GeoMag

Geomagnetism in the MESA Classroom: An Essential Science for Modern Society

Educator Guide

Activities for MESA After-School Programs

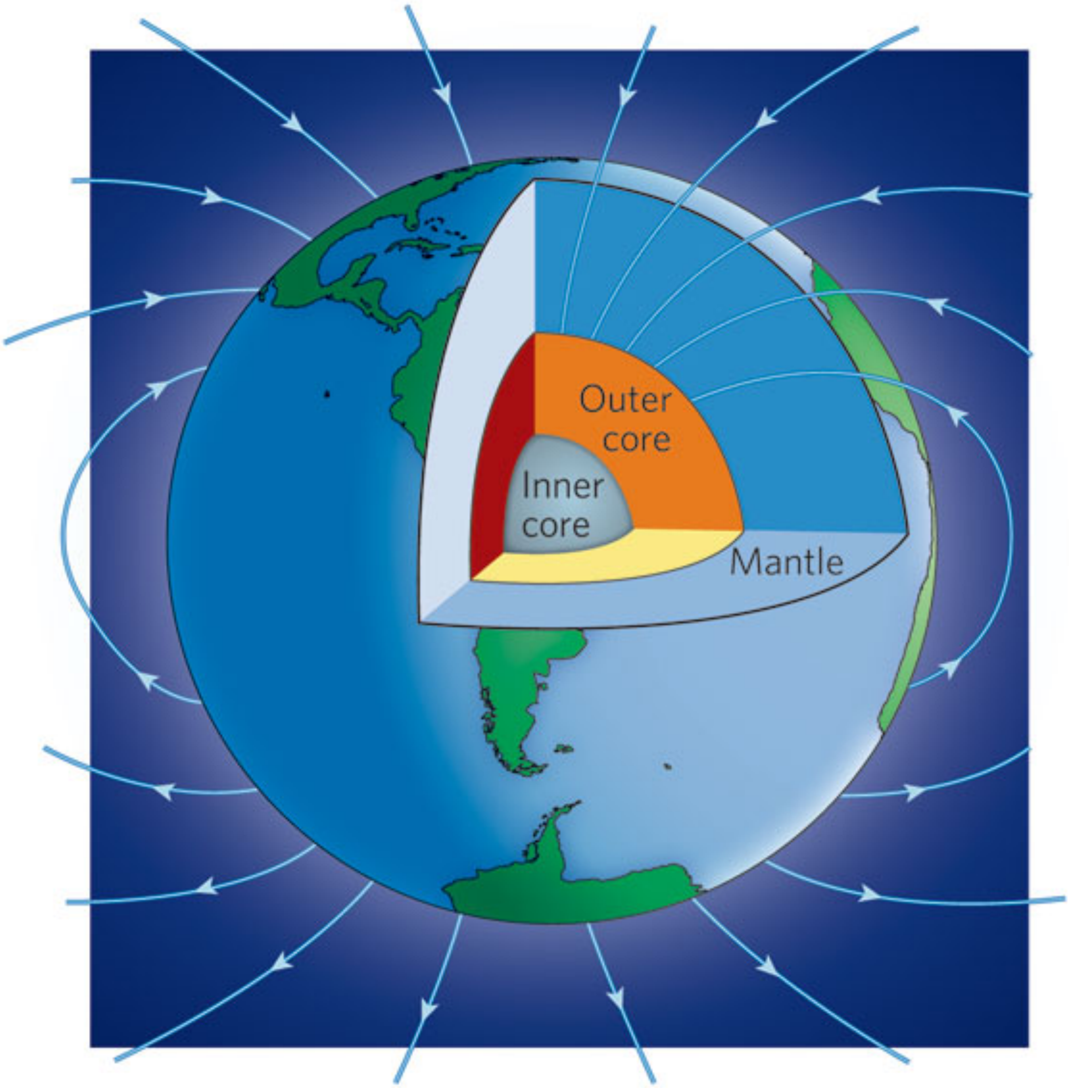

Image source: Earth science: Geomagnetic reversals
David Gubbins, Nature 452, 165-167(13 March 2008), doi:10.1038/452165a

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Overview:

The Cooperative Institute for Research in Environmental Sciences (CIRES) Education Outreach's GeoMag kit is a four-part after-school module that allows students to explore geomagnetism with compasses, navigation exercises, and a geo-caching activity, followed by a field trip to the National Oceanic and Atmospheric Administration's David Skaggs Research Center in Boulder.

These materials are designed to be adapted to suit the interests and abilities of your students, as well as your time available. Please select from the handouts and activities according to what will be most appropriate for your class. The background materials provided for each session are intended to give you further information for customizing the materials, answering questions, or going further into the topics of your choice.

Some terms and topics are fairly advanced for middle school students. There isn't time in this package to address the fundamentals of all areas that are mentioned here. A light touch on some of these complex topics will allow students to explore more of the big picture and get the most out of this program.

Time is allowed at the end of each session for report-outs and discussion.

Grade Levels: 6-8

Essential Questions:

Session One:
- What are some characteristics of Earth's magnetic field?
- How do we use Earth's magnetic field in navigation?

Session Two:
- How do we navigate with a compass?
- What is geocaching?

Session Three:
- What causes an aurora?
- How are Earth's magnetic field and aurora related?
- What is space weather?

Session Four:
- How do the scientists at NOAA's Space Weather Prediction Center use space weather data and information?

Time Needed:

Session One: Two 90-minute in-class sessions

Students will receive

- an overview of the Earth's magnetic field.
- a course-plotting exercise with historic coordinates featuring adjustment for the magnetic field variations in different locations.
- an understanding of airport runway headings.

Session Two: One 90-minute indoor/outdoor session

Students will receive

- an introductory activity reviewing the use of a compass.
- Students will split into teams, each using bearing compasses to construct a navigation route to a cache goal; the teams will then follow another team's navigation instructions to find the cache.
- a course-plotting exercise with historic coordinates featuring adjustment for the magnetic field variations in different locations.

Session Three: One 60-minute in-class session

Students will receive

- An introduction to the effect of solar activity on the magnetic field (including a brief aurora video).
- An opportunity to build a magnetometer.
- An exercise to plot the places where a large aurora was seen.

Session Four: One 3-hour field trip to Boulder's NOAA's David Skaggs Research Center

Students will receive

Guided tour of the Space Weather Predictions Center, where students will see live real-time data of the geomagnetic field; the students will also view the Science on a Sphere (SOS) exhibit facility which can project the Earth's geomagnetic field on a suspended sphere as well as showing solar activity and satellite views of Earth.

Applicable Science Education Standards

Magnetic forces are very closely related to electric forces—the two can be thought of as different aspects of a single electromagnetic force. Both are thought of as acting by means of fields: an electric charge has an electric field in the space around it that affects other charges, and a magnet has a magnetic field around it that affects other magnets. What is more, moving electric charges produce magnetic fields and are affected by magnetic fields. This influence is the basis of many natural phenomena. For example, electric currents circulating in the earth's core give the earth an extensive magnetic field, which we detect from the orientation of our compass needles.
--American Association for the Advancement of Science (1989). Science for All Americans. New York: Oxford, p. 56.

Electric and magnetic forces and the relationship between them ought also to be treated qualitatively. Fields can be introduced, but only intuitively. Most important is that students get a sense of electric and magnetic force fields (as well as of gravity) and of some simple relations between magnets and electric currents. ... Diagrams of electric and magnetic fields promote some misconceptions about "lines of force," notably that the force exists only on those lines. Students should recognize that the lines are used only to show the direction of the field.
--American Association for the Advancement of Science (1993). Benchmarks for Science Literacy. New York: Oxford, p. 93.

