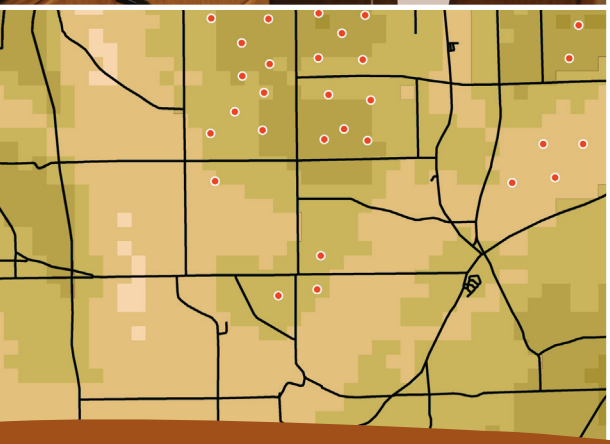
WindWise Education

Transforming the Energy of Wind into Powerful Minds



A Curriculum for Grades 6-12

www.WindWiseEducation.org

WindWise Education was developed with funding from the New York State Energy Research & Development Authority.

WHERE IS IT WINDY?

LESSON 4

KEY CONCEPT

Students will learn how topography and elevation affect wind speeds and will identify optimal locations for wind farms based on wind speed.

TIME REQUIRED

1 – 2 class periods

GRADES

6 – 8
9 – 12

SUBJECTS

Earth Science
Social Studies

BACKGROUND

Wind turbines produce more power at higher wind speeds than at lower wind speeds. This lesson helps students understand how topography and elevation affect wind speed. Students analyze maps and make predictions on where wind farms may be located based on regional topography.

OBJECTIVES

At the end of the lesson, students will

- Understand how topography and elevation affect wind speed
- Be able to identify optimal locations for wind farms based on wind speed
- Know how to interpret topographic and wind speed maps

METHOD

Students will create a 3-dimensional landscape and identify where it is windy in relation to the topography using a box fan and wind flags. Students will then examine a topographic map of their state and predict the optimal locations for wind farms. Students will compare their predictions with the actual wind speeds and wind farm locations.

MATERIALS

- ❑ Box fan (more than one is better)
- ❑ Objects of different sizes that will not blow away
- ❑ 20 wind flags for the model (tape some string to a popsicle stick and place it in a piece of clay to hold it up)
- ❑ New York State Elevation Map*
- ❑ New York State Wind Speed Maps at 70 m*
- ❑ New York State Wind Farm Map*
- ❑ Overhead Projector (if available)
- ❑ Student Worksheets*

*included with this activity

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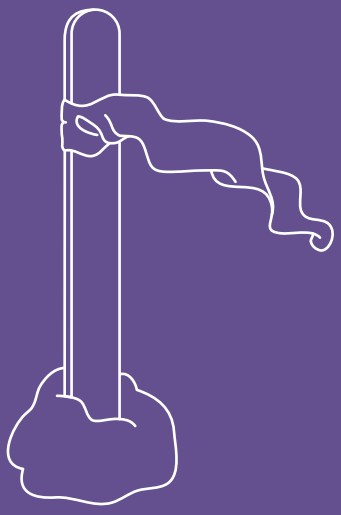
WIND FLAGS



Tie tissue or string to a popsicle stick and stick it in a piece of clay to make a simple wind flag.

GETTING READY

- Collect materials for creating the topography. For example, books, backpacks, blankets or weighted boxes can be stacked to create mountains and valleys.
- Make 20 "wind flags."
- Make copies of New York State Shaded Relief Elevation Map and worksheet for each student.
- Make a transparency of all maps or prepare to project from a computer to use for class discussion. Maps can also be found on the Where is it Windy? activity page of the WindWise website.
- If you have access to a color copier, print wind maps.

ACTIVITY

Step 1: Beginning Questions for Students

- Where do you typically find wind?
- Where is it often calm?
- Where would you go to fly a kite?
- What geographical features influence the speed of the wind?
- Do we have wind farms in our state? If so, where are they located?
- Is it windier in a forest or a field? On a hill or in a valley?
- What parts of the U.S. have the "best" wind for energy production?

Guide students to consider how beaches or open areas such as fields may have more wind than an area with many buildings or trees. Help them extrapolate their local understanding of where it is windy to a regional or national level where larger topographical features come into play, such as mountains or coastlines.

