Climate Change: How is it affecting us? What can we do about it?

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Outline

• As climate changes
  • What is happening to Vermont?
  • What is happening to the Earth?
  • Discussion

• Can we slow down changes?
  • How can we stabilize the climate?
  • Why is it difficult?
  • How do we deal with it?

Discussion
Earth’s climate sustains life

- Burning fossil fuels is increasing greenhouse gases
- Climate is warming: ice is melting, extreme weather is increasing
- Water plays crucial amplifying role
- Planetary modes crucial
Vermont was cold – with a lot of snow cover
Jan-Feb-Mar 2016

Vermont was warm – with little snow cover
Snowfall and Snowmelt

- Temperature falls 18°F (10°C) with first snowfall
- Reverse change with snowmelt
- **Fast transitions in ‘local climate’**
  - Snow reflects sunlight
  - Reduces evaporation and water vapor greenhouse
More snow cover - Colder temperatures

Alberta, Canada October to April

Freezing

$T = 3.9 - 14.6 \times FDS \quad (R^2 = 0.79)$

Betts et al. 2014
• **Above freezing:** Clouds reflect sunlight
  – Less cloud, much warmer in afternoon
• **Below freezing:** Clouds are ‘greenhouse’
  – Snow reflects sun
  – Less cloud, temperatures fall at night, very cold at sunrise
Vermont Temperature Trends 1961-2008

- Summer +0.4°F / decade
- Winter +0.9°F / decade
- Larger variability, larger trend

Less snow (and increased water vapor) drive larger winter warming
Lake Freeze-up & Ice-out Changing
Frozen Period Shrinking: variability large

• Ice-out earlier by 3 days / decade
• Freeze-up later by 4 days / decade
• Lake frozen trend - 7 days/decade
October 2011– March 2012

- Warmest 6 months on record
- My garden frozen only 67 days

- January 15, 2013
- Jan 2014, 2015 frozen
February 5, 2016
(Digging in Feb. first time ever)
Discussion

What have you seen in your lifetime?
2011: IRENE woke up VT
What is happening to the Earth? And why?
• 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

Watch 2016 at
http://nsidc.org/arcticseaicenews/
Carbon Dioxide Is Increasing

Atmospheric CO$_2$ at Mauna Loa Observatory

Scripps Institution of Oceanography
NOAA Earth System Research Laboratory

Winter
Summer

Upward trend
+ 2ppm/ year
Rise of Greenhouse Gases (GHG) Shift Energy Balance of Planet

- The atmosphere is transparent to light from the sun, but not to infrared radiation from the earth.
- **GHG:** $\text{H}_2\text{O}$, $\text{CO}_2$, $\text{CH}_4$, $\text{O}_3$, CFCs trap the infrared from the surface, giving climate suitable for life by warming planet 60°F.
- Rise of $\text{CO}_2$ alone has only a small warming effect.

BUT…
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
Growth of CO$_2$ is Driver: peaking?

- 3%/year

Need 80% drop by 2050

Where is CO$_2$ increase coming from?

Projection 2015
35.7 Gt CO$_2$
-0.6% decline
(-1.6% to +0.5%)

2014: 35.9 Gt CO$_2$
+0.6% increase

- 3%/year
Growth of CO$_2$ Emissions Slowing

- CO$_2$ emissions way too high but
- Declining in US and EU
- Reached peak in China

- Why did China grow so fast in 2000’s?
- Why has China peaked?
Discussion

What is happening and why?

How fast can we cut burning of fossil fuels?
Predicted Change in Temperature
2020-2029 and 2090-2099, relative to 1980-1999 (°C)

“Committed”
(We did nothing for the last 20 years)

Still up to us!
(We could halve this if we act now)
Vermont’s Future with High and Low GHG Emissions

What about VT forests?

Sub-tropical drought areas moving into southern US

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.
Global Climate Change

• One of the many great challenges for the 21st century - present path is unsustainable

• Known about it for 35 years:
  – First National Academy of Science Report in 1979

• Earth science conflicts with political values (and vested interests in fossil fuel economy)
Efficiency Comes First

• We need to double or triple our energy efficiency because…
  
  • We cannot replace current fossil fuel use with biofuels & renewable energy
  
  • Oil and gas reserves are limited, but coal, shale-gas & shale-oil reserves are sufficient to push CO$_2$ to 1,000 ppm — back to hothouse climate that will melt icecaps
  
  • Need to leave 1/3 oil; 1/2 gas; 4/5 coal in ground
Why Is It Difficult for Us?