Electric currents in the earth's interior give the earth an extensive magnetic field, which we detect from the orientation of compass needles.
--American Association for the Advancement of Science (2007). Atlas of Science Literacy Volume 2. Washington, DC: American Association for the Advancement of Science, p. 27.

Introduction to Geomagnetism Kit and Resources:

The Geomagnetism in the MESA Classroom curriculum consists of a classroom set of student materials, a CD of videos, copies of the curriculum and a NASA Aurora brochure for printing.

The Student Materials kit contains:

1 Silva 123 compass
1 ruler
1 protractor
1 magnet
small container of iron filings
1 pencil box container

Geomagnetism in the MESA Classroom CD:

- Aurora Borealis Brochure
- NASA-Aurora Borealis Video
- Geomagnetism Curriculum Images
- Geomagnetism in the MESA Classroom Teacher and Student Guide

Geomagnetism Curriculum Images:
A PowerPoint of images used in the Geomagnetism in the MESA Classroom curriculum is also available for teachers to use with the lessons. They may project color images if they choose to print student guides in black and white or just project images for discussion and reference.

CIRES Education Outreach will provide student kits to teachers free of charge until our supply is depleted. You may contact us at outreach@cires.colorado.edu

CIRES Education Outreach Geomagnetism in the MESA Classroom Website:
We will have the Geomagnetism in the MESA Classroom curriculum available for download on the CIRES Education Outreach website. Teachers may download the full teacher and student guides in addition to several other resources used in the curriculum. The videos used in the curriculum are also on our website for viewing or download.

http://cires.colorado.edu/education/outreach/projects/geomag/index.html

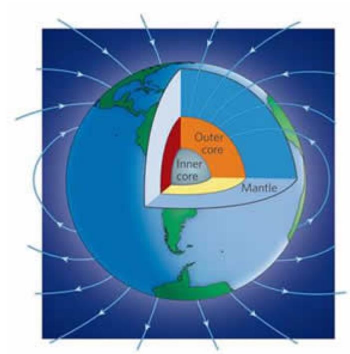
CIRES Education Outreach Student Curriculum Web Links webpage:
We also provide a student links page organized by module. Teachers may bring their students to this page to access all the online links so students may click and go instead of being required to type in each link.

http://cires.colorado.edu/education/outreach/projects/geomag/GeoMagLinks.html

Session One: Geomagnetism and Declination

Lesson Overview:
Students will receive an overview of the Earth's magnetic field, explore magnetic declination using NOAA's declination calculators and learn about airport runway designation.

Background:
The core of Earth is an electromagnet. Although the crust is solid, a mixture of molten iron and nickel surrounds the core of the Earth. Currents of electricity that flow in the molten core cause the magnetic field of Earth. These currents are hundreds of miles wide and flow at thousands of miles per hour as the Earth rotates. The powerful magnetic field passes out through the core of the earth, passes through the crust and enters space.



This image shows the solid inner core region surrounded by a molten outer core. The arrows show the direction of the magnetic field of the Earth that is generated in this outer core. If you imagine a gigantic bar magnet inside of Earth, you'll have a pretty good idea what Earth's magnetic field is shaped like. Of course, Earth DOESN'T have a giant bar magnet inside it; since our planet's magnetic field is made by the swirling motions of molten iron in Earth's outer core our magnetic north is not fixed.

Earth has two geographic poles: the North Pole and the South Pole. They are the places on Earth's surface that Earth's imaginary spin axis passes through. Our planet also has two magnetic poles: the North Magnetic Pole and the South Magnetic Pole. The magnetic poles are near, but not quite in the same places as, the geographic poles.

Links to Learn More:

NOAA's National Geophysical Data Center- Geomagnetism Frequently Asked Questions
http://www.ngdc.noaa.gov/geomag/faqgeom.shtml
National Atlas
http://nationalatlas.gov/articles/geology/a_geomag.html
Windows to the Universe
http://www.windows2universe.org/earth/Magnetosphere/earth_magnetic_poles.html

Learning Objectives:

- Students will understand that movement of the Earth's liquid outer core causes the Earth's magnetic field.
- Students will understand that invisible magnetic fields exist around magnets.
- Students will understand that the magnetic poles move over time.
- Students will understand that compasses point to magnetic north, not geographic north, because the magnetic pole is in a different location from the geographic pole.

- Students will understand that navigation using compasses involves adjusting the direction of a heading with the declination for their location.

Materials:

- Copies of Handouts 1.1, 1.2, 1.3, 1.4, 1.5 and 1.6 in the student guide
- Color images for projection are available GeoMag.Color-Images.pptx
- Bar magnet, iron filings, and sheet of white paper for Handout 1.1.
- Styrofoam ball, toothpicks and a marker for Handout 1.3
- Internet access

Glossary Terms:

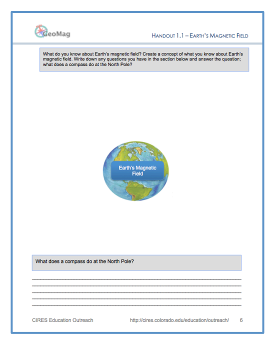
Electromagnet: type of magnet in which the magnetic field is produced by the flow of electric current.
Magnetic declination: The angle between the local magnetic field (the direction the north end of a compass point) and geographic north.
Magnetic field: A field that surrounds magnets and electric currents, detectable because it exerts a force on moving electric charges and on magnetic materials.

Procedure:

Lessons A and B may be done in one 45 minute session. If you have a 90 minute block you will be able to also include lesson C. In the next session you will similarly be able to do lessons D and E in one 45 minute session. If you have a 90 minute block you will be able to also include lesson F.

Lesson A: Earth's Magnetic Field (Handout 1.1)

1. We will start our unit of study with a probe to see what the students already know about earth's magnetic field. This is also a great opportunity to see if your students also hold any misconceptions about geomagnetism. Using Handout 1.1 - Earth's Magnetic Field in the Student Guidebook lesson, ask the students to create a concept map of what they know about earth's magnetic field. There is also a fun question at the bottom of the page asking; "What does a compass do at the North Pole?" Give students 15 minutes to write down what they know and any questions they may have. Have students get in pairs or triads and share their concept maps. Create a class concept map by asking students to add their knowledge to the class concept map then keep the concept map handy so you may add new knowledge as you move through the unit.



Student Handout 1.1- Earth's Magnetic Field

2. Now Watch **"Compass goes crazy near North Pole"** http://www.youtube.com/watch?v=wjGr7IegCVY

Students will be able to watch and learn the answer to this question. If you hold a compass horizontal to the ground at the North Pole, it would have no preferred direction, and might spin around in confusion. If you were to hold the compass sideways, however, the compass would point straight down, toward the North Pole.

Lesson B: Earth's Magnetic Field and a Bar Magnet (Handout 1.2)

1. Engage the students by asking; "What would happen if I sprinkled these iron filings over a magnet?" You might want to record the student's hypothesis. Explain that in the next activity, (Handout 2.1) they will do just that. Have a student read the activity procedure as well as the warning, then allow students groups to proceed.
2. Once the groups have completed the activity review the discussion questions with them.
   Questions:
   1. What did you observe when you sprinkled the iron filings over the paper covering the bar magnet? Draw what you observed.
   The iron filings form curved lines around the magnet,

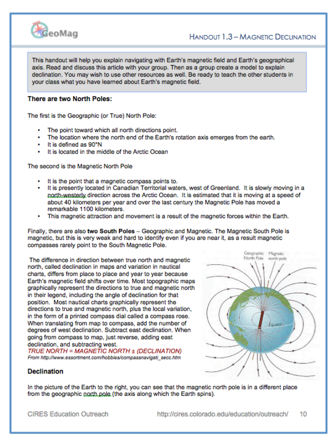
   2. Can you explain why the iron filings behaved that way?
   Every magnet has an invisible magnetic field around it. This field is made up of lines of force that attract magnetic material such as iron filings. The filings form a pattern as they line up in the direction of the magnetic lines of force. The lines of force around each magnet come out of the north pole, loop around the magnet, and enter the magnet's south pole.