Step 2: Create a Model Landscape and Wind Farm

Using various objects around the classroom, have students create a model landscape. Students can use notebooks, textbooks, backpacks, weighted boxes, etc. Help students think about creating a variety of landscape features, such as a mountain range, rolling hills, valleys, plateaus, and open areas.

Have students create a wind farm by placing the wind flags where they think they will get the most wind. Number the flags so you can easily track them on your worksheet. Place the box fan next to the landscape and turn it on. Ask students to record which wind flags are blowing and at what height. Reposition the fan and again record which flags are blowing. Are there some flags that always move and others that never move? Discuss the role that landscape plays in wind patterns.

Step 3: Analyze a State Elevation Map

Give each student a topographic map of the state and discuss how to read it by showing high and low points on a projected version of the map. Ask students to predict where they feel there is the most wind by shading in these areas.

Step 4: Compare Predictions to Data
Using a computer or overhead, project the New York State Wind Speed Map at 70 m for students and ask them to compare their predictions with this map. Pass out maps if you can. Were their predictions similar to the actual wind speeds?

Step 5: Where Are the Wind Farms in New York?
Overlay a transparency of wind farms in New York with the 70m wind speed map. Pass out copies of the maps if you can. Ask students to look for relationships among this map and the topographical and wind speed maps and answer the questions on the worksheet.

Step 6: Wrap Up
Use the following questions to discuss the relationships among wind speed, elevation, and wind energy.

- Where are the windiest areas?
- Are there any trends? If so, what trends do you notice?
- How do wind speeds change as elevation increases?
- Why do you think this is the case?
- Where do you think the most desirable areas for wind farms are?
- Why do you think these locations were selected?
- What role do you think elevation plays in the height of turbines? Where are the wind farms in New York?
- Are turbines always in the windiest spots? Why or why not?

EXTENSION

- Have students examine a topographic map of the U.S. and make predictions about wind speed and wind farm locations. Compare their predictions to real data. Use some of the web resources from the end of this lesson.
- Have students create a scale drawing of their topography.

VOCABULARY

Anemometer – An instrument that measures wind speed

Convection – The air movement due to density differences as heated air rises and is replaced by cooler air

Coriolis Effect – The Earth's rotation causes the wind to flow in a curved path rather than a straight line

Pressure Gradient Force – The difference in air pressure that causes air molecules to move causing wind

Surface Roughness – A measure of surface texture. Trees, houses and other obstacles increase roughness causing the wind to become more turbulent

Topography – The study and mapping of the shape of surface features of the earth such as mountains, valleys, rivers and lakes

Turbulence – Irregular or unstable movement of a gas or liquid

Wind Speed – The rate at which air is moving horizontally past a given point

Wind Speed Units – Wind speed is measured in meters/second (m/s) or miles/hour (mph). 1 m/s = 2.24 mph

RELATED ACTIVITIES

- Lesson 3: What Causes Wind?

ADDITIONAL RESOURCES

AWS TRUEWIND—http://navigator.awstruewind.com —Get average wind speed for any US location. The maps are free, so the data resolution is limited.

NY WIND EXPLORER—http://windexplorer.awstruewind.com/NewYork/NewYorkWRE.htm—Source of wind resource maps for New York State.

3TIER, FIRSTLOOK REPORTS—firstlook.3tiergroup.com —Get average wind speed for locations in the US. Maps are free, so the data resolution is limited.

AWEA—www.awea.org/newsroom/pdf/Top_20_States_with_Wind_Energy_Potential.pdf —A page exploring states with the highest wind energy potential.

NCDC—www.ncdc.noaa.gov/oa/climate/research/2007/dec/extreme-cities.html —NOAA Satellite website has a list of the windiest locations in the US.

U.S. DEPARTMENT OF ENERGY—www.windpoweringamerica.gov/wind_maps.asp —Wind resource maps for some states as well as the entire US.

NY STATE STANDARDS

The Physical Setting–Earth Science: Standard 4 (High School)
Key Idea 2:
Many of the phenomena that we observe on Earth involve interactions among components of air, water, and land.

Performance Indicator 2.1:
Use the concepts of density and heat energy to explain observations of weather patterns, seasonal changes, and movements of the Earth's plates.

Major Understandings:

2.1g Weather variables can be represented in a variety of formats including radar and satellite images, weather maps (including station models, isobars, and fronts), atmospheric cross-sections, and computer models.

