Module 2: Activity 3

Forecasting Air Quality

IT'S OUR AIR

SUMMARY

In this activity, students will use real maps, images, and data to develop an ozone forecast for a particular day in Charlotte, North Carolina. They will then check their forecast against the actual ozone forecast and measurements for that day. Students should already have experience reading weather maps and forecasting weather before doing this activity.

ESSENTIAL QUESTIONS

- How do meteorologists forecast air quality?
- What tools do meteorologists use to forecast air quality?

TIME NEEDED

This activity will take about 30-45 minutes for an AP class and up to a full block period for an Earth/Environmental Science class.

North Carolina ESSENTIAL STANDARDS FOR EARTH/ENVIRONMENTAL SCIENCE

- EEn.2.5 Understand the structure of and processes within our atmosphere.
- EEn.2.5.2 Explain the formation of typical air masses and the weather systems that result from air mass interactions.
- EEn.2.5.4 Predict the weather using available weather maps and data (including surface, upper atmospheric winds, and satellite imagery)
- EEn.2.5.5 Explain how human activities affect air quality.

A product of the NC Air Awareness Program 2015.

MAKING CONNECTIONS

We often use science to forecast the future. Probably the most obvious examples are the daily weather forecast and the daily air quality forecast.

Scientists in all areas, not just meteorology, make predictions based on their knowledge and on data they have collected and analyzed. For example, biologists and ecologists try to predict what will happen to forest ecosystems if the wooly hemlock adelgid (a non-native insect) kills off the hemlocks in the Southern Appalachians. Medical researchers try to predict if giving a mouse a particular drug will prevent a particular disease. Doctors try to predict if an overweight patient is likely to develop diabetes. Astronomers try to predict if an asteroid is on course to hit the Earth. Geologists try to predict if and when a volcano will erupt or an earthquake will occur.

BACKGROUND

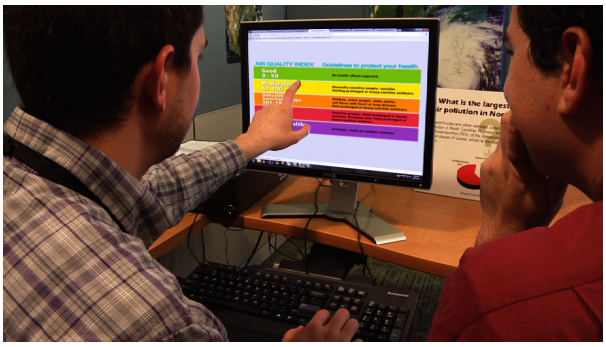
In North Carolina, meteorologists at the Division of Air Quality forecast the air quality every day to help inform citizens how good or bad the air quality is expected to be. The forecast is communicated using the color-coded Air Quality Index (AQI). Knowing how much air pollution is in the air helps people take precautionary steps to protect their health, such as limiting outdoor activity during times when air pollution is higher. One of the biggest air quality problems in North Carolina is ground-level ozone, a strong respiratory irritant that can cause serious health problems. Although the way meteorologists forecast ground-level ozone is considerably more complex, this activity gives students a window into the process.

To forecast air quality, meteorologists first have to forecast the weather, and then forecast the air quality (usually for ozone and particulate matter) on top of that.

Meteorologists use a number of tools to make their forecasts, including information about the past (data from the previous day or days), present (real-time data), and future (computer models that forecast future conditions).

The information they use comes in a number of forms from a variety of reliable sources:

- Data from satellites, such as images of clouds and water vapor
- Daily weather maps, with temperatures, pressures, fronts, winds, precipitation, upper-level analysis



- Weather-prediction computer models
- Weather and air quality data from the previous day(s)
- Hourly air pollutant data from previous day

Here is a weather/air quality forecasting philosophy to share with your students. It's called persistence forecasting: in general, what happened yesterday is likely to happen today. That's because today and yesterday share many characteristics. For example, they are both in the same season (usually!). Also the Earth's location and tilt relative to the sun are virtually the same today as they were yesterday. Of course, a new event – a cold front, or a forest fire – can change the weather and the air quality drastically. There can also be a gradual build-up of pollutants, so if ozone has been in the Code Yellow range for several days and the weather is looking like it will continue to be warm and sunny again, you might expect that it will increase to Code Orange at some point.