   3. Draw what you expect to see when you sprinkle iron filings over two bar magnets in a new configuration.
   Answers will vary depending on magnet configuration.

   4. Draw what you did, in fact, see with your two magnets in the new configuration. How were your expectations the same or different?
   Answers will vary depending on magnet configuration.

Lesson C: Magnetic Declination (Handout 1.3)

1. How can you find your way when you are lost? Have the class brainstorm a list. Lead the discussion towards compasses. Why do people use a compass to find their way when they are lost? Explain to students that compasses point North because the needle is attracted to the Earth's magnetic south pole which is located at the Earth's geographical north pole. Have students predict why a compass will work anywhere. This should lead the



GeoMag HANDOUT 1.3 – MAGNETIC DECLINATION

This handout will help you explain navigating with Earth's magnetic field and Earth's geographical axis. Read and discuss this article with your group. Then as a group create a model to explain declination. You may wish to use other resources as well. Be ready to teach the other students in your class what you have learned about Earth's magnetic field.

There are two North Poles:

The first is the Geographic (or True) North Pole:

- The point toward which all north directions point.
- The location where the north end of the Earth's rotation axis emerges from the earth.
- It is defined as 90°N
- It is located in the middle of the Arctic Ocean

The second is the Magnetic North Pole

- It is the point that a magnetic compass points to.
- It is presently located in Canadian Territorial waters, west of Greenland. It is slowly moving in a north-westerly direction across the Arctic Ocean. It is estimated that it is moving at a speed of about 40 kilometers per year and over the last century the Magnetic Pole has moved a remarkable 1100 kilometers.
- This magnetic attraction and movement is a result of the magnetic forces within the Earth.

Finally, there are also **two South Poles** – Geographic and Magnetic. The Magnetic South Pole is magnetic, but this is very weak and hard to identify even if you are near it, as a result magnetic compasses rarely point to the South Magnetic Pole.

The difference in direction between true north and magnetic north, called declination in maps and variation in nautical charts, differs from place to place and year to year because Earth's magnetic field shifts over time. Most topographic maps graphically represent the directions to true and magnetic north in their legend, including the angle of declination for that position. Most nautical charts graphically represent the directions to true and magnetic north, plus the local variation, in the form of a printed compass dial called a compass rose. When translating from map to compass, add the number of degrees of west declination. Subtract east declination. When going from compass to map, just reverse, adding east declination, and subtracting west.
TRUE NORTH = MAGNETIC NORTH ± (DECLINATION)
From http://www.essortment.com/hobbies/compassnavigati_secc.htm

Declination

In the picture of the Earth to the right, you can see that the magnetic north pole is in a different place from the geographic north pole (the axis along which the Earth spins).

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Student Handout 1.3 – Magnetic Declination

discussion towards magnetic fields that they just observed with the magnet and iron filings.
NOTE: Student will probably bring up using a GPS so a quick discussion about the difference between GPS and a compass would not be off topic.

2. Explain to the students that we have been doing activities that explore Earth's magnetic field. Show the students a globe and ask them "Where is the North Pole?" Probe further by asking if this is the north pole that our compasses align with? The students will discover the answer to this question in the next activity.
3. Using Handout 1.3 – Magnetic Declination, students will make a teaching model to explain the difference between geographic north pole and magnetic north pole. Students will read some background information then make their models. Allow 30 minutes for this activity. Facilitate groups if the have any questions.
4. Debrief the following questions with the students.
   Questions:
   Why do USA cities on the west coast have an easterly declination?
   In areas WEST of the line of zero declination, the magnetic needle points somewhere to the EAST (to the right) of True North. So, these areas are said to have EAST declination.

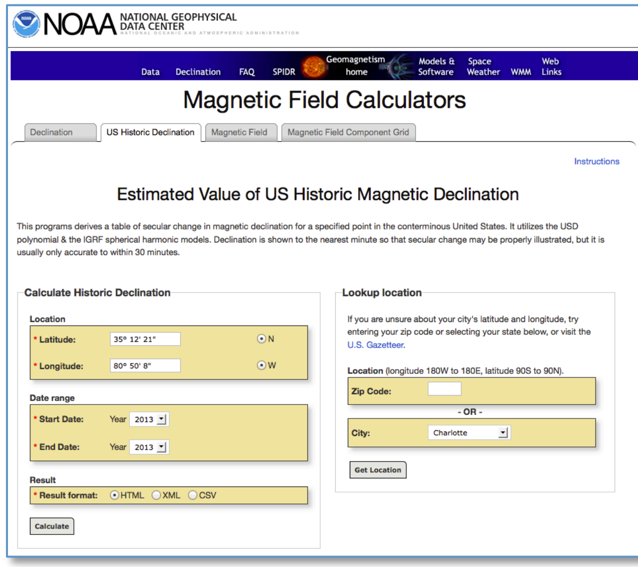
   Why do USA cities on the east coast have a westerly declination?
   It works just the opposite on the other side of the line of zero declination, where the magnetic needle points somewhere to the WEST (left) of True North, these areas have WEST declination.

   TRUE or FALSE   The States of Florida, Georgia and Kentucky will always have a westerly declination. What questions does your group have about declination?
   That will depend on which way the magnetic field lines move. We do not fully understand these patterns.

Lesson D: Magnetic Field Changes Over Time (Handout 1.4)

1. This lesson explores magnetic declination a bit deeper than the previous lesson as students discover that magnetic fields change over time. Students will need internet access to use the historical declination calculator on the NOAA Magnetic Field calculators website. Decide whether to go over the background information in this lesson as a whole class or let the students read through it in small groups. Using Student Handout 1.4, students will choose a location in the United States, a US city will work best. Although it not necessary for major US cities, it is a good idea to have students look up the latitude and longitude for their city and record it on their handout.

2. Go to NOAA Magnetic Field calculators website http://www.ngdc.noaa.gov/geomag-web/#ushistoric. To calculate a US historic magnetic declination, you simply fill out the "Calculate Historic Declination" form under the "US Historic Declination" tab of the Magnetic Field Calculators page, then click "Calculate" at the bottom. Below is an explanation of the each of the sections contained within the calculator form.

   Look Up Location:
   If Students are unsure about their city's latitude and longitude, they may try entering a zip code or selecting a city already in the database from the drop down menu. Then click GET LOCATION. This will fill in the latitude and longitude fields of the Calculate Historical Declination form.
   Calculate Historical Declination:
   Fill in the latitude and longitude fields, then select the Start date and End date. Leave the result as the default HTML and click the CALCULATE button.