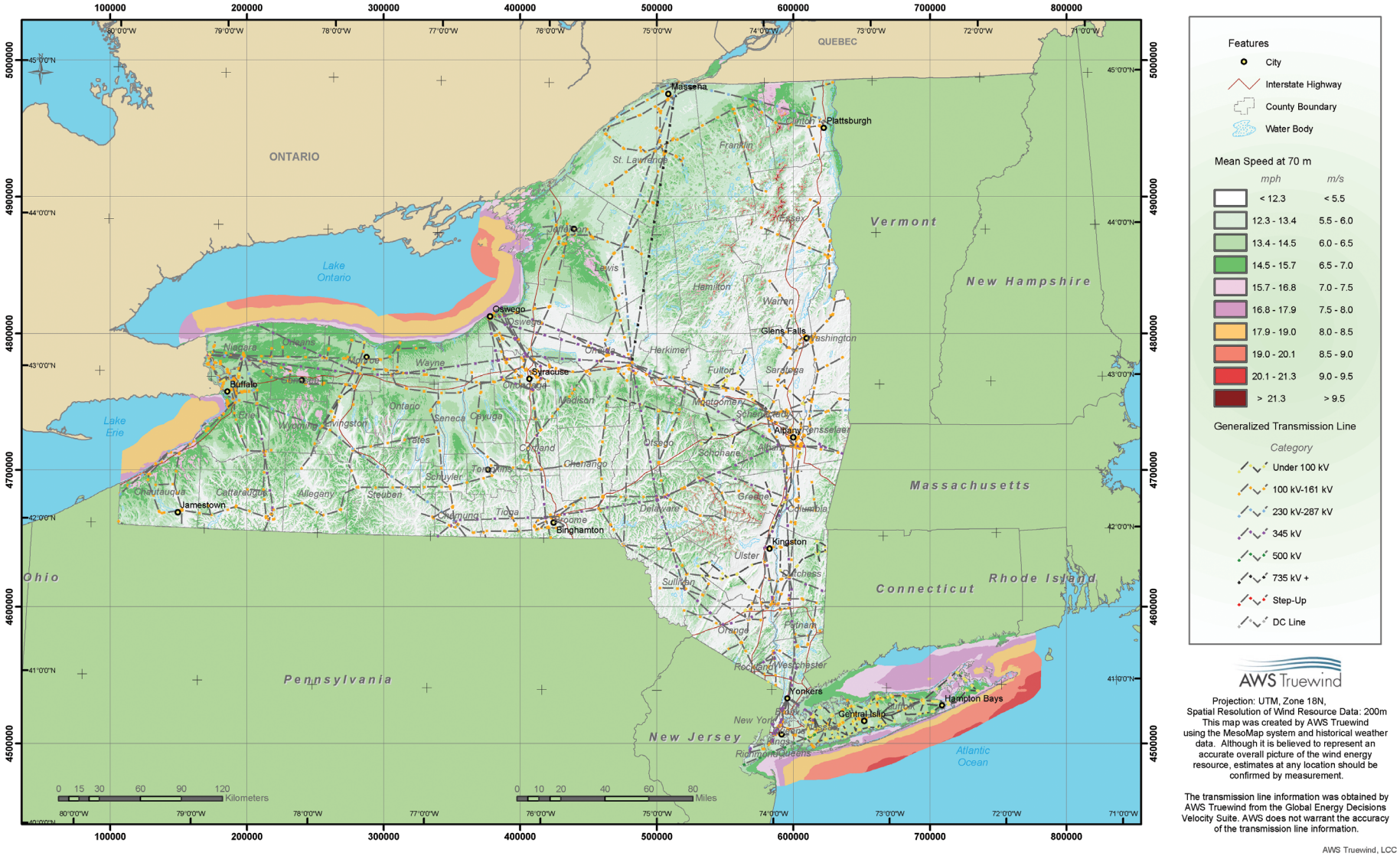
2.1q Topographic maps represent landforms through the use of contour lines that are isolines connecting points of equal elevation. Gradients and profiles can be determined from changes in elevation over a given distance.

2.2a Insolation (solar radiation) heats Earth's surface and atmosphere unequally due to variations in

- the intensity caused by differences in atmospheric transparency and angle of incidence which vary with time of day, latitude, and season
- characteristics of the materials absorbing the energy such as color, texture, transparency, state of matter, and specific heat
- duration, which varies with seasons and latitude.

