Satellites, Weather and Climate Module 40:

Agriculture & forestry in a changing climate
Today’s topics

• role of weather and climate

• important linkages with environmental factors

• climate change projections
Factors that affect plant growth

- topography
- soil characteristics
- microclimate
- urban vs. rural
- seasonality
- plant hardiness
- weather & climate
1. Role of topography

- Appalachian mountains can divert moisture – Ice Storm

- Green Mountains can restrict cold, dense air to the valleys
  - Champlain

- air is funneled
- orographic uplift along the Greens

- shirkshires
  - gravity winds blowing downslope
Orographic enhancement or blocking

Daily Snowfall
Ending 12Z March 7, 2011

Seven-Day Snowfall for Vermont, March 5 – 11, 2011
Inches of Snow, Cut Off Time 1500Z

This map is based on preliminary reports. Station values may differ from final Quality Controlled data.

New England ice storm 11-12 Dec 2008
2. How do weather & climate affect Vermont’s vegetation?
Fifty Years Of Severe Weather (1950-2000)

Courtesy: NWS/BTV
Downburst animation

Courtesy: NWS/BTV
Downburst damage

Straightline wind damage in Cavendish, Vermont.
Photo taken by Steve Hogan & Brooke Taber. (July 21, 2003)
Wind speeds 55-72 mph

Courtesy: NWS/BTV
Wind speeds +113 mph

Courtesy: NWS/BTV
Ice storms

- timing
  - Nov, Dec 1800s
  - February 1961
  - January 1998
  - October 2010

- duration
- amount
- species

Photos: L-A. Dupigny-Giroux
3. How does climate affect agriculture?

- moisture extremes can be detrimental
- timing of moisture inputs & temperature extremes is crucial
- deep snowpack - insulation, beneficial to sugar maple
- local characteristics - microclimate, topography, soils
- thermal stress on crops
- plant hardiness
- impacts vary by crop type
- rice?
3b. Weather factors that affect haying

- cool, wet conditions are ideal
- drought – few cuttings
- relative humidity
- wind
- frequency of storms
- soil moisture content
How does climate affect agriculture?

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2010 frosts
Vermont Department of Forests, Parks & Recreations

• “Late spring frost injury to hardwoods is widespread.

• Over 200,000 acres of damage have been observed during aerial surveys, with the heaviest damage to sugar maple.

• Christmas tree growers are reporting heavy frost damage to balsam fir, the worst in many years if not ever.”


June 2010
Temperature stress on trees

**Summer**
- heat waves (drought)
  - can be beneficial after cool wet summer (August 1996, 2007)
- frost (phenology)

**Winter**
- extreme cold
- record warmth
- freezing of soils – influence on cold tolerance (Paul Schaberg, USFS)
Plant hardiness maps

http://usna.usda.gov/Hardzone/hzm-ne1.html
http://www.arborday.org/treeinfo/zonelookup.cfm
4. Stressors related to climate change impacts
Simulated difference in the mean annual length of the freeze-free season

National Climate Assessment, 2013
Trends in forest canopy green cover over the eastern United States from 2000 to 2010

Image credit: NASA

http://newswatch.nationalgeographic.com/2013/03/07/declining-forests-in-the-eastern-united-states-as-seen-from-space/
Effect of changing growing seasons 1982-2011

• warming + longer growing season
• changes in land carbon cycle
• could be tempered by
  • forest fires
  • pest infestations
  • summer droughts

Credit: NASA’s Goddard Space Flight Center Scientific Visualization Studio
http://science.nasa.gov/science-news/science-at-nasa/2013/10mar_greenhouseshift/
Is Vermont susceptible to drought?
Droughts are cyclical & vary in severity

Photos: L-A. Dupigny-Giroux

Rutland County 4/17/08
Drought in Vermont

- severe droughts
  - rare
  - statewide
  - multiyear

- less severe droughts
  - more frequent
  - localized

- tends to be a summer occurrence, but can occur at any time

- timing influences who is affected
  - farmers
  - water management

- tendency for drought & floods to occur in the same year
Lake Champlain Extremes and Level

Click and drag in plot area to zoom in

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Max Level | Ave Level | Min Level | 2014 Level

Courtesy: National Weather Service. As of 30 April 2014
Lake Champlain Extremes and Level
Click and drag in plot area to zoom in

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Courtesy: National Weather Service. As of 29 June 2014
Who is affected by drought?