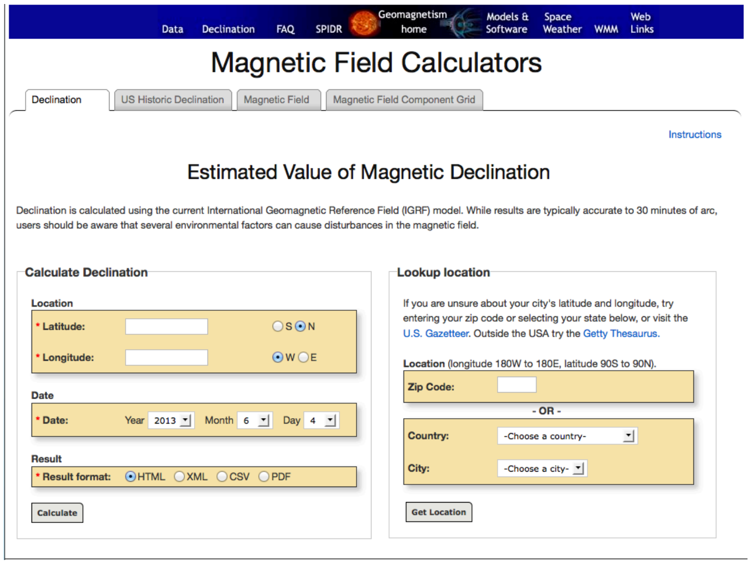
3. Debrief with the students their findings. How much shift in magnetic declination in their location did they see?

Lesson E: Finding Magnetic Declination (Handout 1.5)

1. Knowing declination is very important, this activity uses the NOAA Magnetic Field calculator for declination. Students will see a pattern as the find the declinations for US cities across America. Students will need internet access to complete this activity.
2. Go to NOAA Magnetic Field calculators website http://www.ngdc.noaa.gov/geomag-web/ - declination. To calculate a the magnetic declination for a location, you simply fill out the "Calculate Magnetic Declination" form under the "Declination" tab of the Magnetic Field Calculators page, then click "Calculate" at the bottom. Below is an explanation of the each of the sections contained within the calculator form.

   Look Up Location:
   All the cities are already in the database, so use the drop down menu to select each one. Then click GET LOCATION. This will fill in the latitude and longitude fields of the Calculate Declination form.
   Calculate Historical Declination:

Fill in the latitude and longitude fields, then select the Start date and End date. Leave the result as the default HTML and click the CALCULATE button.



3. Debrief the following questions with the students.

Questions:

What patterns did you notice?

Answers will vary depending on what year you are doing this activity. In 2012, the cities listed created almost a numerical countdown from Sacramento, CA at 13°E to Jefferson City, MO at 0°E to Boston, MA at 14°W.

Find four cities with the same or nearly the same declination.

Answers will vary depending on what cities were chosen.

Is there a difference in between the east and west coast of the USA in regards to declination?

What difference did you notice?

Answers will vary depending on what year you are doing this activity. In the West coast the declination

The NOAA declination calculator also notes how much the declination is changing in a location over a year's time. Look up Anchorage, AK and Albany, NY. Now predict how much declination change Honolulu, HI might experience.

Anchorage, AK __18 degree change_ Albany NY __2 degree change___

Honolulu, HI (prediction) _____________ Honolulu, HI (actual) __2 degree change __

Pick three cities to explore further that might have an intersting declination pattern.
Answers will vary depending on what cities the student chooses.

What pattern did you think you might find and what pattern did you actually find?
Answers will vary

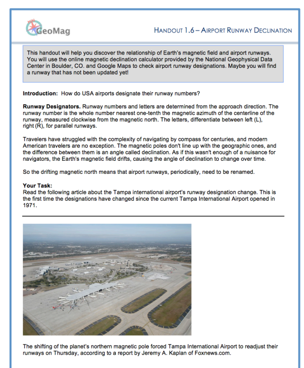
Lesson F: Airport Runway Declination (Handout 1.6)

1. The numbers on the runway represent the magnetic heading of the runway (NOT true heading, which can be quite different), rounded to the nearest ten degrees, with the final zero dropped. So runway 36 has a heading of 360 degrees (due north), and runway 27 has a heading of 270 degrees (due west). Since runways are straight, opposite ends of the runway will have numbers that always differ by 18. So the opposite end of runway 27 is runway 9 (27 - 18), and the opposite end of runway 36 is runway 18 (36 - 18). The letters, differentiate between left (L), right (R), for parallel runways. Since the exact direction of magnetic north changes slowly over time, runways must occasionally have their numbers changed. Students will learn how airport runways numbers are changed every few years as the magnetic declination changes in an area. They might find some runways that have not repainted their runways yet using Google Maps satellite view.
2. After reading the article, discuss the following questions with the students

   Questions

   Do you think that airports in one geographical location of the Unites States would be more affected by magnetic poles drift than another?
   Answers will vary depending on what year you are doing this activity

   List a few states that you think might be impacted more and why.
   Answers will vary depending on what year you are doing this activity



GeoMag HANDOUT 1.6 – AIRPORT RUNWAY DECLINATION

This handout will help you discover the relationship of Earth's magnetic field and airport runways. You will use the online magnetic declination calculator provided by the National Geophysical Data Center in Boulder, CO. and Google Maps to check airport runway designations. Maybe you will find a runway that has not been updated yet!

Introduction: How do USA airports designate their runway numbers?

Runway Designators. Runway numbers and letters are determined from the approach direction. The runway number is the whole number nearest one-tenth the magnetic azimuth of the centerline of the runway, measured clockwise from the magnetic north. The letters, differentiate between left (L), right (R), for parallel runways.

Travelers have struggled with the complexity of navigating by compass for centuries, and modern American travelers are no exception. The magnetic poles don't line up with the geographic ones, and the difference between them is an angle called declination. As if this wasn't enough of a nuisance for navigators, the Earth's magnetic field drifts, causing the angle of declination to change over time.

So the drifting magnetic north means that airport runways, periodically, need to be renamed.

Your Task:
Read the following article about the Tampa international airport's runway designation change. This is the first time the designations have changed since the current Tampa International Airport opened in 1971.

The shifting of the planet's northern magnetic pole forced Tampa International Airport to readjust their runways on Thursday, according to a report by Jeremy A. Kaplan of Foxnews.com.

Student Guide Handout 1.6

3. Students will first compare two declination maps for the United States, noting three differences.
4. Students will next look at the Airport Runway data table and choose five airports. Then they will predict what the runways would be numbered based on the 2005 Declination Map.
5. Students will now look up the declination of each of their selected airports.
6. They will then follow the instructions on how to calculate the runway designation on page 27 of the student guide. (See Calculation Directions below)
7. Students can then use Google maps to look up the airport. If you select satellite view, you will be able to zoom in and check the runway designation to see if the runway is marked correctly.

Runway Designation Calculation Directions:
Subtract the magnetic declination from the runway true heading for this airport
___________________ - ___________________ = _____________________ Divide the number by 10.
The rounded value is the actual runway number

EXAMPLE:

Airport	Latitude	Longitude	Declination	Runway 1 True heading	Runway Number	Runway 2 True heading	Runway Number
Example: SFO	37.619 N	122.375 W	14	298	28, 10	27	1, 19

Magnetic declination for the SFO airport on 01-26-2012 = 14° 4' 13"
Runway 1:
Subtract declination from the runway heading:
298 – 14 = 284
Divide the number by 10
= 28.4
The rounded value 28 is the actual runway number
The numbers at the ends of a runway always differ by 18. So the opposite end of runway 27 is runway 9 (27 - 18), and the opposite end of runway 36 is runway 18 (36 - 18). Hence the runway numbers for runway 1 are 28 and 10

Extension: Explain how the other end of the runway is labeled and how you might calculate that.