Wind Resource of New York

Mean Annual Wind Speed at 70 Meters



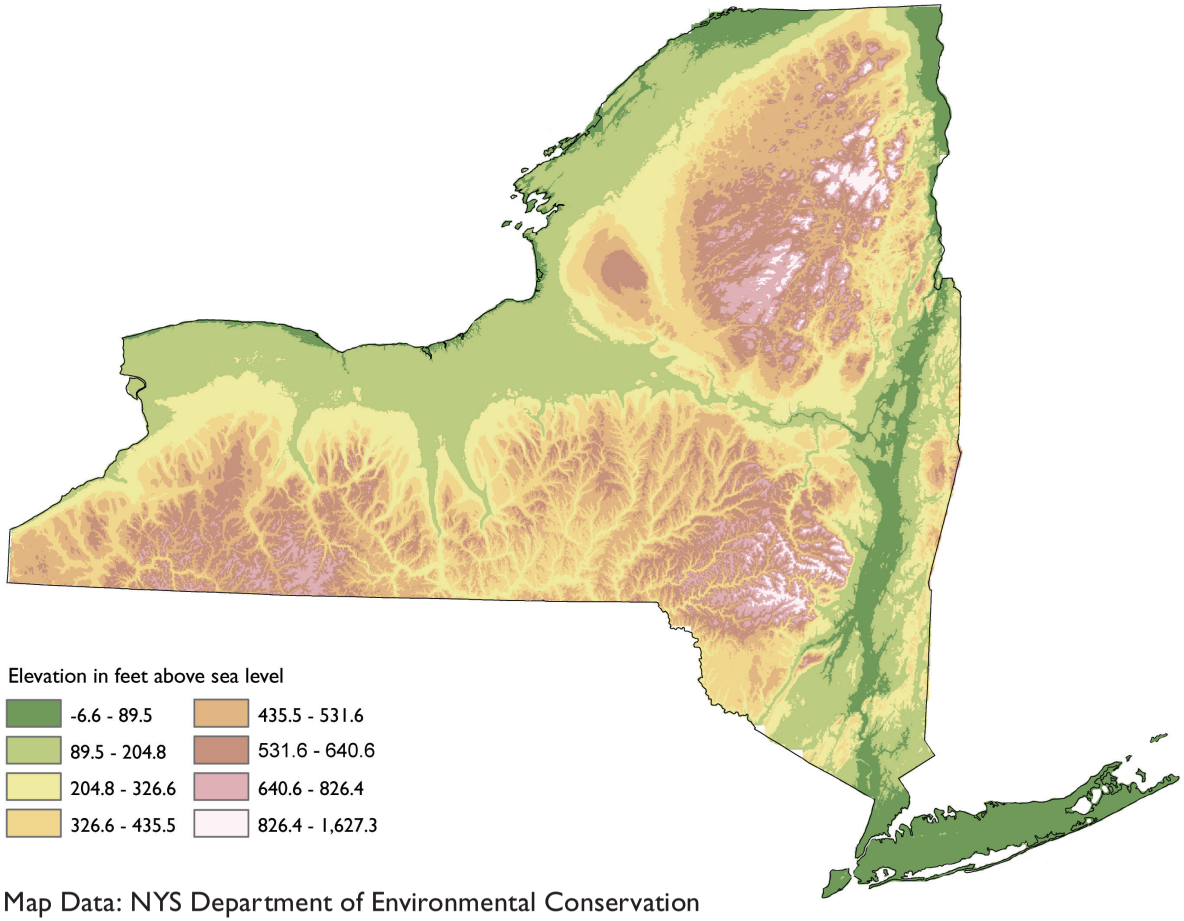
AWS Truewind

Projection: UTM, Zone 18N,
Spatial Resolution of Wind Resource Data: 200m
This map was created by AWS Truewind using the MesoMap system and historical weather data. Although it is believed to represent an accurate overall picture of the wind energy resource, estimates at any location should be confirmed by measurement.

The transmission line information was obtained by AWS Truewind from the Global Energy Decisions Velocity Suite. AWS does not warrant the accuracy of the transmission line information.

