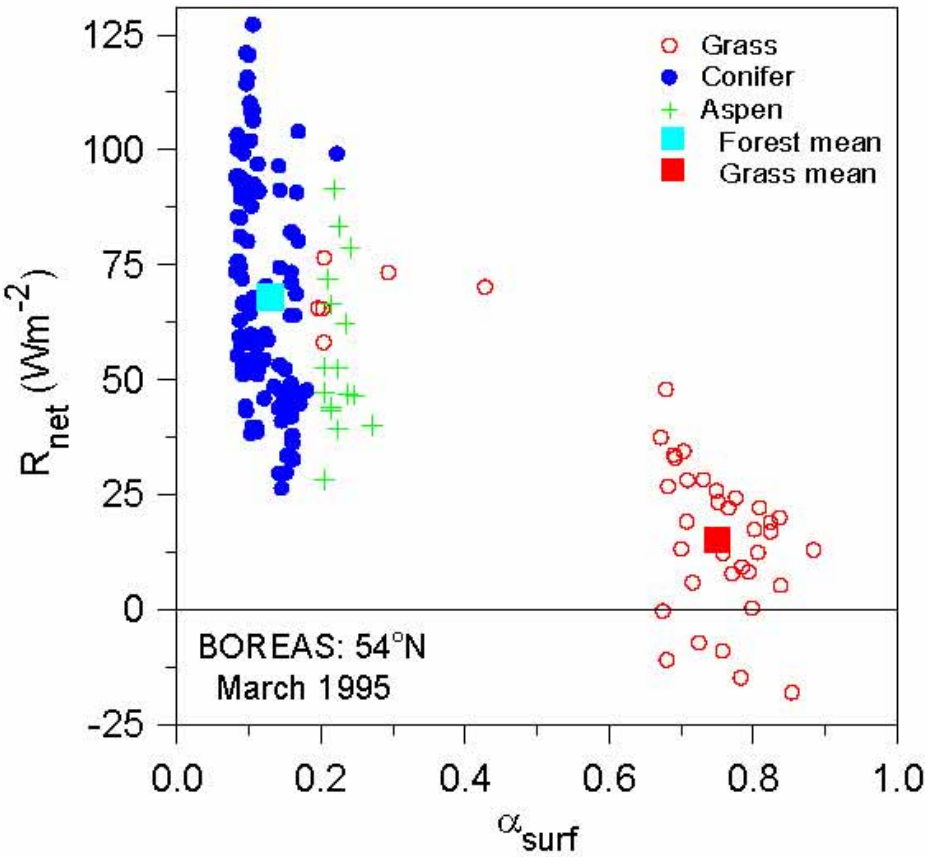
- First heavy snow brings plunge of Temp. because reflection of sunlight drops net radiation below zero – *[plus reduced water vapor greenhouse]*
- Related to snow/ice-albedo feedback in climate system
- Related to accelerated warming & melting in the Arctic
- *Sublimation of snow by residual SW_{net} 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*

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

Vermont winter, 2006

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

January 7, 2007

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

Gardening in Pittsford, VT in January

Jan 7, 2007

December, 2006, *warmest on record*

[since 1894]

