Global and Local Climate and our Future

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BREE Intern Orientation
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Outline

• **Science of climate change**
  • Global and local
  • What is happening to Vermont?

• **The transition we face**
  • How can we stabilize the climate?
  • What are scientists’ responsibilities?

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
Jan-Feb-Mar 2015

Jan-Mar 2015

L-OTI(°C) Anomaly vs 1951-1980

0.86
Jan-Mar 2016

L-OTI(°C) Anomaly vs 1951-1980

1.24
Snowfall and Snowmelt

- Temperature changes 10°C with snow cover
- Snow cover is a ‘climate switch’
  - 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

Mean Temperature (°C)

Mean Temperature (°F)

Fraction of Days with Snow Cover

T = 3.9 - 14.6 * FDS (R² = 0.79)

Betts et al. 2014
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)
Clouds, Snow and Climate

- **Above freezing**: Opaque 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

Betts and Tawfik (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
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
STILES POND

- Ice-out earlier
  - by -3 days / decade
- Freeze-up later
  - by +4 days / decade
- Lake frozen trend
  - -7 days/decade

Steve Maleski: “Eye on the Sky”
- First leaf and ice-out changing: -3 days/decade
- Large variability linked to temperature: -5 days/°C
- (No-snow – Snow) winter = 6*5 ≈ -30 days earlier leaf-out
First and Last Frosts Changing

- Growing season for frost-sensitive plants increasing 3.7 days / decade
- A help for growing “local food”
October 2011–March 2012

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

January 15, 2013
February 5, 2016
(Digging in Feb. first time ever)
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.

NECIA, 2007
Very Heavy Precipitation Is Increasing

- **Precipitation Extremes**
- Most of the observed precipitation increase during the last 50 years has come from the increasing frequency & intensity of heavy downpours.
- 71% increase in Northeast
- *Recent study: abrupt shift in 1996* (Walsh et al., 2014)
2011 Floods: VT and NY

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

March-August 2011 Statewide Ranks

March-August, 2011

- Record wet: OH to VT
- Record drought: TX & NM
- ‘Quasi-stationary’ pattern
TS Irene

Roads in valleys

Massive damage

Some roads took months to repair

Rte 131, Cavendish
Sept, 2011
Value of Flood Plains

• Otter Creek after Irene on August 30, 2011
  – River rose ten feet: flood plain saved Middlebury
Flooding Issues

• Maintain mountain forest cover
  – Devastating floods in 1920’s, 30’s with reduced forest cover

• Manage water/pollutants on landscape
  – Maximize infiltration: urban and on farms
  – Don’t wall-in rivers

• Preserve flood plains
  – Saves downstream towns (Middlebury)
  – Stop building houses and trailer parks in flood plains
• 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**

http://nsidc.org/arcticseaicenews/
September Arctic Sea Ice Loss

Linear fit: 
-3 m² sea ice / ton CO₂

-15 m²/car/year

350 Gt/decade
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
  - Change the global circulation
Can We Stop “Dangerous Climate Change”? (UNFCCC 1992)

• **Yes:** Quickly stabilize atmospheric CO$_2$

• This means an 80% drop in CO$_2$ emissions!

• **This is possible but very difficult**
  • Fossil fuels have driven our industrial growth and population growth for 200 years
  • “Lifestyle” has become dependent on fossil fuels
  • Powerful vested interests: trillions $ at stake
2015 was Transition Year

- Climate meeting in Paris in December
  - 188 Nations made ‘national commitments’

- Pope Francis encyclical on the environment, climate change and our responsibilities to the Earth
  - Exploitation of the Earth and the poor are inseparable
  - Short-term profit as primary motive is immoral

- 2017: US wants to avoid the commitments it made; China and Europe are taking lead
Growth of CO₂ Emissions
Flat for 3 years

China shifts to renewables

China burns coal

1990–99
+1.1%/yr

2000–09
+3.4%/yr

2015: 36.3 Gt CO₂

Projection 2016
36.4 Gt CO₂

- 3%/year

Need 80% drop by 2050
What can we “safely” burn?

• Only 750 Gt more for an even chance of keeping warming below 2°C
  
  Requires leaving 2/3 of remaining fossil fuels in ground

• Only 21 years left at 36 Gt/year

• Rapid phase-down extends period
System Issues

• Human waste streams are transforming the Earth’s climate, and human and natural ecosystems

• How will this affect landscape, water supplies, food system and human health?