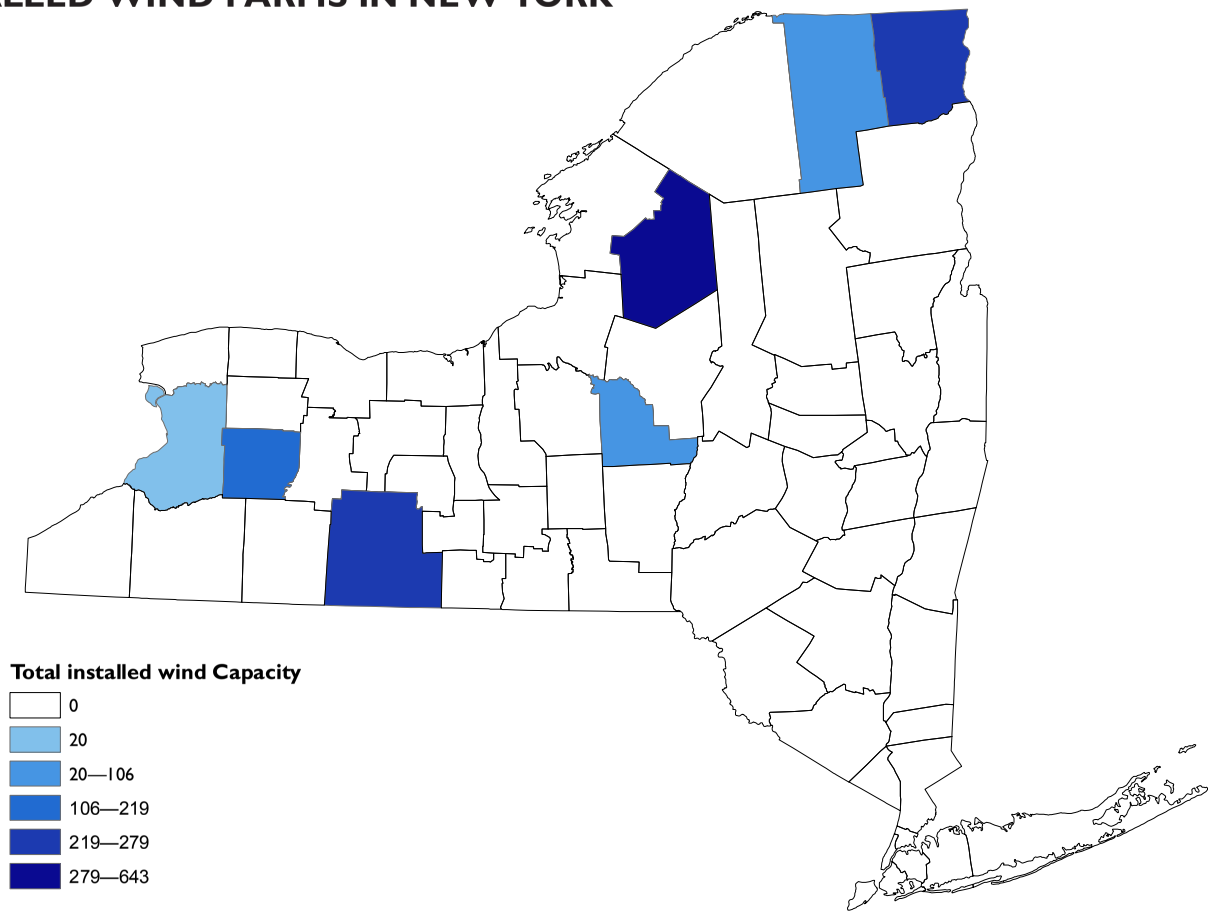
AWS Truewind, LCC

ELEVATION MAP OF NEW YORK



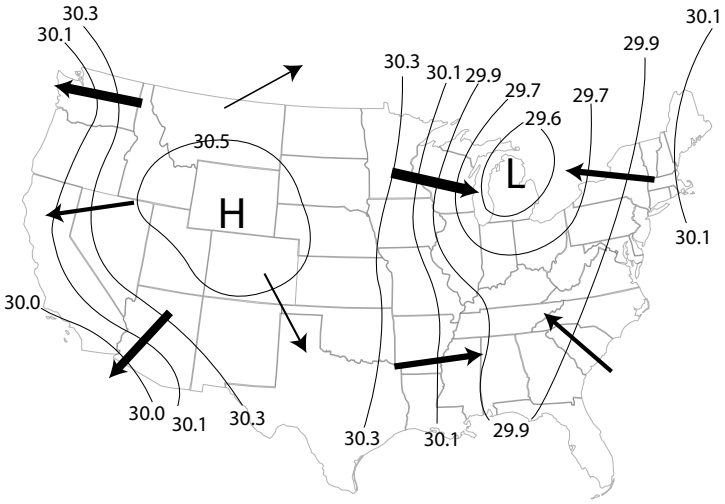
Map Data: NYS Department of Environmental Conservation
via Cornell University Geospatial Information Repository
Projection: UTM Zone 18N NAD 1927