Jan 10, 2008

Warm Fall, *record Arctic sea-ice melt*

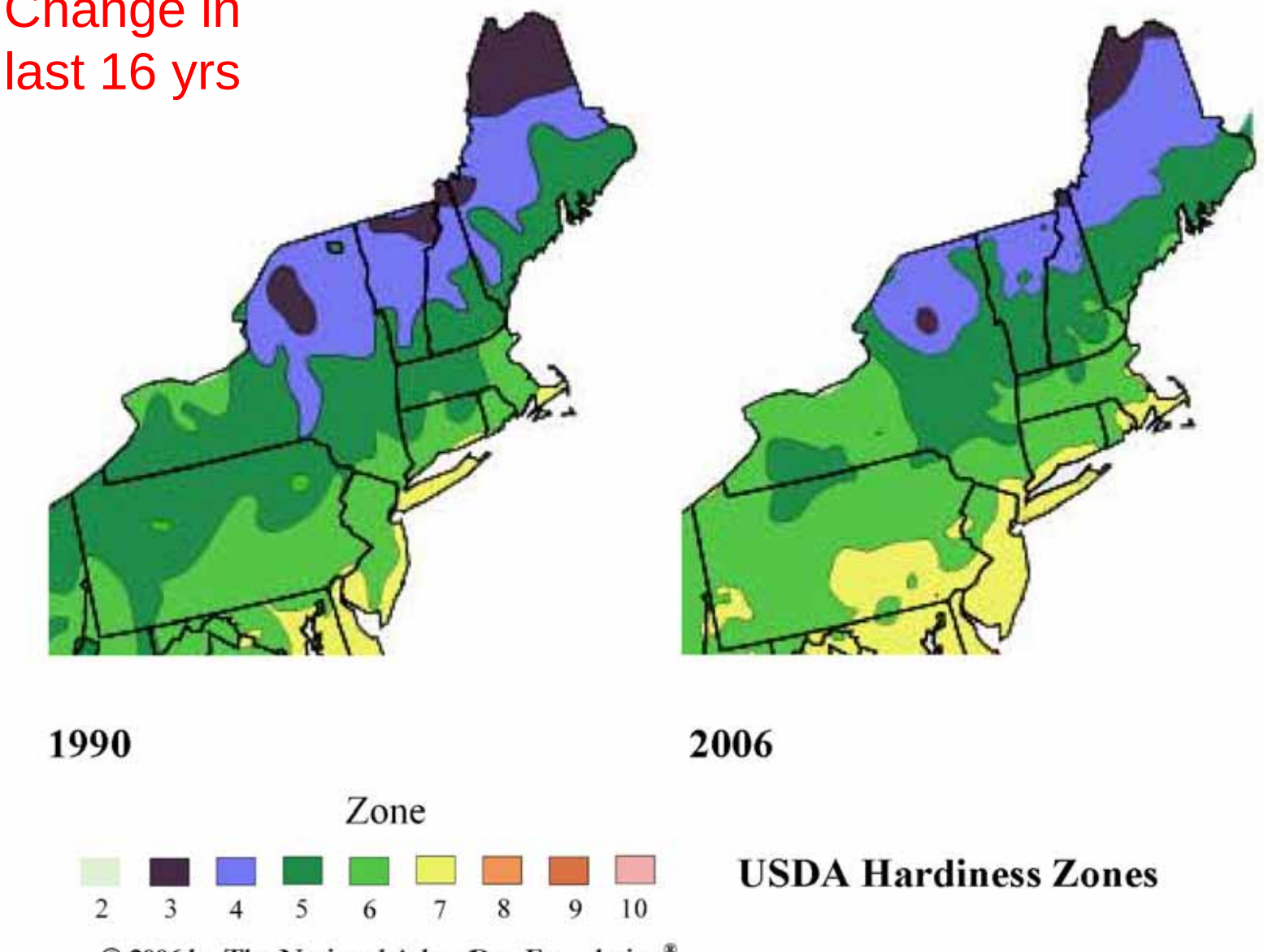
Snow cover in December, ground unfrozen

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

Picked February 10, 2008, Pittsford, VT

