Teaching about Weather, Climate and Climate Change in Bergen County

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Science Educator (1970 – present)
What is your earliest weather memory?
My own earliest memory goes back 70 years, but geological evidence allows us to go back much further in time. 10,000 years ago, our region was under a few thousand feet of snow and ice.
As the ice sheets melted, glacial lakes covered the landscape. Where we now are was once the floor of a 200-ft deep lake that froze over and thawed annually, leaving thick deposits of clay. These were mined in the 19th and 20th century in places like Little Ferry to make bricks.
As the climate warmed, taiga-like coniferous forests covered our region, with large mammals (mastodons)
Hackensack Mastodon (1960)
Excavating the Dwarsskill Mastodon (1974)
Continued warming over the centuries led to the expansion of the Eastern Woodlands forest.
The areas were occupied by the Lenni Lenape, an indigenous group that lived in harmony with their environment and climate. They lived in communal longhouses in villages connected through family ties.
Some animals important to the Eastern Woodlands Indians are still with us
One leader of the Hackensack Indians was Chief Oratam, who lived in the 17th century and was critical to bring peace between indigenous people and the Dutch settlers.
We respectfully acknowledge that Bergen County occupies land in Lenapehoking, the traditional and expropriated territory of the Lenape. As an institution, we recognize and support the sovereignty of New Jersey’s three state-recognized tribes: the Ramapough Lenape, Nanticoke Lenni-Lenape, and Powhatan Lenape nations.

We recognize the sovereign nations of the Lenape diaspora elsewhere in North America, as well as other Indigenous individuals and communities now residing in New Jersey.

By offering this land acknowledgement, we commit to addressing the historical legacies of Indigenous dispossession and dismantling practices of erasure that persist today.

We recognize the resilience and persistence of contemporary Indigenous communities and their role in educating all of us about justice, equity, and the stewardship of the land throughout the generations.
Part 1 Weather & Climate Science Basics
1A) Weather affects us everyday, everywhere
Weather is what you get, Climate is what you expect; or, Weather determines what you wear, Climate determines what you buy

Weather includes
- Temperature
- Air pressure
- Wind speed and direction
- Humidity & dew point
- Clouds
- Precipitation

Climate describes
- All of the above
- Average (normal), high (maximum), and low (minimum)(30-year)
- Anomalies (variations from normal)
- Record values
- Long-term conditions (droughts, floods)
What, basically, causes weather?

1. Air Masses

Large parcels of air with similar temperature and humidity at any elevation

http://www.fas.org/irp/imint/docs/rst/Sect14/Sect14_1b.html
4 Basic Types of Air Masses

- **Continental Polar (cP)** – dry and cool or cold
- **Maritime Polar (mP)** – humid and cool
- **Continental Tropical (cT)** – dry and hot
- **Maritime Tropical (mT)** – humid and warm
What, basically, causes weather?

2. Weather Fronts
   Boundary zones where air masses “battle” to move over regions
Cold Fronts

Cold Front – cooler air pushes under warmer air

- Relatively steep slope
- Move relatively fast (25 mph/40 km per hr)
- Often bring violent weather – strong thunderstorms, squall lines, tornadoes
- Cooler weather, clearing skies, change in wind direction

http://okfirst.mesonet.org/train/meteorology/Fronts.html
Frontal Movement

Cold

Warm

Frontal Movement

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...move more slowly...
Occluded Front

• Forms when a second cold front overtakes a warm front and lifts it

• Weather ahead of the occlusion is similar to that of warm front, and weather behind similar to that of a cold front
Stationary Front

• Forms when neither air mass can push the other
• Other form when polar air masses are significantly modified (“stalled cold fronts”)
• Behave like mild warm fronts—gentle precipitation, overcast
• Winds on both sides may be parallel to the front
Comparing Highs and Lows
(‘the clock is high, the counter is low’)

• Air in anticyclones moves downward, outward, clockwise
• Air in cyclones moves inward, counterclockwise, upward

http://www4.uwsp.edu/geo/faculty/ritter/geog101/textbook/circulation/cyclones_and_anticyclones.html
Weather Maps
Observing weather

- Thermometers (temperature)
- Barometers (pressure)
- Anemometers (wind speed)
- Wind vane (direction)
- Hygrometer (humidity, dew point)
Monitoring Weather on the Surface
ASOS – Automated Surface Observing System

Automatically collects data every minute, 24/7

• Sky conditions
• Temperature
• Pressure
• Humidity
• Wind
• Visibility/fog/haze
• Precipitation

http://www.nws.noaa.gov/ost/asostech.html
Summarizing Weather Data – ‘Station Models’

Coded diagram to represent conditions at location

Lake Effect Snow Continues Over the Eastern Great Lakes; Parade of Storms to Impact the Western U.S.

