Climate Change & Society

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BREE High School Teams
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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 our social challenges?

Discussion
Fundamentals

• **Burning fossil fuels: transforming climate**
  – Many water cycle amplifying feedbacks
  – *Heading for high CO₂ “Carboniferous era climate”*
  – *Climate extremes increasing.*
  – *Severe weather costs: $300B in US in 2017*
  – *Decadal to centennial - long timescales*

• **Avoidance of responsibility for decades**
  – Politicians, professionals, public
  – *Climate change: Incompatible with business-as-usual*

• **Linked to unmanaged technology**
  – Soluble by changing system guidelines
  – *Create efficient society, based on renewable energy*

• **Choices are value based**
  – Beyond science and economics
  – Community based
Earth’s climate sustains life

• Increasing greenhouse gases reduces cooling to space

• Climate is warming: ice is melting, extreme weather is increasing

• Water plays crucial amplifying role: loss of reflective ice; more water vapor
Build Resilience

• Understand technical/ecological issues
  • Can’t build bridges with alternative facts

• Engineer for efficiency and resilience
  – Not “cost effective for today’s bottom line”

• Spend $1 trillion on climate resilience
  – saves $60 trillion later this century

• If we ignore climate change
  – costs to human civilization and Earth’s ecosystem catastrophic

• Community resilience!
Hurricane season: 2017

- Earth is warming as greenhouse gases increase and reflective ice cover falls

- Oceans are storing 93% of heat
  - Warmer Atlantic, Caribbean, Gulf of Mexico and Gulf Stream means stronger hurricanes; when vertical shear is low

- 2017: Harvey, Irma, (Jose), Maria
Why was Harvey so Damaging?

• Huge evaporation off warm ocean
• Category 4 hurricane landfall: Aug 25, 2017
• Heavy rain-rate: 10-12 inches per day
• Two stationary high pressure systems to the north trapped Harvey for 4 days over Houston
• Result 40+ inches of rain & massive flooding
2pm Sept. 6

Category 5*

IRMA

grazing

St Thomas

*Cat 5 >155mph

IRMA >180mph
Irma (Cat. 5)
Sept. 6
St Thomas
Irma and Jose: Sept 7

After Jose passed; East Wind Catamaran to Puerto Rico on Sept 11 (alanbetts.com/writings)
Maria: 5:30am Sept. 20
Category 4 hits Puerto Rico

Cat 4
>130mph
Maria
>150mph

Wiped cell towers and power grid
(90% back after 6 mos)
Two Severe Tropical Cyclones hit Mozambique

• **Southeast Africa cyclones were very rare**
• *Idai* in March left 1000 dead from flooding
• Cat 4 *Kenneth* in April
  – 60 in of rain
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

*(Walsh et al., 2014)*
TS Irene

Rte 131,
Cavendish
Aug 29, 2011

Roads in valleys

Massive damage

Some roads took months to repair

Wake-up call
2011 Classic Flood Situations

• **Spring flood**: heavy rain and warm weather, melting large snowpack from 2010-11 winter
  – 70F (April 11) and 80F (May 27) + heavy rain
  – record April, May rainfall: 3X at BTV
  – Severe floods on Winooski and Adirondack rivers
  – Lake Champlain record flood stage of 103ft

• **Irene flood**: tropical storm moved up east of Green Mountains and Catskills
  – dumped 6-10 ins rain
  – **Extreme flooding**
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

• Pattern nearly stationary
Value of Flood Plains

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

Ask around in your towns: Are there other markers for past floods?
Irene: Resilience

- 13 towns cut off overnight
- State emergency systems flooded
- FEMA: no road access
- Communities reorganized overnight
- Those with equipment stepped in
  - “Can fix this in 72 hrs”: will need engineer to check bridge (Brandon)
  - “We worked 120hrs last week…” (Wardsboro)
  - Social networks collected supplies; and rescue services across mountains
  - Communication networks critical
The Wardsboro excavator Harvey Plimpton spoke for Vermont’s community spirit when he said: “Nobody gave us permission. We just started because we knew what had to be done. We put in 120 hours last week. We worked until we couldn’t work. We still have a long way to go.”

When a stranded guest took Beth aside to ask what would happen when she ran out of food, she just looked at him, incredulous. “We’re a farm,” she said finally. “This is where food comes from.”