Checking for Understanding:
Now can you do the math in reverse?
If the Runway for Boulder, Colorado is labeled 8 …. What is its geomagnetic declination?
8^0 East

Airport	Latitude	Longitude	Runway 1 True Heading (In degrees, Geographic)	Runway 2 True Heading (In degrees, Geographic)	Declination	Runway 1 Number	Runway 2 Number
Alabama							
Birmingham Airport	33.564 N	86.752 W	55	235	3W	06	24
Arkansas							
Clarksville Municipal Airport	35.471 N	93.427 W	95	275	4E	09	27
Arizona							
Scottsdale Airport	33.623 N	111.911 W	44	224	12E	03	21
California							
San Diego International Airport	32.734 N	117.19 W	106	286	14E	09	27
Colorado							
Denver International Airport	39.862 N	104.673 W	180	001	11E	16	34
Boulder Municipal Airport	40.039 N	105.226 W	N/A	N/A	12E	08	26
Florida							
Orlando Sanford International Airport	28.777 N	81.236 W	90	270	5W	09	27
Illinois							
Chicago O'Hare International Airport	41.982 N	87.907 W	90	270	3W	10	28
Iowa							
Des Moines International Airport	41.534 N	93.663 W	54	234	3E	05	23
Kansas							
Garden City Regional Airport	37.928 N	100.724 W	180	000	9E	17	35
Kentucky							
Addington Field Airport	37.686 N	85.925 W	47	227	3W	05	23

Source: http://www.globalair.com/airport/state.aspx

Airport	Latitude	Longitude	Runway 1 True Heading (In degrees, Geographic)	Runway 2 True Heading (In degrees, Geographic)	Magnetic Variation	Runway 1 Number	Runway 2 Number
Louisiana							
Baton Rouge Metropolitan	30.533 N	91.15 W	43	223	3E	04	22
Maine							
Augusta State Airport	44.321 N	69.797 W	153	333	18W	17	35
Bangor International Airport	44.807 N	68.828 W	134	314	19W		
Michigan							
Capitol Region Intl Airport	42.212 N	83.353 W	29	271	5W	10	28
Detroit Metropolitan Wayne County Airport	42.212 N	83.353 W	29	209	6W	04	22
Mississippi							
Cleveland Municipal Airport	33.761 N	90.758 W	178	358	0E	17	35
Missouri							
Lambert-St Louis International Airport	38.749 N	90.37 W	122	302	0E	12	30
New Jersey							
Atlantic City International Airport	39.458 N	74.577 W	118	298	10W	13	31
New Mexico							
Double Eagle Ii Airport	35.145 N	106.795 W	046	226	11E	04	22
New York							
Greater Rochester International Airport	43.119 N	77.672 W	31	211	10W	04	22
North Dakota							
Bismark Municipal Airport	46.773 N	100.746 W	138	318	7E	13	31

Source: http://www.globalair.com/airport/state.aspx

Airport	Latitude	Longitude	Runway 1 True Heading (In degrees, Geographic)	Runway 2 True Heading (In degrees, Geographic)	Declination	Runway 1 Number	Runway 2 Number
Ohio							
Findley Airport	41.012 N	83.669 W	180	000	5W	18	36
Oregon							
Portland International Airport	45.589 N	122.597 W	119	299	20E	10	28
Texas							
Dalhart Municipal Airport	36.022 N	102.547 W	180	360	9E	17	35
Virginia							
Richmond International Airport	37.505 N	77.32 W	147	327	9W	16	34
Wisconsin							
Kings Land O' Lakes Airport	46.154 N	89.212 W	143	323	2W	14	32

NOTE:
Students who enjoy this activity might be interested in looking for patterns. For Example there are a lot of Airports with the bearing of 180 and 000, or runways numbered 04 and 22. You could expand this lesson so students are looking up more airports to find patterns.

Source: http://www.globalair.com/airport/state.aspx

Session Two: Course-Setting and Course Following

Lesson Overview:

Students will receive a hands-on introduction to using a compass, followed by an activity that allows them to set a course for other students and an opportunity to follow a course that other students have set. Finally students may try to figure out the mystery of the 1823 Pirate map that uses declination, historic declination and compass bearing to solve.

NOTE: Adjustment for magnetic declination is not used in the geocaching activity because it is not necessary when using line-of-sight headings. As an optional enhancement, the instructor may have all teams add the declination to their headings, thus integrating the topic from the previous session.

Background:

The invention of the navigational compass is credited by scholars to the Chinese, who began using it for navigation sometime between the 9th and 11th century. Before compasses people navigated to places based on landmarks and the stars. The invention of the compass allowed travelers to navigate when the sky was overcast or foggy. This enabled mariners to navigate safely far from land, increasing sea trade, and contributing to the Age of Discovery.

Learning how to use a compass is still very valuable as a backup to GPS, which can be affected by space weather, foggy or whiteout conditions, and requires battery use. Scientists were able to calculate distance using a compass and you can also find the height of a structure or tree if your compass has a clinometer scale.

Links to Learn More:

Compass Dude: http://www.compassdude.com/compass-skills.shtml
How Compasses Work: http://adventure.howstuffworks.com/outdoor-activities/hiking/compass.htm

Learning Objectives

- Students will use bearing compasses to identify headings to different objects.
- Students will demonstrate setting a heading and distance for one leg of a journey using a bearing compass.
- Students will demonstrate being able to follow a heading and distance to a destination using the bearing compass.
- Students will use their understanding of magnetic headings and declination to locate a navigation course form a historical map.

Materials:

- Copies of Handouts 2.1, 2.2, 2.3, and 2.4 in the student guide.
- Color images for projection are available GeoMag.Color-Images.pptx
- Bearing compass for each three-student team.
- Two plastic containers per team (one for the directions and one for the cache)
- Goodies for cache, paper, and pencils.
- Tape measure for each team.

Glossary Terms:

Compass Bearing: A hand *bearing compass* is used to measure the magnetic direction of sighted objects relative to the user.
Cardinal Directions: The four *cardinal directions* or *cardinal points* are the directions of north, east, south, and west, commonly denoted by their initials: N, E, S, W.
Geocaching: is a treasure hunting game where you use a GPS to hide and seek containers with other participants in the activity.

Procedure:
Lessons A and B may be done very quickly depending on how much background information you decide to provide. If you have a 90 minute block you will be able to also include lesson C. In the next session you will be similarly be able to do lessons D in one 45 minute session.

Lesson A: Using a Compass to Navigate (Handout 2.1)
Introduction to Compasses: You may wish to give your students a brief history of the compass using the background information links above. A basic question to ask is; What are some possible explanations for why the magnetic compass retains its original role as the basic navigational instrument despite its old age? Pass out one bearing compass to each team of three students and go over the features of the compass using Handout 2.1. Students will label a compass diagram. (10 minutes) Each team goes through this together.

Lesson B: Bearing Compass Use (Handout 2.2)
The students will then learn about how to use a compass for simple bearing heading. You may want to go over the background information with them, then let them practice first with the worksheet then with the compasses by calling out a heading and having everyone move to the heading. Each team goes through this together. It is helpful if the students memorize "*Red in the Shed" which means that the red end of the needle is inside the two red lines marking North on the compass.* (15 minutes)

Lesson C: Creating a Navigation Map to a Cache (Handout 2.3)
Students will split into three-student teams, each using bearing compasses to construct a navigation route to a cache goal (30 minutes) For the purposes of this activity, declination will be ignored.
The teams will then exchange places and follow another team's navigation instructions to find the cache (15 minutes). Debrief with the students what was successful with this activity and what might have been a challenge.