In any case, looking at today's weather and air quality is the first step in making a forecast for tomorrow. Next, look for upcoming events that might make tomorrow's weather different than today's.

In this activity, students will look at a variety of maps and data from September 1, 2011, and use that information to make an ozone forecast for Charlotte, NC, for September 2, 2011, a day when maximum 8-hour average ozone levels were in the Code Orange range.

The point of this activity is not to get the right forecast – it's to understand the basics of how to forecast air quality, and to gain an appreciation of how difficult forecasting is, given all the different variables.

If students have completed "Making a Simple Predictive Model for Ground-Level Ozone" (Module 2, Activity 2), they will be able to apply some of that knowledge to this activity.

For more information on how ground-level ozone pollution forms, see "Criteria Pollutants and a Closer Look at Ozone" (Module 1, Activity 4).

MATERIALS

These materials are all provided. On the maps, "Z" refers to Greenwich Mean Time, so18Z or 18:00Z = 2:00 p.m. EDT.

WARM UP

Sample forecast discussion from the Division of Air Quality (provided in Warm Up section)

PART A: Looking at Past Weather and Ozone Conditions

- Weather Maps and Satellite Images for Sept. 1, 2011
  - Surface Analysis Map (ground-level air pressure) for Sept. 1, 2011
  - Map with maximum temperatures for Sept. 1, 2011
  - Map with precipitation for Sept. 1, 2011
  - Map with average wind speeds for Sept. 1, 2011
  - Satellite images showing clouds for Sept.1, 2011
- Table of ozone forecast history for the month of Aug., 2011
- Map with ozone data from Sept.1, 2011

PART B: Looking at Weather and Ozone Forecast Models

- Maps from two different precipitation forecast models
- NOAA air quality forecast model

WRAP UP AND ACTION

North Carolina Division of Air Quality Forecast Discussion of September 1, 3:00 pm (provided in Wrap Up section)

AIR QUALITY FORECASTING VIDEO

- Discusses how we know which pollutants are in our air, how that information is communicated to the public, and why knowing that information is important for people who are active outdoors because of the health problems these pollutants can cause, in particular ground-level ozone and particulate matter.
- Tour of a Division of Air Quality monitoring station.
- Interview with NC Division of Air Quality meteorologists who talk about the complexities of air quality forecasting.
- Introduces the Air Quality Index and what the color codes mean.

Video Length: 11:15 minutes
Key Elements: virtual tour, interviews, animation, video footage

Teacher Tips

If your students are keeping or have kept weather logs, with daily temperatures, cloud conditions, air pressure, and so forth, they may already have experience making educated guesses about the coming weather. If this is the case, help them draw on that experience in doing this activity. Although this activity uses much more complicated data and data depictions, the underlying process of collecting data and drawing conclusions is the same.

My students liked using the full color versions of maps and images that I printed and laminated for their tables much better than projecting the maps on the board. Laminating them allows me to reuse the maps for years. Hand out the maps for Part A and Part B as students are working on the relevant part to prevent confusion and keep students working at a reasonable pace.

If you do not have access to a color printer, or if you would like to save paper, then it would be best if you could do this activity in a computer lab or with a laptop or iPad cart in the classroom for each group to use. Then the students could type their 100-200 word response for Part C there as well.

Because of the written component to Part C, this is a great activity for practicing science literacy skills.

– Mark Townley

WARM UP

Lead a class discussion to review the ingredients of ground-level ozone formation: heat, sunlight, NO_x (from vehicles, fossil-fuel-burning power plants, and industry), and VOCs (from vegetation, industry, and vehicles).

Show the class the sample Forecast Discussion from the Division of Air Quality to illustrate some of the factors that influence a forecast.