• What strategies and mindset are needed to mitigate, adapt and build resilience
  – Can we better manage our relation to the Earth?
  – Is this an efficient way of doing this?
  – Can we manage our waste streams better?
  – How can we adapt?
“Systems Engineering” for a Sustainable Society

• Minimize the lifetime of human waste products in the Earth system: remove dangerous wastes

• Maximize the efficiency with which our society uses energy and fresh water, and

• Maximize the use of renewable energy

• Minimize the use of non-renewable raw materials, and

• Maximize recycling and re-manufacturing
Efficiency Comes First

• We need to double or triple our energy efficiency because...
  • We cannot replace current fossil fuel use with biofuels & renewable energy
  • Fossil fuel reserves are enough to push CO$_2$ to 1,000 ppm
    • Radically change climate/wipe out many species
    • In time melt icecaps, raise sea-level >100ft
Why Is It Difficult for Us?

• The “American dream” is crumbling
  • “Economic growth” based on fossil fuels, debt, and consumerism is unsustainable — and a 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
Powerful interests are threatened

• Fossil fuels reserves are worth $20-30T
  – Big money: of course we will burn them
  – Regulating or taxing emissions of CO₂ is an ‘unfair cost to the free market’
  – (Too bad if the Earth’s ecosystems are destroyed: ‘others’ can pay the price)

• Our politics are facing collapse:
  fantasy disconnected from real world
  – We are deeply embedded in system!
Step back from dark side

• Cannot be solved with mindset that created it
  • Oppose new fossil fuel “solutions”
  • *But stand for the Earth and ‘reality’*

• Push practical solutions
  – Efficiency and renewables
  – And a fossil-carbon tax

• Social, moral, spiritual shift needed
  – Your personal role
  – Role of community
How do we plan/adapt?

• Future needs creative approaches
  – Community support
  – Efficient society run on renewable energy

• We need to work with the Earth
  – *People reconnected to landscape*
  – Manage water on landscape
  – Manage forest diversity for a warmer climate
  – Manage diversified year-round agriculture
  – Manage energy crops and solar farms
Scientific Integrity

• What are the challenges scientists face?
  – Insufficient knowledge to give a balanced accurate assessment
  – Social resistance to change
  – Political hostility/attempts to silence scientists
  – Corruption in the system at many levels

• Rapid change over your lifetime
  – Scientific, technical and social challenges
  – Climate refugees, internal and from overseas
What are the Responsibilities of Environmental Scientists?

• Just do research?
  – Publish in the usual jargon in copyrighted journals not available to the public?
  – Avoid public discussion and politics?

• Or accept that with understanding comes responsibility
  – To the future of society
  – To the Earth
Discussion

(http://alanbetts.com)
What is a pollutant?

• First it was the obvious hazards to health
  – Smoke/smog from burning coal and exhausts
  – Toxic contaminants dumped in drinking water
  – These were regulated by the Clean Air and Clean Water legislation in 1980’s & 1990’s

• But many of our waste products that look harmless to humans are hazards to life on Earth!
  – CFCs that destroy the ozone layer that protects life
  – CO₂ from burning fossil fuels, driving climate change
  – Plastics dumped into the oceans

• *In our disconnected human world, these are harder for us to deal with*
‘Managing’ Our Relation to the Earth System

• Our technology and our waste-streams are having large local and global impacts on the natural world and must be carefully managed — because we are dependent on the natural ecosystems

• We need new ‘rules’ because
  – Our numbers and industrial output are so large
  – Maximizing consumption and profit have led to present predicament
Technical solutions

• Electrical power
  – Renewable: solar, wind, hydro
  – Storage: lithium batteries down to $150/kWh
  – Electric car industry generating massive storage

• New technologies: electricity to liquid fuels

• Net-zero housing

• Rethink transport
Efficient transport

- Gasoline to hybrid: 50% gain to 50 mpg
- Hybrid to plug-in hybrid: now 120 mpg
- Electricity from community solar array

>3000lbs and 120 mpg
Payload: 750 lbs at 60 mph

180lbs gets “1800 mpg”
Payload: 350lbs at 25 mph
The Cabal of Libertarian Billionaires

• **Aim:** *purchase control of the Republican Party*
  – US Congress (“Freedom Party”); many state legislatures

• **Doctrine:** *limited role for government*
  – protect wealth, property and the rule of law

• **Freedom to exploit the earth:**
  – Shall not be limited by environmental regulation
    – *Doctrine in direct conflict with Earth’s ecosystem*

• **Leading to**
  – *Climate science is a (fictitious) conspiracy*