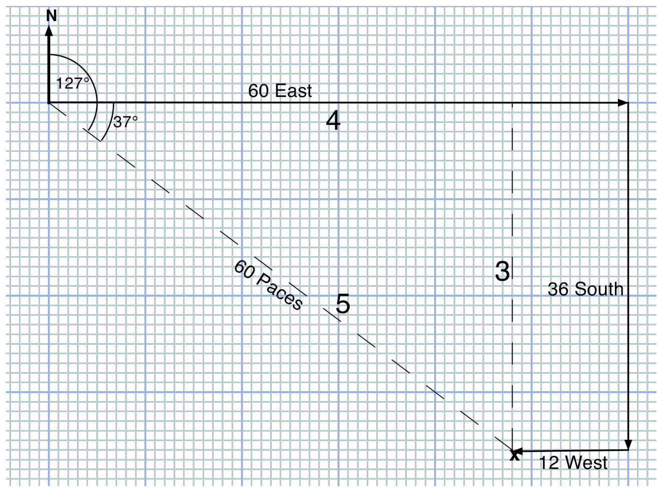
NOTES: If time allows, students may add a waypoint for a two-leg course. To do this, add another plastic container that includes a heading sheet (Handout 2) for the second leg.
This activity can be done outside or inside; ideally, the teams should be able to set up their course out of sight of the other teams.

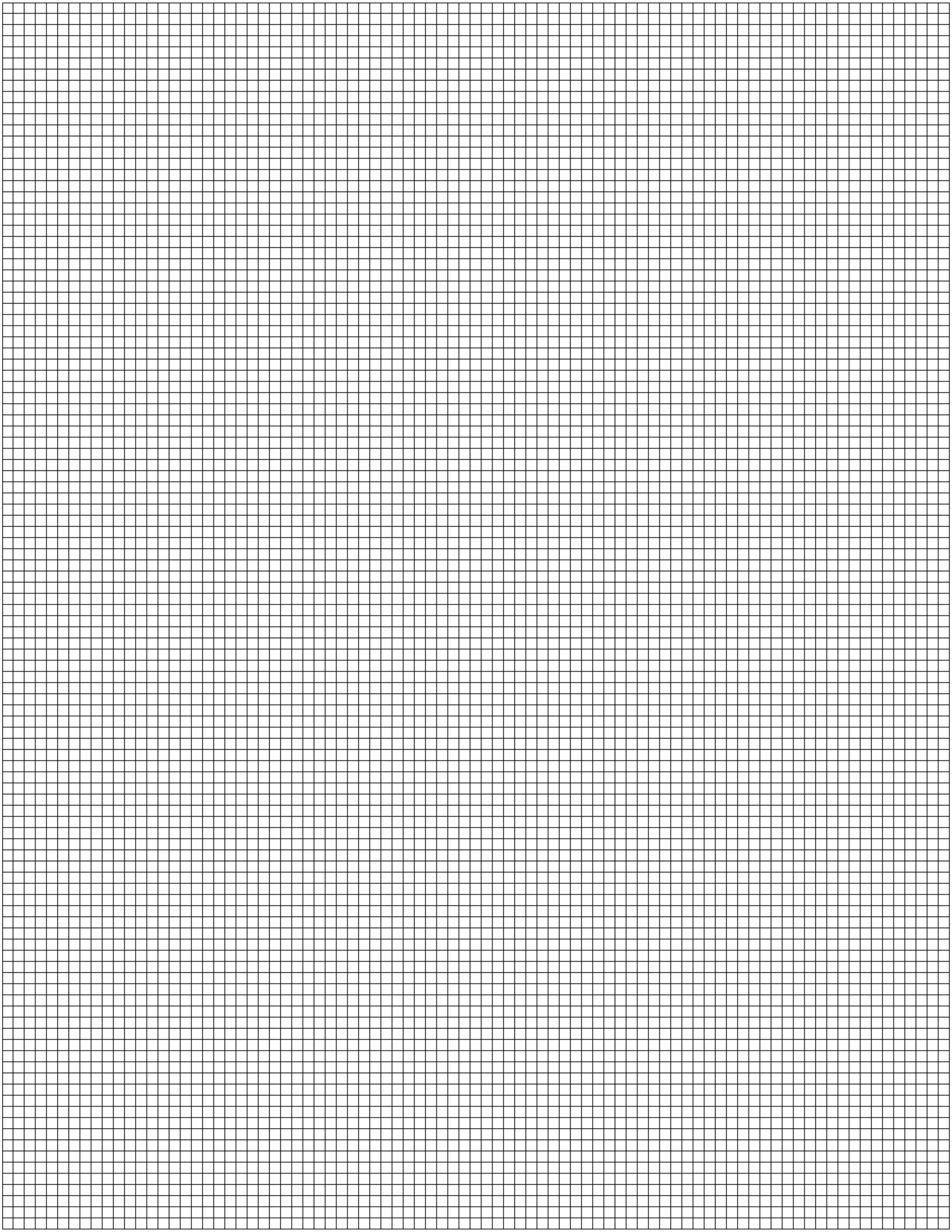
Lesson D: Navigation with an 1823 Pirate Map (Handout 2.4)

This activity in best in mixed ability groups or with students who have had a little bit of basic geometry. The instructions in the student guide will help you step the students through the first puzzle of finding the location of the treasure in Long Beach, CA. Students may solve part 2; Long Beach, NY on their own.

Be sure to print out this section of the students guide to help the students work through part one.

Here is the answer to Navigation with an 1823 Pirate Map Part 2





Session Three: Solar Activity and the Earth's Magnetic Field

Lesson Overview:
Students will receive an overview of the interaction between solar activity and the Earth's magnetic field. Effects on Earth of solar activity include aurora and electromagnetic field disruptions. These changing environmental conditions in near-Earth space are called space weather. Scientists monitor space weather in order to predict events and help people be ready for them.

Background:
Space Weather is a relatively new term that came into usage in the 1990's when it became apparent that the space environment impact on human systems needed further research and coordination. The aurora is a dynamic and visually exciting manifestation of a solar-induced geomagnetic storm. The aurora provide pretty displays, but they are just a visible sign of atmospheric changes that may wreak havoc on technology systems. Throughout the history of mankind, many legends, myths and superstitions have revolved around the aurora. There are many great resources on the internet to learn more about aurora and space weather.

Links to Learn More:

Aurora FAQ by Dirk Lummerzheim, Geophysical Institute, University of Alaska, Fairbanks
http://odin.gi.alaska.edu/FAQ/
Legends of the Aurora http://www.gi.alaska.edu/asahi/hist01.htm
NOAA's Space Weather Prediction Center
http://www.swpc.noaa.gov/Education/index.html

Learning objectives:

- Students will understand that solar activity affects Earth's geomagnetic field.
- Students will understand that auroras are caused by interaction between particles in the Earth's magnetic field and molecules in the upper atmosphere.
- Students will be able to list several issues affecting human society that can be influenced by space weather, including power supply problems, communication disruptions, and navigation system problems.

Materials:

- Copies of Handouts 3.1, 3.2, 3.3, and 3.4 in the student guide.
- Color images for projection are available GeoMag.Color-Images.pptx
- Aurora videos cued up and ready to project.
- Materials for Lesson B (see material list below).

Glossary Terms:

Magnetosphere: Earth's magnetosphere is a region in space whose shape is determined by the Earth's internal magnetic field, the solar wind, and the interplanetary magnetic field.
Solar wind: A stream of charged particles ejected from the upper atmosphere of the Sun.
Solar Flare: A violent explosion in the Sun's atmosphere.
Coronal Mass Ejection (CME): An ejection of material from the outer solar atmosphere.