USDA Hardiness Zones - Northeast

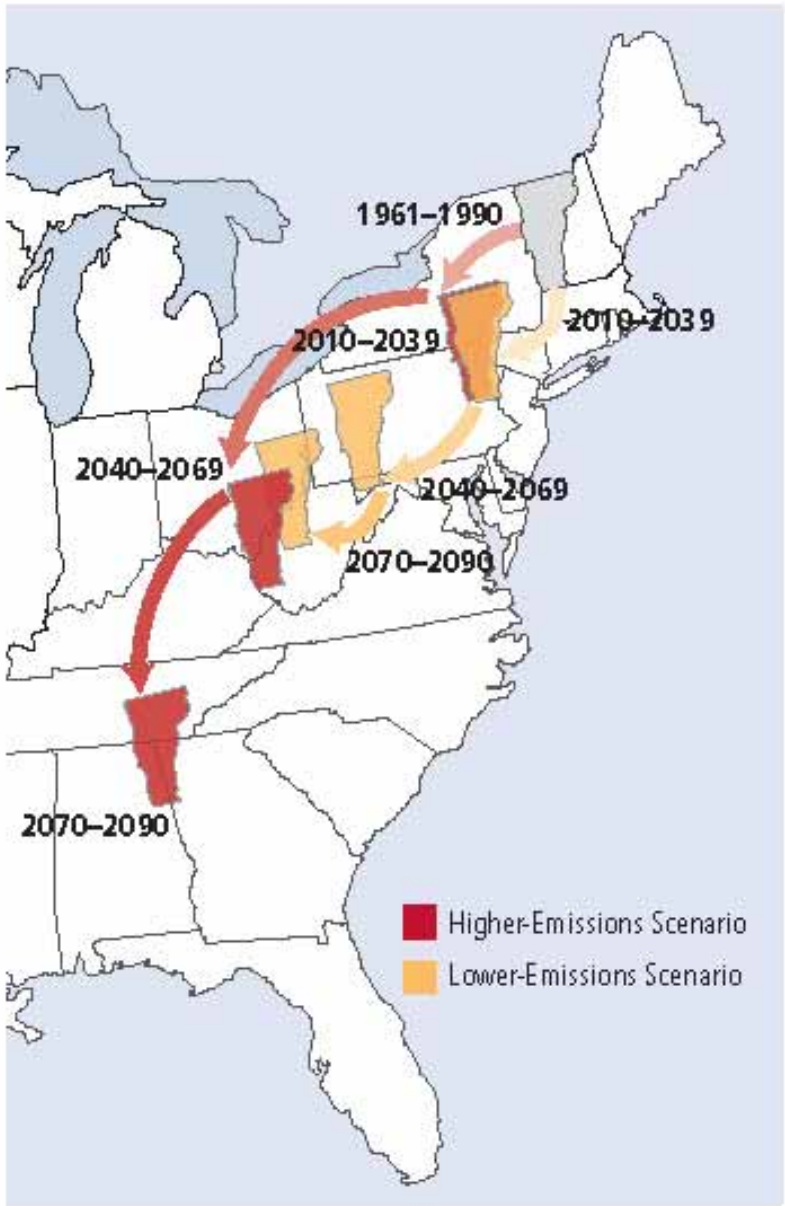
Change in
last 16 yrs



Vermont's future with high and low GHG emissions

Red is high emissions

What about the tropics?