Heavy lake effect snow will continue downstream of Lakes Erie and Ontario into Sunday. A parade of storms will bring additional heavy rain and mountain snow to the Western U.S. this coming week. Energy from each of these storms will likely then move across the central and eastern U.S. with areas of snow and blowing snow to the north and heavy to severe thunderstorms to the south. Read More >
Hazardous Weather Conditions

- Hazardous Weather Outlook
- Red Flag Warning in effect from March 19, 10:00 AM EDT until March 19, 08:00 PM EDT

Current conditions at Teterboro, Teterboro Airport (KTEB)
Lat: 40.86°N  Lon: 74.06°W  Elev: 7 ft.

- Humidity: 34%
- Wind Speed: W 15 G 20 mph
- Barometer: 30.01 in (1016.0 mb)
- Dewpoint: 3°F (-18°C)
- Visibility: 10.00 mi
- Wind Chill: 19°F (-7°C)
- Last update: 19 Mar 8:51 am EDT

Extended Forecast for Hackensack NJ

- Today: Red Flag Warning
- Tonight: Mostly Clear
- Monday: Sunny
- Monday Night: Mostly Clear
- Tuesday: Sunny
- Tuesday Night: Partly Cloudy
- Wednesday: Partly Sunny
- Wednesday Night: Chance Showers
- Thursday: Chance Showers

Click here for hazard details and duration

More Information:
- Local Forecast Office
- More Local Weather
- 3 Day History
- Mobile Weather
- Hourly Weather Forecast
Weather occurs in 3-D

- **Radiosondes** carried by weather balloons give data about conditions aloft
- Temperature, pressure, winds, relative humidity
- Carried by weather balloon up to more than 100,000 ft

http://www.ua.nws.noaa.gov/factsheet.htm
Launched 2x a day at 0000 GMT and 1200 GMT

http://www.ncdc.noaa.gov oa/climate/igra/

Stuve diagram shows radiosonde information
Upper Atmosphere Observations

Weather Balloon – launched twice daily from locations across the US and world
(note: Not a Chinese spy balloon)
Upper-Air Weather Maps (especially useful to forecaster and aviators)
Weather Radar

Emits radio-wavelength signals and records echoes that detect clouds, precipitation, and winds in a 200-mi (320-km) radius

http://www.radartutorial.eu/15.weather/wx04.en.html
Activity 1) How do you/your students get their weather information? (7 - 10 minutes)

Ben Franklin said, “some people are weather wise, most are otherwise.”

• What can you do in your classroom to help them become more weatherwise?

• How could you suggest careers as a meteorologist or meteorological technician to your students?
Climate ‘Normals’

• 30-year period, updated every 10 years (currently 1990 – 2020)
• Many specialized data sets are available through organizations such as CIESEN and the IRI (International Research Institute Climate and Society at Columbia)
Additional factors that influence climates
What causes/influences climate?
1) Local influences

Geographers recognize a number of factors that affect a region’s climate:

• latitude
• elevation
• proximity to large water bodies, mountains, or other surface features
• Orientation (direction faced)
• Temperature patterns
• Moisture patterns
What causes/influences climate
2) Regional Patterns
3) Global factors that influence climates
Greenhouse Gases

<table>
<thead>
<tr>
<th>Natural greenhouse gases</th>
<th>Anthropogenic (man-made) greenhouse gases</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Water (H₂O)</td>
<td>• Hydrofluorocarbons</td>
</tr>
<tr>
<td>• Carbon dioxide (CO₂)</td>
<td>• Sulfur hexafluoride</td>
</tr>
<tr>
<td>• Methane (CH₄)</td>
<td>• Nitrogen trifluoride</td>
</tr>
<tr>
<td>• Nitrous oxide (N₂O)</td>
<td>• Perfluorocarbons</td>
</tr>
<tr>
<td>• Ozone (O₃)</td>
<td></td>
</tr>
</tbody>
</table>

They can retain heat energy and act as blankets to warm the atmosphere.
Activity 2) Sources of Climate Information (10 minutes)

Groups 1 and 3
Go to https://www.climate.gov/
What types of information are available on this website, and how could you use it in your classroom?

Groups 2 and 4
Go to: https://climate.rutgers.edu/stateclim/
What types of information are available on this website and how can you use it in your classroom?
Milankovitch Cycles

Excentricity
(100,000 Years)

Obliquity of Ecliptic
41,000 Years

Precession
26,000, 21,000 Years

Milankovitch Cycles (ossfoundation.us)
El Niño-La Nina
Periodic changes in Pacific Ocean

La Nina

Activity (10 minutes)

• Go to: https://toolkit.climate.gov/reports/climategovs-el-nino-page

• Group 1) What are the usual impacts of El Nino conditions on the continental U.S.?
• Group 2) What are the usual impacts of La Nina conditions on the continental U.S.?
• Group 3) What are the impacts of El Nino and La Nina on Australia?
• Group 4) What conditions dominate now? What is the current forecast?
What causes/influences climate?