Procedure:

Lesson A: Introduction to Aurora (Handout 3.1)

1. Begin by showing the students the video "Alaska Aurora Borealis March 17 2013" http://www.youtube.com/watch?v=flawnHtX9ao with this introduction. "Imagine that you have stepped outside and are seeing these images, after the video we will share your thoughts and ideas about this video." You may also download the video from http://cires.colorado.edu/education/outreach/projects/GeoMag.html.

   After the video, ask the students what this video was about. This is a great opportunity to become aware your students knowledge and/or misconceptions about aurora.

2. Guide the students to the idea that through science we know understand these beautiful light displays in the sky and can predict when they will occur but for many hundreds of years humans did not know what caused aurora and as is often the case they created myths about phenomenon they did not understand. You might suggest a few myths from the **Legends of the Aurora** website to get the students intrigued and their creative juices flowing.
   Example of Discussion Questions: How/why are myths created? Do myths differ among cultures? How can myths help a culture/people understand their environment? How do myths reflect the environment in which they were created?
3. Have the students get in groups and create their own myths about the aurora. They will have a few examples from the **Legends of the Aurora** website in their handout 3.1. Suggest that they work on an outline and visuals. They can story board their ideas to share them with the other.

Lesson B: Introduction to Space Weather (Handout 3.2)
1. Show the students video "NASA SDO - Graceful Eruption, March 16, 2013" http://www.youtube.com/watch?v=4KAlXcIr-y4 or March 16, 2013 from the

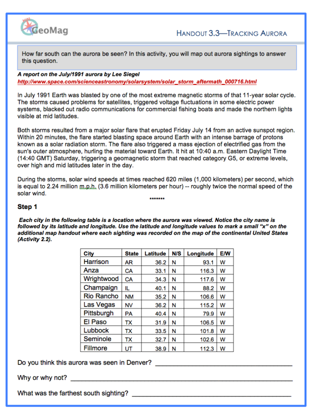
jhelioviewer site
http://sdo.gsfc.nasa.gov/gallery/gallery/assets/movies/March_prom.mpg.
The last video we watched was "Alaska Aurora Borealis March 17 2013" now I have another video to show you. After the video, ask if the students think these two videos are related and how. Share with the students that the NASA SDO video is a video of the solar activity that produced the aurora on March 17, 2013.

2. The next video presents an overview of how the Earth's magnetic field interacts with high energy particles and how activity on the Sun can interfere with various human activities as well as producing the aurora.
   NASA Destination Tomorrow Segment - Aurora Borealis (5:32min)
   http://cires.colorado.edu/education/outreach/projects/geomag/NASADT10-AuroraBorealis1.mpeg
   Or NASA | The Mystery of the Aurora (2:15 min)
   http://www.youtube.com/watch?v=PaSFAbATPvk

3. Now students will explore the effect of the solar wind on the geomagnetic field. Students will make a magnetometer apparatus. For best results the Magnetometer will need to be constructed and left in place for several days. It is ideal to take 2-3 measurements each day over 5-7 days or longer.

Lesson C: Tracking Aurora (Handout 3.3)

1. Introduce this activity for plotting the locations of aurora reports for a significant geomagnetic storm by reading a report on the July 1991 Aurora by Lee Siegel on the student handout. (15 minutes)
2. **Optional Activity 3.4** is available if time and equipment allows. This will give students experience with the website maintained by the Space Weather Prediction Center, which they will visit on the field trip.
3. **Group Report-Outs on Activity and Discussion** (10 minutes)


GeoMag HANDOUT 3.3—TRACKING AURORA

How far south can the aurora be seen? In this activity, you will map out aurora sightings to answer this question.

A report on the July/1991 aurora by Lee Siegel
http://www.space.com/scienceastronomy/solarsystem/solar_storm_aftermath_000716.html

In July 1991 Earth was blasted by one of the most extreme magnetic storms of that 11-year solar cycle. The storms caused problems for satellites, triggered voltage fluctuations in some electric power systems, blacked out radio communications for commercial fishing boats and made the northern lights visible at mid latitudes.

Both storms resulted from a major solar flare that erupted Friday July 14 from an active sunspot region. Within 20 minutes, the flare started blasting space around Earth with an intense barrage of protons known as a solar radiation storm. The flare also triggered a mass ejection of electrified gas from the sun's outer atmosphere, hurling the material toward Earth. It hit at 10:40 a.m. Eastern Daylight Time (14:40 GMT) Saturday, triggering a geomagnetic storm that reached category G5, or extreme levels, over high and mid latitudes later in the day.

During the storms, solar wind speeds at times reached 620 miles (1,000 kilometers) per second, which is equal to 2.24 million m.p.h. (3.6 million kilometers per hour) -- roughly twice the normal speed of the solar wind.

****

Step 1

Each city in the following table is a location where the aurora was viewed. Notice the city name is followed by its latitude and longitude. Use the latitude and longitude values to mark a small "x" on the additional map handout where each sighting was recorded on the map of the continental United States (Activity 2.2).

City	State	Latitude	N/S	Longitude	E/W
Harrison	AR	36.2	N	93.1	W
Anza	CA	33.1	N	116.3	W
Wrightwood	CA	34.3	N	117.6	W
Champaign	IL	40.1	N	88.2	W
Rio Rancho	NM	35.2	N	106.6	W
Las Vegas	NV	36.2	N	115.2	W
Pittsburgh	PA	40.4	N	79.9	W
El Paso	TX	31.9	N	106.5	W
Lubbock	TX	33.5	N	101.8	W
Seminole	TX	32.7	N	102.6	W
Fillmore	UT	38.9	N	112.3	W

Do you think this aurora was seen in Denver? ______________________

Why or why not? ______________________

What was the farthest south sighting? ______________________

Session Four: Field Trip to NOAA's David Skaggs Research Center

Lesson Overview:
You may request a tour of NOAA David Skaggs Research Center. A guided tour of the Space Weather Predictions Center, where students will see live real-time data of the geomagnetic field is a wonderful way to show students science in action. Another stop will give the students an opportunity to view the Science on a Sphere (SOS) exhibit facility which can project the Earth's geomagnetic field on a suspended sphere as well as showing solar activity and satellite views of Earth.

Background:
Tours of the David Skaggs Research Center last approximately 1.5 hours and include stops at the Space Weather Prediction Center, ESRL Global Monitoring Division for information on the carbon dioxide record, the National Weather Service Forecast Office, and Science On a Sphere.

Links to Learn More:

NOAA Boulder Labs Tours
http://www.boulder.noaa.gov/?q=node/3
NOAA ESRL Public Tours
http://www.esrl.noaa.gov/outreach/tours.html
NOAA's Space Weather Prediction Center
http://www.swpc.noaa.gov/Education/index.html

Learning objectives:

- Students will understand that scientists monitor space weather at the NOAA Space Weather Prediction Center in Boulder, CO and see how these scientists work.
- Students will see Earth's magnetic field data projected on Science on a Sphere as well as other NOAA data sets.
- Students will get a little history of NOAA and information on possible science careers.

Materials:

Copies of Handout 4.1 in the student guide.

Glossary Terms:

Magnetosphere: Earth's magnetosphere is a region in space whose shape is determined by the Earth's internal magnetic field, the solar wind, and the interplanetary magnetic field.
Solar wind: A stream of charged particles ejected from the upper atmosphere of the Sun.
Coronal Mass Ejection (CME): An ejection of material from the outer solar atmosphere.
Science on a Sphere: is a unique visualization tool that is a room sized and use computers and video projectors to display planetary data.

Procedure:

For all **school tours** and **special group tours**, please call 303-497-4091.
Visit the NOAA link for more information: http://www.boulder.noaa.gov/?q=node/3

If you would like to give your students some more background information about NOAA before their field trip please visit
http://www.boulder.noaa.gov/?q=node/17

Students may complete Handout 4.1 during their trip to the facility to stimulate discussion.