Forecast Discussion from a summer morning in North Carolina (meteorologists were concerned about Code Orange in the Charlotte region and discussed the relevant forecast concerns of the day):

A strong upper-level ridge is the dominating weather feature for the region today, resulting in sunny skies and hot temperatures across the state. With light winds and a drier air mass, ozone levels have the potential to elevate into the Code Orange range in the Charlotte area. Some models are showing the development of showers and thunderstorms in the Charlotte region this afternoon, which would significantly reduce ozone production in that region and allow for concentrations to only elevate into the Code Yellow range. Whether or not the Charlotte area achieves ozone concentrations in the Code Orange range will depend upon whether or not this convection occurs. Elsewhere across the state, ozone concentrations in the Code Yellow range are expected. Particle pollution concentrations across most of North Carolina are expected to remain around the upper Code Green/lower Code Yellow threshold statewide.

If necessary, review relevant weather information, including the fact that high pressure systems lead to clear skies and stagnant air. In a high-pressure system, air is relatively dense, so it sinks, becomes warmer, and moisture evaporates. There is no build-up of thunderclouds, nor is there a release of latent energy that occurs when moisture condenses. The lack of mixing can lead to an accumulation of ozone precursors (nitrogen oxides and volatile organic compounds) and ozone itself.

Discuss the concept of persistence forecasting – that the weather tomorrow is likely to be similar to the weather today (see Background for more).

Show the video, which covers AQI and air quality forecasting, including interviews with meteorologists from the Division of Air Quality.

THE ACTIVITY

Make a color-coded AQI ozone forecast for the Charlotte area for September 2, 2011, using the data and maps provided.

Answer the questions given for each set of data, then write up your ozone forecast, along with your reasoning. Your forecast and explanation should be about 100-200 words long. Your explanation should demonstrate that you understand factors leading to ozone formation, the concept of persistence forecasting, and how to read a variety of maps, satellite images and tables.

PART A: Looking at Past Weather and Ozone Conditions

Look at the weather maps and satellite images for September 1, 2011, and answer these questions:

1. At the surface level, describe the pattern of air pressure above Charlotte. [Answer: high pressure (anti-cyclone, i.e. clockwise rotation)]
2. What type of weather usually accompanies high pressure systems? [Answer: clear skies and little to no wind]
3. What was the maximum temperature in Charlotte on this day? [Answer: 92° Fahrenheit]
4. Was there any precipitation in Charlotte? [Answer: no]
5. What were the average wind speeds in central North Carolina? Use numbers and descriptive comparative words in your answer. [Answer: 1-3 mph, which is not very windy.]
6. Do the satellite images show heavy or sustained cloud cover in Charlotte on September 1? Based on these images, do you think it was overcast or sunny on September 1? Note: The 12 images were taken at one-hour intervals, beginning at 8 a.m. and ending at 7 p.m. [Answer: no heavy or sustained cloud cover, so we can assume it was mostly sunny]
7. Looking at the last three satellite images, representing 5-7 p.m., note the cloud cover moving rapidly south toward Charlotte. These are thunderstorms. Do you think these storms reached Charlotte later in the evening on September 1? What is your reasoning? [Answer: no, because the precipitation map showed there was no precipitation in Charlotte on September 1.]
8. Using what you've learned about the weather on September 1, 2011, what type of weather might you forecast for Charlotte on September 2, 2011? [Answer: high pressure, warm temperatures, few clouds, sunny, no precipitation, relatively calm.]
9. What are the limitations of this forecast? [Answer: There's a lot of information we don't have – for example, we don't know anything about the movement of large air masses into or out of the area that might quickly change the weather.]

Look at the table showing air quality forecast history for ozone conditions during the last week of August 2011 (August 25-August 31), and answer these questions:

10. How many days in Charlotte were Code Orange for ozone? [Answer: 0]
11. How many days were Code Yellow? [Answer: 5]
12. How many days were Code Green? [Answer: 2]
13. What was the most common AQI color code for the week? [Answer: Code Yellow]

Look at the ozone data map from September 1, 2011, and using the chart above, answer these questions:

14. What is the maximum measured ozone level reported from September 1, 2011 and what city is it near? [Answer: 95 ppb, Charlotte]
15. What AQI color code does this represent? [Answer: Code Orange]

Ozone Measurements and the AQI

Air Quality Index	8-Hour Ozone
Good 0-50 Code Green	0-59 ppb
Moderate 51-100 Code Yellow	60-75 ppb
Unhealthy for Sensitive Groups 101-150 Code Orange	76-95 ppb
Unhealthy 151-200 Code Red	96-115 ppb
Very Unhealthy 201-300 Code Purple	116-374 ppb