(Liberty Hill dairy farm, Rochester)
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/
Snowfall and Snowmelt

- Temperature changes 10°C (18°F) with snow cover
- Snow cover is a ‘climate switch’
- Fast transitions in ‘local climate’
  - Snow reflects sunlight; insulates ground
  - Reduces evaporation and water vapor greenhouse
More snow cover - Colder temperatures

Alberta, Canada October to April

Fraction of Days with Snow Cover

Mean Temperature (°C)

Mean Temperature (°F)

T = 3.9 - 14.6 * FDS (R² = 0.79)
Impact of Snow

• Distinct warm and cold season states
• Snow cover is the “climate switch”

With snow

• **Prairies:** Temperature falls 10°C (18°F)
  • snow reflects 70%
• **Vermont:** Temperature falls 6°C (10°F)
  • snow reflects 35% (because more forest)
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)
January 10 and 12, 2018

January 10, 2018
After cold snowy period
$T_{\text{min}}$ down to -10 to -20F

January 12, 2018
After $T_{\text{max}}$ up to 50F
Marker: Lake Freeze-up & Ice-out

Frozen Period Shrinking: variability huge

- Freeze-up later by +4 days / decade
- Ice-out earlier by -3 days / decade
- Lake frozen period trend - 7 days/decade
- Interannual variability ≈ 40 yr trend

Stiles Pond:
“Eye on the Sky”
Winters are changing
- Arctic warming twice as fast as tropics
  so Arctic vortex weakening

• Sea-ice minimum mid-September

• Winter sea-ice coverage falling
• Sea-ice thinning
• Polar vortex weakening
“Polar Vortex”: Cold air and low pressure near the pole

The jet stream and cold air surge south into the U.S.

Image: NOAA
Jan-Feb-Mar 2015
Warm Atlantic, record temp in west; cold NE, strong coastal storms - Boston record snow

Jan-Feb-Mar 2016
Warm Atlantic, warm NE, little snow, warm Arctic
Feb-2019

Extreme cold, central US, Canada
Extreme warmth UK, Europe, Asia, NW Alaska

March-2019

Cold eastern US, Canada
Extreme warmth UK, Europe, Asia Alaska
Feb-2019
Second warmest in South-east
Second coldest in north-central

Very wet across much of US
May-2019

Record temps in Florida & South-east
Still cold in north-central

Record wet across Central US
• 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
Efficient transport

• Gasoline to hybrid: 50% gain to 50 mpg
• Hybrid to plug-in hybrid: now 130 mpg
• Electricity from community solar array

>3000lbs and 130 mpg
Payload: 750 lbs at 60 mph

180lbs gets “1800 mpg”
Payload: 350lbs at 25 mph
Can We Stop “Dangerous Climate Change”? - signed by 197 countries (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 plans to avoid the commitments it made
  – 2019 UN report says one million species will be gone in the next decade or two from habitat loss and climate change
Growth of CO₂ Emissions slowed – now increasing

China shifts to renewables
- China burns coal
- Need 80% drop by 2050

#OnePlanetSummit (2017 projection)
36.8 GtCO₂
2.2% over 2015

#ParisAgreement 2015: 36.0 GtCO₂
- 3%/year
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
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!
We have 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

• *Needs change in attitude!*
So how do we deal with this?

• **Future needs creative approaches**
  – *Efficient society run on renewable energy*
  – *Waste-free society*
  – *Community support*

• **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
March 15, 2019

- School strikes, 123 countries, 1.6 million students, demanding climate action
Greta Thunberg (born Jan 2, 2003)
On 20 August 2018, Greta Thunberg decided to not attend school until the 2018 Sweden general election on 9 September, after heat waves and wildfires in Sweden. Her demands were that the Swedish government reduce carbon emissions in accordance with the Paris agreement. She protested by sitting outside the Swedish parliament every day during school hours with the sign Skolstrejk för klimatet (school strike for the climate).

After the general elections, she continued to strike only on Fridays, gaining worldwide attention — prompting global ‘Friday’ protests by students who realized they and their children were to be sacrificed.

“we can’t change the world by playing by the rules, because the rules have to be changed.”
Extinction Rebellion

• Destruction of Earth now a Civil Rights issue
  – Can only be checked by civil disobedience
  – To defend the rights of our children
  – To defend the rights of the Earth’s biosphere

• Shut down London (4/16) till UK and Scottish governments declared “Climate Emergency”
  – Government must act now to halt biodiversity loss and reduce greenhouse gas emissions to net zero by 2025
  – Government must create and be led by the decisions of a Citizens’ Assembly on climate and ecological justice.

https://rebellion.earth
Work on your high school science projects

Study the issues ahead

Discussion

(http://alanbetts.com)
Tornadic Ca storm, 2” hail: 24 May 2019
Vermont’s Future with High and Low GHG Emissions

What about VT forests?

Sub-tropical drought areas moving into southern US

Business as usual

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
How do we do it?

Systems Engineering

- *Change the rule-book from Maximizing Profit*
- 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
‘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
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
  – CO$_2$ 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*
March-2018

Warm Atlantic, 4 Nor’Easter snowstorms; Warm E. Canada; cold Europe

April-2018

Warm Atlantic, (Record) cold NA; warm Europe
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