3) Local influences

- Orographic (mountain) effects
- Urban “Heat Island”
Paleoclimate proxies – Part 1

• Oxygen isotopes in ice cores, shells, and microfossils
• Carbonate (CaCO$_3$) fossil shells of forams, corals, and other organisms, and siliceous (SiO$_2$) fossils of diatoms contain isotopes of Oxygen.
• O-18 is heavier and precipitates faster, O-16 is lighter and evaporates faster, so the O-18/O-16 ratio can be used to determine whether the temperatures were relatively warmer or cooler at the time the organisms lived
Near the poles, atmospheric water vapor is increasingly depleted in $^{18}$O.

Heavy, $^{18}$O-rich water condenses over mid-latitudes.

Snow in the interior of Antarctica has 5 percent less $^{18}$O than ocean water.

Water, slightly depleted in $^{18}$O, evaporates from warm sub-tropical waters.

Meltwater from glacial ice is depleted in $^{18}$O.

Source: https://earthobservatory.nasa.gov/features/Paleoclimatology_OxygenBalance
Global temperature trends

https://climate.nasa.gov/vital-signs/carbon-dioxide/
Climate Change and Human Impacts

• Melting glaciers
• World glaciers melting at accelerating rate
Albedo—portion of incoming light reflected back to space. Ice and snow have high albedos (warm more slowly). Dark surfaces have low albedos (warm faster).

- As glaciers melt and expose darker land or water, surfaces warm and continue to impact the albedo.
- This is an example of a positive feedback loop.
- What are some other examples of feedback loops in science?
Climate change impact: Intensifying Storms

Hurricanes
Warmer surface waters are causing stronger tropical storms
Storms need ocean heat, atmospheric humidity, and winds, and changing climates can affect all three of these.
There may not be more storms each year, but they will be more intense, with increase in potential damages and deaths

Nor’Easters
Nor’easters are low-pressure systems that forms off the northeast coast in winter
Many derive strength from difference between cold air over Canada and warm air over the Atlantic
Blizzard of 1978 caused 99 deaths and $250 million in damages
Again, not necessarily more, but more intense
Droughts and Wildfires

• As air mass patterns shift away from moisture sources, air becomes drier and more droughts may occur. Vegetation becomes more vulnerable to becoming kindling for fires.
• Droughts also affect aquifers and underground water sources, as well as snow pack.
• Major impacts on water resources and agriculture.

Climate Changes and Cold Spells

• As Arctic ice cover diminishes, the jet stream becomes weaker and artic air can dip further south, bringing cold spells to the northern US and southern Canada.

• Changing temperatures mean changes in the polar vortex (strong winds circulating around the north pole).

Understanding the polar vortex

The Arctic polar vortex is a strong band of winds in the stratosphere, surrounding the North Pole 10–30 miles above the surface. The polar vortex is far above and typically does not interact with the polar jet stream, the flow of winds in the troposphere 5–9 miles above the surface. But when the polar vortex is especially strong and stable, the jet stream stays farther north and has fewer “kinks.” This keeps cold air contained over the Arctic and the mid-latitudes warmer than usual.

Every other year or so, the Arctic polar vortex dramatically weakens. The vortex can be pushed off the pole or split into two. Sometimes the polar jet stream mirrors this stratospheric upheaval, becoming weaker or wavy. At the surface, cold air is pushed southward to the mid-latitudes, and warm air is drawn up into the Arctic.

https://www.climate.gov/news-features/understanding-climate/understanding-arctic-polar-vortex
Paleoclimate proxies (Part 2a)

- Dendrochronology (tree rings) width (wide or narrow) indicate weather/climate conditions during growth season pattern can be used to find the age of the tree overlapping patterns can extend length of time involved in the study
Paleoclimate proxies (2b)

- Palynology (pollen)
  - Pollen is extremely resistant to decay
  - Collected in cores from swamps and other wetlands
  - Can reveal changes in plant ecosystems over time

https://nmnh.typepad.com/.a/6a01156e4c2c3d970c01b7c79e86970b-600wi
Pollen can reveal changes in plants over time

https://la.utexas.edu/users/denbow/labs/palynology.htm
Paleoclimate Proxies Part 2c

• Foraminifera

• Diatoms

Many other types of microfossils are climate-sensitive
Phenology

- Study of cyclic and seasonal natural phenomena, especially in relation to climate and plant and animal life.
- Examples include when first shoots or leaves appear, when ice cover on lakes melts, when migrating animals appear or leave.

Definition of Phenology

- Phenology, which is derived from the Greek word *phaino* meaning to show or to appear, is the study of plant and animal life cycle events, which are triggered by environmental changes, especially temperature. Thus, timings of phenological events are ideal indicators of global change impacts.
- Seasonality is a related term, referring to similar non-biological events, such as timing of the fall formation and spring break-up of ice on fresh water lakes.