- AGRICULTURE
  - dairy farming & other animal husbandry
  - forage crops
  - corn

- FORESTRY
  - wildfires
  - health

- TOURISM
  - fall foliage
  - ski industry
Drought implications

• heat and moisture stress decrease plant ability to absorb CO₂

• mitigate against “greening trend”

• forest dieback, accelerated soil carbon loss could potentially occur
Concurrent stressors in 2006

Photos: L-A. Dupigny-Giroux
2004 moisture stress

Tent caterpillar damage

White pine damage

Photos: L-A. Dupigny-Giroux
5. The climate change conversation
"Climate change in IPCC usage refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods."
Increased human vulnerability
Observing climate variability

• “The temporal variations of the atmosphere–ocean system around a mean state. Typically, this term is used for timescales longer than those associated with synoptic weather events (i.e., months to millennia and longer). The term “natural climate variability” is further used to identify climate variations that are not attributable to or influenced by any activity related to humans.” AMS Glossary

Photo credit: L-A. Dupigny-Giroux
Snow cover – February 2011 - 2014

http://www.climatewatch.noaa.gov/2011/articles/another-wintry-winter-for-the-eastern-u-s

2 Feb 2011
Backward spring 2010

- low temperatures in January – June
- land-locked stations colder
- winter freeze/thaw cycles – predictor
- snow, freezing rain – April to June
- summer killing frosts
- summer drought
- NW flow

Photos: L-A. Dupigny-Giroux
Significant Events for March 2014

The Northwest and Northern Rockies were wet. A landslide near Oso, WA caused at least 30 fatalities.

AZ and CA had a record warm start to the year, with Jan-Mar temperatures more than 5°F above average.

The Northeast and Great Lakes were cold. VT had its coldest March on record, with a temperature 8.9°F below average.

Nearly two-thirds of the Great Lakes remained frozen by early April, impacting commercial shipping.

The contiguous U.S. drought footprint expanded to 38.4%, up from 35.9% at the beginning of March. Drought worsened in parts of the Plains. Drought and abnormally dry conditions expanded into the Southeast.

AK had its 3rd warmest start to the year, with a Jan-Mar temperature 6.3°F above average.

Extreme drought persisted on central Molokai, where low water levels in the Kualapuu Reservoir forced mandatory restrictions.

The average U.S. temperature during March was 40.5°F, 1.0°F below the 20th century average. March U.S. precipitation was 2.29 inches, 0.22 inch below the 20th century average.
Significant Events for April 2014

The contiguous U.S. drought footprint changed little during April. Drought improved in parts of the Midwest but worsened in parts of the Great Plains and West.

AZ and CA had their warmest Jan-Apr on record, with drought conditions expanding to cover all of CA.

The HI drought footprint shrank to 0.7% of the state, the smallest since 2008. Moderate drought persisted in central Molokai.

At the end of April, 24% of the Great Lakes remained ice covered, including most of Lake Superior.

A severe weather outbreak on 27-29 April spawned deadly tornadoes across the Midwest and Southeast. At least 33 fatalities were reported.

In late April, record-breaking rains across the Gulf Coast caused significant flash flooding in AL and FL. Pensacola, FL received over 20" of rain in two days.

Heavy rains and snowmelt throughout April caused flooding across the Northeast. Several rivers in NY and New England approached near-record crests.

The average U.S. temperature during April was 51.7°F, 0.7°F above the 20th century average. April U.S. precipitation was 2.83 inches, 0.31 inch above the 20th century average.
6. Understanding climate change as a complex system
Climate change as a system

A simplistic view of climate change

- Greenhouse gas emissions
- Global warming
- Undesirable effects

A more realistic view

- Greenhouse gas emissions
- Global energy balance disturbed
- Changes in wind patterns
- Changes in rainfall
- Changes in clouds and humidity
- Changes in soil moisture
- Other effects: sea-level rise, etc.
Three aspects of climate change - process, impact, strategies

Figure 1: Potential impacts of climate change on agricultural crops in Canada

**POSITIVE IMPACTS**
- Increased productivity from warmer temperatures
- Possibility of growing new crops
- Longer growing seasons
- Increased productivity from enhanced CO₂
- Accelerated maturation rates
- Decreased moisture stress