Source: http://daq.state.nc.us/monitor/aqi/codeChart.shtml

PART B: Looking at Weather and Ozone Forecast Models

Look at the maps from the two different precipitation forecast models, and answer these questions:

1. Does either Model A or Model B predict precipitation in Charlotte for 8 a.m. on September 2? [Answer: no]
2. Does either Model A or Model B predict precipitation in Charlotte for 2 p.m.? [Answer: no]
3. Does either Model A or Model B predict precipitation in Charlotte for 8 p.m.? [Answ**er:** Model A does, and Model B doesn't]
4. What impact does precipitation have on ozone formation? [Answer: precipitation stops ozone formation]
5. Review the thunderstorms on the satellite images from September 1, and recall that thunderstorms approached but did not reach Charlotte. What might have been the effect on ozone levels if those storms HAD reached Charlotte in the late afternoon? [Answer: ozone levels would have been lower]
6. How do the differences between Model A and Model B make it more difficult to forecast the air quality for September 2, 2011? [Answer: Rain has such a big impact on ozone production that if there's uncertainty about the precipitation forecast, there will be uncertainty about the air quality forecast.]

Look at the NOAA ozone forecast model and answer these questions:

7. What is the maximum 8-hour ozone level forecast by this model for Charlotte for September 2, 2011? [Answer: 89 ppb]
8. What AQI color code is this? [Answer: Code Orange]

PART C: Making Your Forecast

Using all the data you have about the past weather and ozone conditions in Charlotte, combined with information from the precipitation forecast models and the ozone forecast model, what AQI color code do you predict for Charlotte on September 2, 2011?

Write 100-200 words explaining your prediction. Include supporting evidence regarding past weather and ozone conditions, as well as information from the models that forecast precipitation and ozone.

WRAP UP AND ACTION

Ask students to share their forecasts, then share the forecast discussion from the DAQ meteorologists on September 1, 2011. Note that the discussion includes information about weather and about pollution precursors, as well as the AQI color code forecast. ("Ridging" refers to the high-pressure system.)

Code Orange *- Air Quality Action Day for ozone in Charlotte on Friday, September 2, 2011!*

Date: *Thursday, September 1, 2011 - 15:00 EDT*

Forecast Valid: *Friday, September 2, 2011*

Today's Air Quality Conditions: Ozone is making a run for the upper Code Yellow to lower Code Orange across the state today as sunny skies have prevailed. Particle pollution remains elevated in the western half of the state, as well.

General Forecast Discussion: For tomorrow, more of the same as high pressure remains anchored over the state. The ridging we're experiencing will begin to break down late tomorrow. However, we should see plenty of sunshine and temperatures in the low 90s. Ozone should move to the lower Code Orange to upper Code Yellow again tomorrow. Particle pollution will continue to moderate, with the higher values expected from the foothills westward.

Outlook: Saturday sees an increase in cloudiness and less pollutant precursors. As such, have knocked down the expectations for ozone on Saturday. On Sunday, a strong frontal boundary will make its way eastward and will provide a stark shift in the air mass over the state. We can expect air quality to generally return to Good levels late Sunday and beyond as temperatures Monday into Wednesday hover in the upper 70s to lower 80s. Autumn is rapidly approaching and this is a good thing.

A key ingredient to this particular forecast is the question of whether afternoon clouds or precipitation will occur on September 2, which would lower ozone production. As a class, look at the two precipitation forecasts for the area – Model A and Model B. Despite the major differences between the two, the key for the Charlotte forecast is that neither model predicts precipitation until late in the day, leaving plenty of time for ozone levels to reach a maximum 8-hour average concentration in the Code Orange range. This in fact did occur. Monitors in and around Charlotte recorded maximum 8-hour average ozone levels of 93 ppb, 86 ppb, and 87 ppb on September 2, 2011 – all resulting in Code Orange AQI.

Model A did the best job capturing a complex of storms that did in fact move out of Virginia towards the Charlotte region around 8 p.m., but by this time the ozone levels had been in the Code Orange range for many hours.