Excellent way to document changing climates.
Evidence and cause of Climate Change
Part 3
Some Projected Impacts of Climate Change for Our Region
Northeast - Fourth National Climate Assessment (globalchange.gov)

• Increased rainfall intensity (possibly more flood damage)
• Strain on infrastructures will require rebuilding and mitigation
• Enhanced urban heat island effect (impact on health)
• Sea level rise (loss of property and communities)
• Rising temperatures (heat stress on vulnerable populations, services)
• Changes in lengths of cold and warm seasons
Coastal marshes, uplands, forests, and estuaries provide critical habitat and ecosystems services throughout the Northeast.

Present

The Region's barrier islands and beaches support recreational areas, habitats, and cultural areas of value. Much of the Northeast's open ocean coast is backed by hard structures and/or development.

Possible Future

Forests, uplands, and marshes will either adapt to changing conditions by migrating landward or will become submerged. Bluffs will erode, and barrier islands and beaches will migrate landward, erode, or narrow, particularly where sediment supply is limited.

Coastal erosion and flooding will require ongoing efforts to protect or adapt existing development.

Northeast - Fourth National Climate Assessment (globalchange.gov)
Impacts of Climate Change

- **Climate change creates new risks and exacerbates existing vulnerabilities in communities across the United States, presenting growing challenges to human health and safety, quality of life, and the rate of economic growth.**

- **Extreme temperatures leave many families living in poverty with less food, less clean water, lower incomes and worsening health.**

- **Droughts and flooding can destroy crops and cut access to clean water.**

# Predictions for Sea Level Rise

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<th>Chance SLR Exceeds</th>
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<th>2050</th>
<th>2070</th>
<th>2100</th>
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<td>0.9</td>
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<td>1.3</td>
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<tr>
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<td>0.9</td>
<td>1.3</td>
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<tr>
<td>~50% chance</td>
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<td>1.9</td>
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<td>4.2</td>
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<tr>
<td>&lt;17% chance</td>
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<td>2.1</td>
<td>2.7</td>
<td>3.9</td>
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<td><strong>High End</strong></td>
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<tr>
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*2010 (2001-2019 average) Observed = 0.2 ft

Part 4
Samples of classroom activities and addressing the Standards

• ESS2.D: Weather and Climate
  Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. (MSESS2-6)
  Because these patterns are so complex, weather can only be predicted probabilistically. (MSESS2-5)
  The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents. (MS-ESS2-6)
Climate Change Education in the Classroom

• With the adoption of the **2020 New Jersey Student Learning Standards (NJSLS)**, New Jersey became the first state in the nation to include climate change across content areas. These standards are designed to prepare students to understand how and why climate change happens, the impact it has on our local and global communities and to act in informed and sustainable ways.
Possible opportunities for you and your students

- Chemistry of climate change
- Physics and engineering of climate change
- Math of climate change (probability)
- Climate and changing ecosystems
- Climate change and water supply
- Climate injustice
- Climate financing and law (national and international)
- Instrument technician

- “ADAPTATION and MITIGATION”
Exploring Resources for Classroom Activities

• 4th National Climate Assessment
  https://nca2018.globalchange.gov/

• Intergovernmental Panel on Climate Change (IPCC)
  https://www.ipcc.ch/

• Office of NJ State Climatologist
  https://climate.rutgers.edu/stateclim/

• Northeast Regional Climate Center
  https://climate.rutgers.edu/stateclim/

• US Facts/Climate
  https://usafacts.org/issues/climate
Other Useful Resources

• Montclair State University Land Acknowledgement Statement
  • https://www.montclair.edu/land-acknowledgement-statement/

• Meadowlands Environmental Center
  • https://www.njsea.com/meadowlands-environment-center/
  • https://www.montclair.edu/land-acknowledgement-statement/
  • Three classroom activities I used with my students available at https://earth2class.org/site/?page_id=6134

• What Factors Can Affect Climate

• How Can We Observe, Represent, Analyze, and Compare Climate Data?

• Phenology and Climate Patterns
  • https://earth2class.org/site/wp-content/uploads/2016/12/Phenology.pdf

• Weather Tech jobs
  • https://www.indeed.com/q-Weather-Instrument-Tech-jobs.html?vjk=9d0017dc00de9c56
Earth2Class programs at Lamont-Doherty Earth Observatory

- You are cordially invited to attend these free programs (offered for now via zoom) and learn directly from Columbia research scientists about their cutting edge investigations. Email me (see next slide) to get on the mailing list.
- Students also invited
Thank you!

michael @earth2class.org

This slide show will be available at
https://earth2class.org/site/?page_id=4969
(Earth2Class.org, Michael J Passow resources)