**NEGATIVE IMPACTS**
- Increased insect infestations
- Crop damage from extreme heat
- Planning problems due to less reliable forecasts
- Increased soil erosion
- Increased weed growth and disease outbreaks
- Decreased herbicide and pesticide efficacy
- Increased moisture stress and droughts

**PROJECTED CHANGES**
- Warmer temperatures
- Drier or wetter conditions
- Increased frequency of extreme climatic events
- Enhanced atmospheric CO₂
- Changing market conditions

The net impact on Canadian crops is uncertain, and depends largely on the adaptation measures undertaken.

Greenhouse gases and vegetation
Drivers of climate change

![Graph showing drivers of climate change](http://www.climatechange2013.org/images/figures/WGI_AR5_FigSPM-5.jpg)
Ground-level ozone

- reduces plant growth & vigor
- reduces seed production
- increases susceptibility to insects & disease
- cumulative effect over growing season
- Black cherry, white ash, yellow poplar

Ozone Injury to White Ash
Photo by Gretchen Smith

R. Poirot – VT ANR/ Air Quality
Three-Year Average Trends in Ozone Pollution & Plant Injury in Northern & Southern VT

![Graph showing trends in ozone pollution and plant injury from 1995 to 2006. The graph compares the 3-year average W126 Ozone (ppm-hours) and the 3-year average percent plant injury (%). The estimated ozone injury threshold is indicated by a dashed line.]

Courtesy R. Poirot – VT ANR/Air Quality
Ozone injury

- Ozone injury to milkweed.
- Ozone injury to yellow-poplar.

USFS
7. Climate change projections for the Northeast & Vermont
2035 (Northeast)

• “changes in precipitation are not significant for most models (category 1) over the majority of grid points. This means that most models are in agreement that any changes will be smaller than the normal year – to -year variations that occur.”

National Climate Assessment, 2013
Western Vermont
Extreme precipitation index for the occurrence of 1-day, 1 in 5-year extreme precipitation

Trend line is not statistically significant
2055 & 2085 (Northeast)

• “for emissions scenarios in 2055 and 2085, most models indicate changes that are larger than these normal variations (category 3), i.e., the models are mostly in agreement that precipitation will increase over the entire region.”

National Climate Assessment, 2013
Model difference in mean annual number of days with precipitation of greater than one inch

Statistically significant change

National Climate Assessment, 2013
Model difference in the mean annual maximum number of consecutive days with precipitation of less than 0.1 inches
Changing recurrence intervals

• “Thus the amount of rain that was expected to occur once in 100 years, may now occur on average once every 60 years. This could lead to the premature failure of infrastructure or more frequent infrastructure disruptions.”
Changing recurrence intervals

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• “DeGaetano (2009) shows that what would be expected to be a 100 - year event based on 1950 -1979 data, occurs with an average return interval of 60 years when data from the 1978 - 2007 period are considered.”
Changing recurrence intervals

• “Thus the amount of rain that was expected to occur once in 100 years, may now occur on average once every 60 years. This could lead to the premature failure of infrastructure or more frequent infrastructure disruptions. “

• “DeGaetano (2009) shows that what would be expected to be a 100 - year event based on 1950 -1979 data, occurs with an average return interval of 60 years when data from the 1978 - 2007 period are considered. “

• “Similarly, the amount of rain that constituted a 50 -year event during 1950-1979 is expected to occur on average once every 30 years based on the more recent data.”

National Climate Assessment, 2013
Model difference in annual and seasonal mean precipitation

NARCCAP, SRES A2, PRECIPITATION CHANGE
Multi-Model Mean Simulated Difference - (2041-2070 minus 1971-2000)

ANNUAL

WINTER

SPRING

SUMMER

FALL

Percent Change

-12  -8  -4   0   4   8  12  16  20

National Climate Assessment, 2013
Take home messages

- spatial and temporal variability important
- regional and continental scale processes affect us
- nonlinear system (atmosphere, pests, carbon)
- need to factor in topography

- vegetation can be affected in every season by temperature & moisture extremes
- impacts can be species-specific
- flexibility in planting and species selection