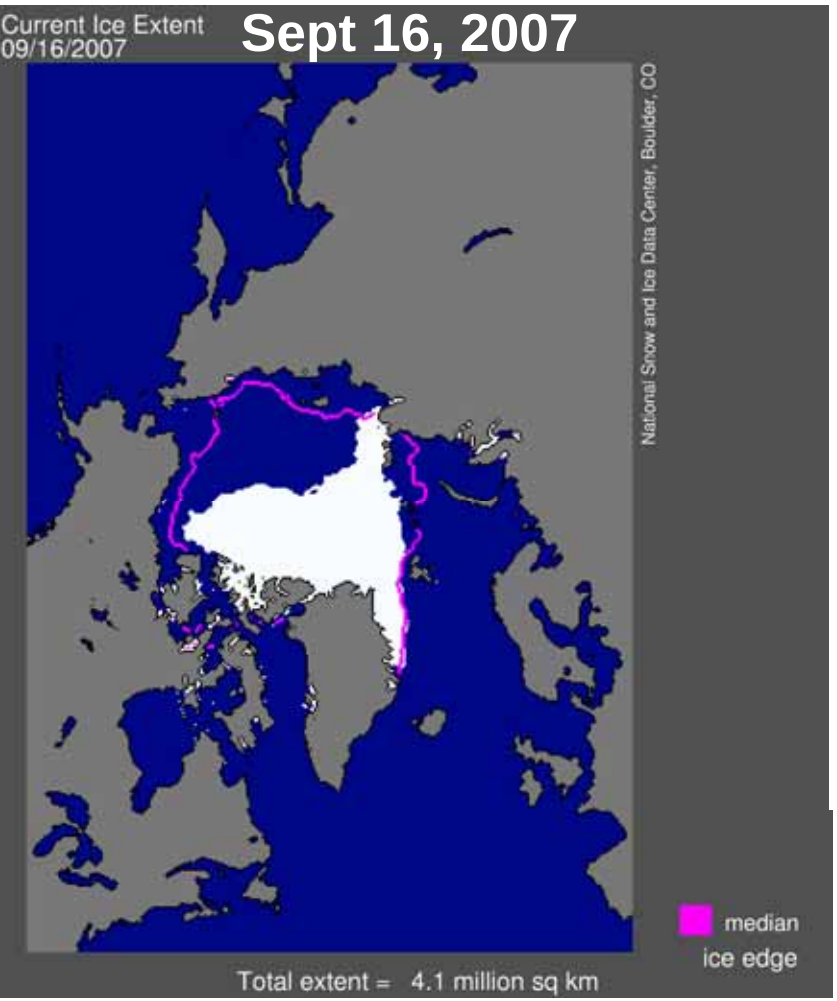


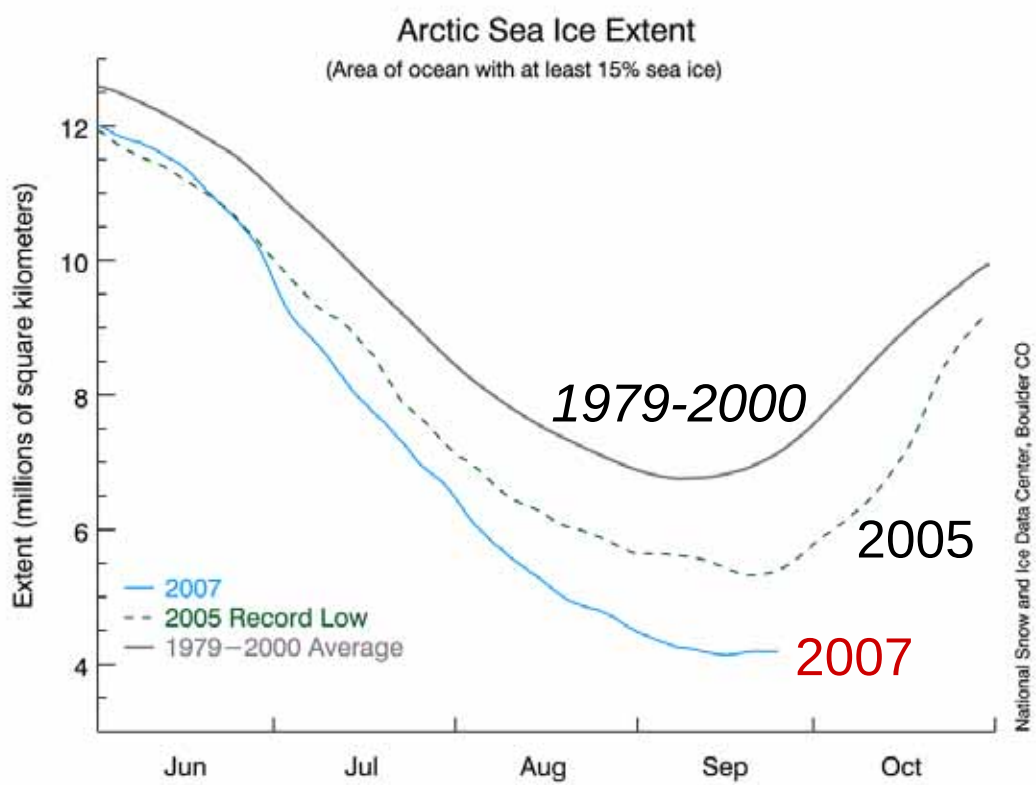
Migrating State Climate

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



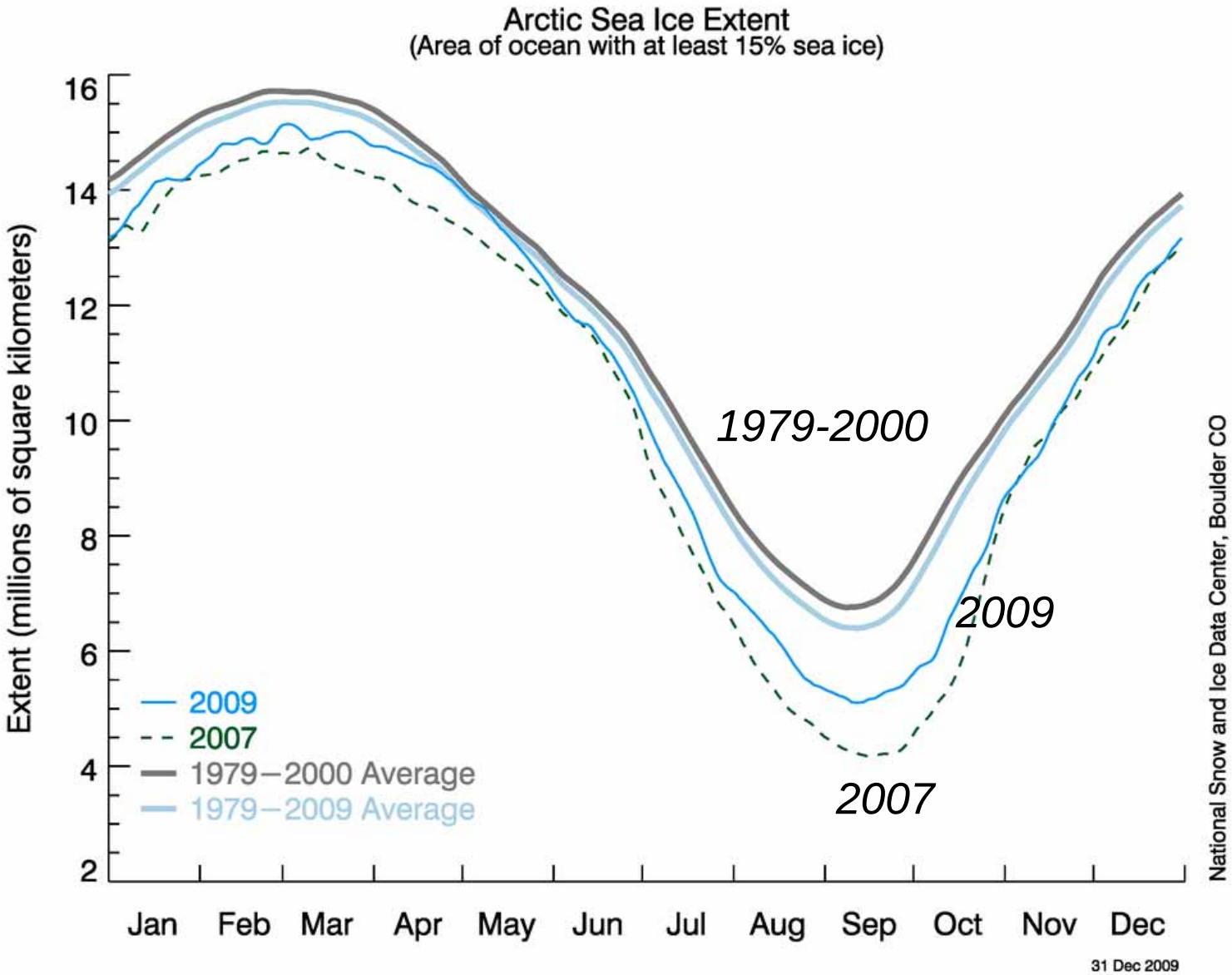


Double feedback: loss of reflective ice and increased water vapor greenhouse from more evaporation

(www.nsidc.org)

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

2007 and 2009 Sea-Ice



Conclusions

- Understanding seasonal climate transitions helps us understand key climate processes

- These can be seen locally; and this helps us grasp the global impacts on the earth

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

(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