INSTALLED WIND FARMS IN NEW YORK



Data: NYISO Interconnection Queue
Projection: UTM Zone 18N NAD 1927

READING PASSAGE



Wind is the result of air moving from areas of high pressure to areas of low pressure. Air pressure changes are created by the uneven heating of the Earth. As parts of the Earth heat up, the air heats up, becomes less dense, and rises. As the hot air rises (convection), cooler air moves in, creating a breeze. This pressure difference, which causes wind, is called the pressure gradient force.

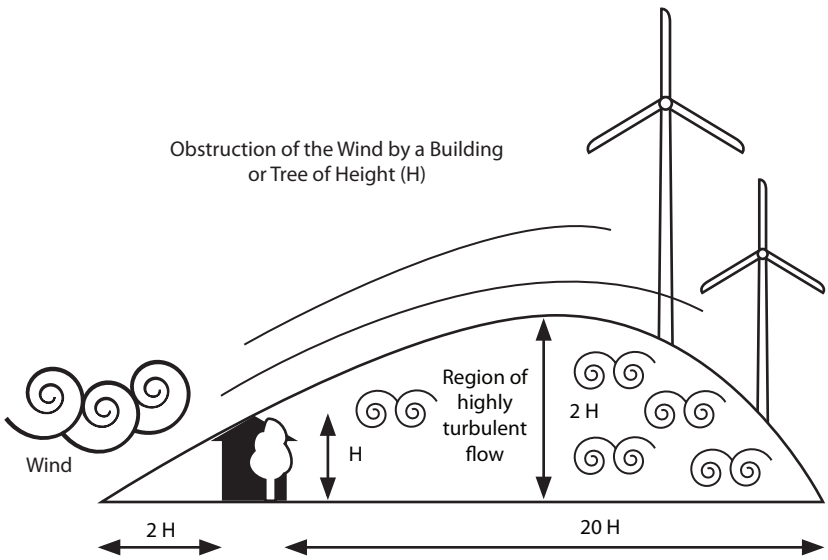
A number of factors determine the speed and direction of wind. Some factors, like the rotation of the Earth, create large-scale wind patterns, while other factors, such as the type of landscape, only affect local wind speeds. Wind developers may look at large-scale wind patterns to determine what region to place a wind farm. However, when determining an exact location for the turbines, the wind developer will collect years of wind data from proposed turbine locations.

Earth's Rotation

While wind is the movement of air from high to low pressure areas, the wind does not actually move in a straight line. Why not? The Earth's rotation actually causes the wind to flow in a curved path rather than a straight line. This is known as the Coriolis effect. The winds in the Northern Hemisphere turn to the right and the winds in the Southern Hemisphere turn to the left. The effect is zero at the equator. Find an animation of how the Coriolis effect impacts wind direction at: www.classzone.com/books/earth_science/terc/content/visualizations/es1905/es1905page01.cfm

Surface Roughness

Rough landscape surfaces tend to slow wind speeds, while smooth surfaces allow for higher wind speeds. For instance, a forested area creates more friction for moving air, resulting in slower wind speeds than a prairie. This is called surface roughness and can be defined according to different classes. An open sea provides very little friction for air and would be a class 0, whereas a large city with skyscrapers is a class 4. When siting a wind farm, it's important to look at the surrounding area to determine how the surface roughness will alter the local wind speeds.



Topography
Topography can impact wind speeds in two ways. First, land masses tend to heat up more quickly during the day than oceans. This results in warm air above the land rising and cooler air from the water blowing toward the land, creating "ocean breezes." A second impact of topography is natural or manmade obstacles that can block air movement. For example, a mountain range is an obstacle that winds have to move around. This can increase the wind speed in some areas while reducing it in others. Obstacles can also create turbulence in the air movement. Turbulence happens when the air moves irregularly, which creates the bumps you sometimes experience on an airplane when flying over a thunderstorm or mountain.

Elevation
Wind speeds generally increase with elevation. As elevation increases, there are typically fewer obstacles allowing wind to blow at faster speeds. Also, the friction with the earth is reduced higher above the ground, so wind moves faster. Over time, engineers have designed turbines to be taller so that they can capture these faster winds.