• Fossil fuels reserves are worth $20-30T
  – Regulating emissions of CO$_2$ is an “unfair cost” to the “free market”
  – Carbon tax needed to change economics

• Political conflicts
  – Prefer to ignore climate issues
  – Society ignores future costs
    • Manhattan within 1-ft of flooding with Irene
    • Did they put waterproof doors on tunnels?
      – NO! Sandy did $5B of damage to subway system
Why Is It Difficult for Us?

• The “American dream” is crumbling
  • “Economic growth” based on fossil fuels, debt, and consumerism is unsustainable
  • Global market capitalism is disaster for the planet

• Individual “rights” and the needs of humanity must be balanced against the needs of the earth’s ecosystem

• We don’t know how to guide and manage technology —so the result is tremendous successes and catastrophic failures
Technology can Minimize Impacts

• Minimize the lifetime of human waste products in the Earth system and eliminate waste with critical biosphere interactions

• Minimize use of non-renewable raw materials

• Maximize recycling and re-manufacturing

• **Maximize efficiency** of energy use and fresh water use

• Maximize the use of renewable resources

• *(Earth needs priority over short-term profit)*
Change of Attitude Needed?

• Do we just exploit the Earth’s wealth
  – For greater ‘economic growth’
  – For a wealthy few
  – What is left for our children?
  – What happens to the ecosystems we depend on?

• Moral Issue
  – Don’t we need to co-operate with the Earth?
  – Shift in understanding and mind-set needed
2015 was Transition Year

• Climate meeting in Paris in December
  – 196 nations made commitments to cut emissions
  – Now need follow-through!

• First Papal Encyclical on the environment, climate change, our responsibilities to the Earth
  – Shifts the position of the churches
  – Shift from short-term profit as primary motive

• New values that respect the Earth
What do you agree with?
Disagree with?
What matters to you?
What do we need?
Technical solutions

- Electrical power
  - Renewable: solar, wind, hydro
  - Storage: lithium batteries down to $150/kWh
  - Electric car industry will generate massive storage

- New technologies: electricity to liquid fuels

- Net-zero housing: need standards

- **Rethink transport: hard for us!**
  - Shipping all over the world? Or local suppliers?
Radically change ‘transport’

100W Solar panel
From heavy SOVs to light vehicles with separate lanes/roads

Danish electric tricycle
Other paths for transport?

• Smart phone/GPS ride sharing on Vermont roads.
  – We have the App (Uber): China is trying!

• Electric cars
  – Continue with old – just a bit lighter!
  – Chevy Bolt: 200 mile range for $30K this fall (?)
What about the rest of the world?

- Solar power for light, cell phones and internet and critical refrigeration (clinics)

Columbian Kogi and Arhuaco tribes have come to believe that solar power complements their spiritual connection with nature and need to protect it.
The Future Is Not Our Past

- Collectively, we create the future, so we need to plan for a transition to a sustainable society.

- In the face of a powerful economic and financial system driven by short-term profit.

- Needs deep community discussion:
  - New values *that respect the Earth*.
So let us dream
And act!

(http://alanbetts.com)
What Do We Need?

• So we need **honest, truthful, smart** pathways forward
  • That will **not frighten people into paralysis**
  • That will **spread hope, not anger or despair**
  • That sidestep ideological barriers **with new language**
  • That **develop adaptive governance**
    • The US Constitution gives no rights to the Earth

• That **respect Earth system limits**

• That **accept our moral responsibilities**
Very Heavy Precipitation Is Increasing

(USGCRP, 2014)

- **Precipitation Extremes**

- Most of the observed precipitation increase over the *last 50 years* comes from increasing frequency and intensity of heavy downpours.

- **71% increase in Northeast**
2011 Floods: VT and NY

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

March-August 2011 Statewide Ranks

- Record wet: OH to VT
- Record drought: TX & NM
- ‘Quasi-stationary’ pattern
Impact of Snow on Climate

Separate mean climatology into days with no-snow and snowdepth >0

$$\Delta T = T:\text{no-snow} - T:\text{snow} = -10.2(\pm 1.1) ^\circ \text{C}$$

Betts et al. (2016)
Climatological Impact of Snow: Vermont

Separate mean climatology into days with no-snow and with snow

Difference $\Delta T = -6.1(\pm 0.7) ^\circ C$

$= -11 (\pm 1.3) ^\circ F$

Less than Prairies: Vermont has more forest
• Leaf-out -2.9 days/decade; Bloom -1.6 days/decade
• Year-to-year variation coupled to temperature
  – 4 to 5 days/ °C: (No-snow – Snow) winter = 6*5 ≈ 30 days!
First and Last Frosts Changing

- Growing season for frost-sensitive plants increasing 3.7 days / decade
- A help for growing “local food”