Discuss issues that the students may have struggled with or that may have contributed to the accuracy or inaccuracy of their forecasts. Point out that meteorologists at the Division of Air Quality forecast an AQI number, not just the color code.

ASSESSMENT

HAVE STUDENTS:

Explain, in writing, what an air quality forecaster does and what tools he or she uses. What is the difference between a weather forecaster and an air quality forecaster? How does an air quality forecaster use computer models?

EXTENSIONS

Review trends in ground-level ozone pollution in North Carolina relative to the passage of the N.C. Clean Smokestacks Act of 2002. See "Making a Simple Predictive Model for Ground-Level Ozone" (Module 2, Activity 2) for more information.

Have students work up a particulate matter forecast for the same day.

Have students follow the same directions, but using maps and information from the current day. Have them make an air quality forecast for tomorrow and then see how accurate it is.

As a class, go through the Interactive Ozone Forecasting Simulation provided with this activity at www.itsourair.org and forecast the ozone AQI for the Triangle on June 29, 2012.

RESOURCES

Weather Forecasting

http://cimss.ssec.wisc.edu/satmet/modules/7_weather_forecast/wf-1.html

WORKSHEET

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PART A: Looking at Past Weather and Ozone Conditions

Look at the weather maps and satellite images for September 1, 2011 and answer these questions:

1. At the surface level, describe the pattern of air pressure above Charlotte.

2. What type of weather usually accompanies high pressure systems?

3. What was the maximum temperature in Charlotte on this day?

4. Was there any precipitation in Charlotte?

5. What were the average wind speeds in central North Carolina? Use numbers and descriptive comparative words in your answer.

6. Do the satellite images show heavy or sustained cloud cover in Charlotte on September 1? Based on these images, do you think it was overcast or sunny on September 1? Note: The 12 images were taken at one-hour intervals, beginning at 8 a.m. and ending at 7 p.m.

7. Looking at the last three satellite images, representing 5-7 p.m., note the cloud cover moving rapidly south toward Charlotte. These are thunderstorms. Do you think these storms reached Charlotte later in the evening on September 1? What is your reasoning?

8. Using what you've learned about the weather on September 1, 2011, what type of weather might you forecast for Charlotte on September 2, 2011?

9. What are the limitations of this forecast?

Look at the table showing air quality forecast history for ozone conditions during the last week of August 2011 (August 25-August 31), and answer these questions:

10. How many days in Charlotte were Code Orange for ozone? _____
11. How many days were Code Yellow? _____
12. How many days were Code Green? _____
13. What was the most common AQI color code for the week? _____

Ozone Measurements and the AQI

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Source: http://daq.state.nc.us/monitor/aqi/codeChart.shtml

Look at the ozone data map from September 1, 2011, and using the chart above, answer these questions:

14. What is the maximum measured ozone level reported from September 1, 2011 and what city is it near?

    _____
15. What AQI color code does this represent? _____

WORKSHEET

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Look at the maps from the two different precipitation forecast models, and answer these questions:

1. Does either Model A or Model B predict precipitation in Charlotte for 8 a.m. on September 2? _____
2. Does either Model A or Model B predict precipitation in Charlotte for 2 p.m.? _____
3. Does either Model A or Model B predict precipitation in Charlotte for 8 p.m.? _____
4. What impact does precipitation have on ozone formation?

5. Review the thunderstorms on the satellite images from September 1, and recall that thunderstorms approached but did not reach Charlotte. What might have been the effect on ozone levels if those storms HAD reached Charlotte in the late afternoon?

6. How do the differences between Model A and Model B make it more difficult to forecast the air quality for September 2, 2011?

Look at the NOAA ozone forecast model and answer these questions:

7. What is the maximum 8-hour ozone level forecast by this model for Charlotte for September 2, 2011? _____
8. What AQI color code is this? _____

PART C: Making Your Forecast

Using all the data you have about the past weather and ozone conditions in Charlotte, combined with information from the precipitation forecast models and the ozone forecast model, what AQI color code do you predict for Charlotte on September 2, 2011?

Write 100-200 words explaining your prediction. Include supporting evidence regarding past weather and ozone conditions, as well as information from the models that forecast precipitation and ozone.