CAREER PROFILE: ROLF MILLER, TECHNICAL CONSULTING SERVICES MANAGER

I am a Technical Consulting Services Manager for a wind resource assessment and wind energy forecasting company. We provide wind farm developers, financiers, and utilities with highly accurate estimates of how much clean, renewable energy a wind farm will produce. In my current role, I work with a team of meteorologists and analysts to gather data from a variety of sources and help our customers understand how the weather will affect their wind farm.

As with many in the wind industry, I did not start out here. My undergraduate degree is in geology. At school, I wanted to meld the power of computers with studying natural systems. Geology had the irresistible appeal of working outdoors and a wide variety of things to study—fossils, plate tectonics, and mineral structures. For my senior thesis, I compiled a database of rock samples and mapped them with some of the earliest versions of geographic information system (GIS) software. I still use GIS software on a regular basis.

After school, I worked as a groundwater scientist for a consulting company, where I compiled one of the largest groundwater chemistry databases of its kind at the time. I also became interested in groundwater modeling, which uses computers to simulate the flow of water in the ground. It can predict where contaminants in the groundwater are likely to flow. I liked it so much that I enrolled in graduate school, where I studied groundwater flow.

Over time, I have held many jobs for the company, including research scientist, software designer, programmer, manager, and salesperson. My current job is exciting because I can help our customers solve challenging problems that also have significant financial impacts. My motivation is providing customers with valuable information that results in well-designed and efficient wind farms.

Name_____ Date_____ Class_____

WHERE IS IT WINDY?

Model Landscape and Wind Farm

1. Place a check under the appropriate angle for each flag in the model landscape.

	TRIAL 1			TRIAL 2		
FLAG						
1						
2						
3						
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20						

2. Were there some flags that never received any wind? If so, where were they located in the landscape?

3. Were there some flags that always received a lot of wind? If so, where were they located in the landscape?

4. Why do you think some flags received a lot of wind and others not as much?

WIND IN NEW YORK

Where are the highest wind speeds in New York?
Using the elevation map of New York, shade the areas that you believe might have the highest wind speeds.

Were your predictions correct?
Compare your predictions to the Wind Speed Map at 70 m.

1. Are your predictions similar to the actual wind speeds?

What happens to the wind speed as you go higher in the atmosphere?
2. How do wind speeds change as elevation increases?

2. Why do you think this happens?

3. What role do you think elevation plays in the engineering design of turbines?

Where are the wind farms in New York?
Compare topography and wind speed maps with the New York State Wind Farm Map.

1. What is the wind speed and topography of the wind farm locations in New York?

2. Why do you think these locations were selected as opposed to areas where wind speed is the highest?

1. Place a check under the appropriate angle for each flag in the model landscape.
   Student observation

2. Were there some flags that never received any wind? If so, where were they located in the landscape?
   Student observation

3. Were there some flags that always received a lot of wind? If so, where were they located in the landscape?
   Student observation

4. Why do you think some flags received a lot of wind and others not as much?
   Landscape features can get in the way of the path of wind. In nature, the wind speeds increase as you increase elevation.

WIND IN NEW YORK

Where are the highest wind speeds in New York?

Using the elevation map of New York, shade the areas that you think might have the highest wind speeds.

Were your predictions correct?

Student observation

Compare your predictions to the Wind Speed Map at 70 m.

1. Are your predictions similar to the actual wind speeds?
   Answers will vary depending on student's predictions.

What happens to the wind speed as you go higher in the atmosphere?

2. How do wind speeds change as elevation increases?
   As one increases in elevation in a particular spot, the wind speed increases.

3. Why do you think this happens?
   There are fewer obstructions as you increase in elevation.

5. What role do you think elevation plays in the engineering design of turbines?
   Engineers have increased the height of turbines over time to access the higher wind speeds. With this increase in elevation, there are other issues that engineers have to take into consideration such as the transportation of the wind turbine parts and the potential impacts to wildlife.

Where are the wind farms in New York?

Compare topography and wind speed maps with the New York State Wind Farm Map.

1. What is the wind speed and topography of the wind farm locations in New York?
   See the map.

2. Why do you think these locations were selected as opposed to areas where wind speed is the highest.
   Sites are typically selected for a number of reasons: proximity to population centers (closer proximity means less loss due to transmission), land availability, ability to get the project approved in a cost effective way.