Questions:

What does NOAA stand for?

N___ National ____________________
O___ Oceanic ____________________
A___ and Atmospheric ____________________
A___ Administration ____________________

What kind of commercial airline flights are the most dependent on the Space Weather Prediction Center and why?

Commercial airline flights that travel over the poles are most susceptible to space weather. Aircraft communications and GPS navigation may be degraded along with potential flight rerouting.

Where in Hawaii do space weather forecasters get some of their data from?

The US Air Force Weather Observer in Kaena Point, Hawaii also monitors space weather.

How many hours a day does the Space Weather Prediction Center stay open to provide data?

24 hours a day - 7 days a week

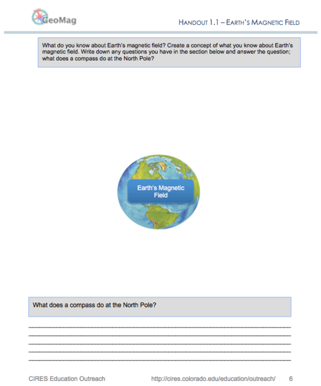
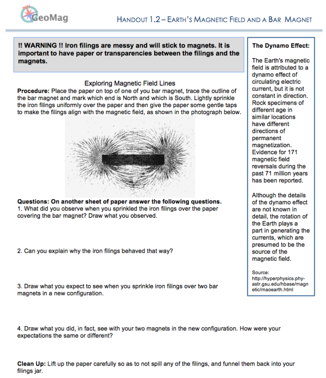
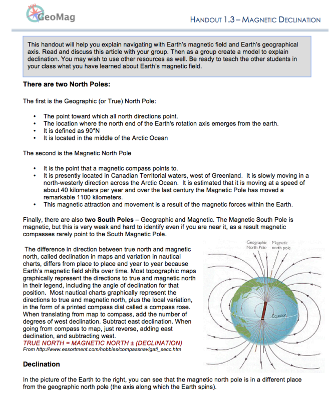
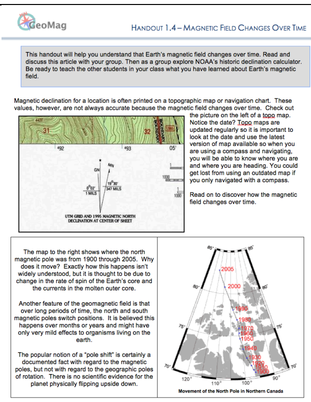
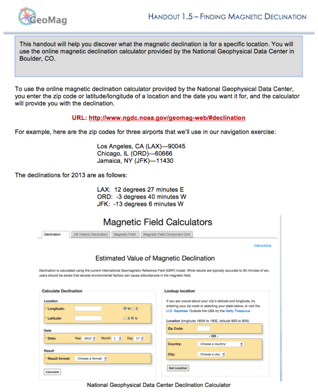
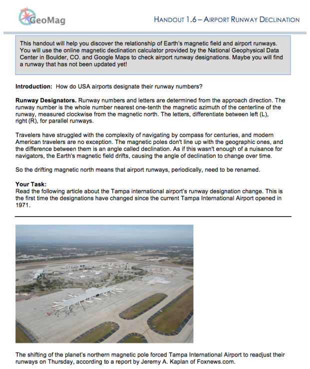
What was the most interesting thing you saw at Science on a Sphere?

Answers will vary

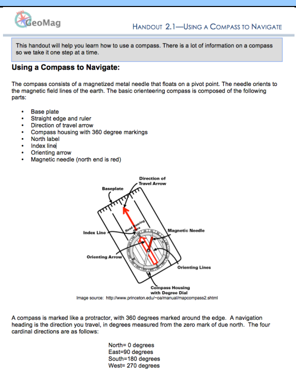
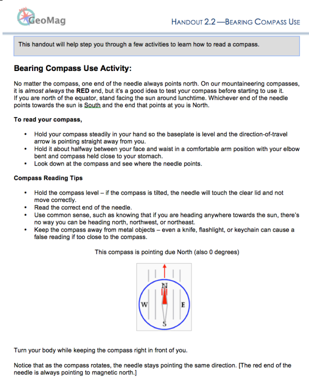
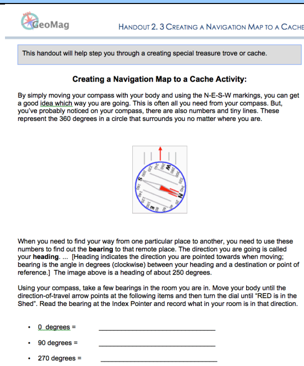
Term	Definition
agonic line	An imaginary line on the earth's surface connecting points where the magnetic declination is zero.
aurora	A faint visual phenomenon associated with geomagnetic activity that is visible mainly in the high- latitude night sky.
azimuth	The direction of a celestial object from the observer, expressed as the angular distance from the north or south point of the horizon to a point. The horizontal angle or direction of a compass bearing.
cardinal directions	the four *cardinal directions* or *cardinal points* are the directions of north, east, south, and west, commonly denoted by their initials: N, E, S, W.
compass	a small magnet suspended so that it can freely point to earth's magnetic north pole
compass bearing	a hand *bearing compass* is used to measure the magnetic direction of sighted objects relative to the user
geocaching	an outdoor sporting activity in which the participants use a Global Positioning System (GPS) receiver or other navigational techniques to hide and seek containers, called "geocaches" or "caches", anywhere in the world.
geomagnetism	The study of the earth's magnetism.
magnetic declination	The angle between magnetic north and true north at a particular location. Also called *magnetic variation*.
magnetic field	area around and affected by a magnet or charged particle.
magnetic storm	interaction between the Earth's atmosphere and charged particles from solar wind.
magnetometer	scientific instrument used to measure the presence, strength, and direction of Earth's magnetic field.
magnetosphere	teardrop-shaped area, with the flat area facing the sun, around the Earth controlled by the Earth's magnetic field.
solar flare	explosion in the sun's atmosphere, which releases a burst of energy and charged particles into the solar system.
solar wind	flow of charged particles, mainly protons and electrons, from the sun to the edge of the solar system.
space weather	changes in the environment outside the Earth's atmosphere, usually influenced by the sun.

Student Guide handout snap-shots for reference.

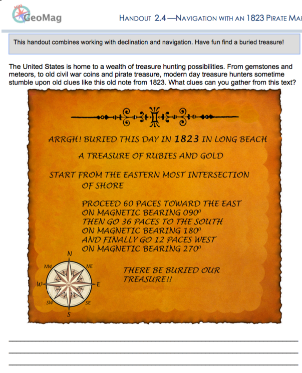
Session One – Geomagnetism and Declination

		
Lesson A -- Handout 1.1	Lesson B -- Handout 1.2	Lesson C -- Handout 1.3
		
Lesson D -- Handout 1.4	Lesson E -- Handout 1.5	Lesson F -- Handout 1.6

Session Two – Course-Setting and Following

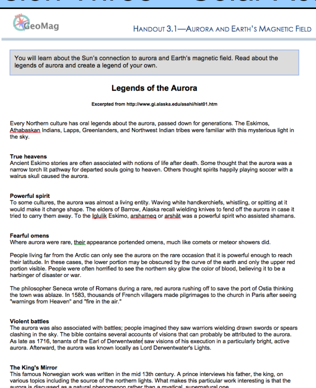
		
Lesson A -- Handout 2.1	Lesson B -- Handout 2.2	Lesson C -- Handout 2.3

Session Two – Course-Setting and Following

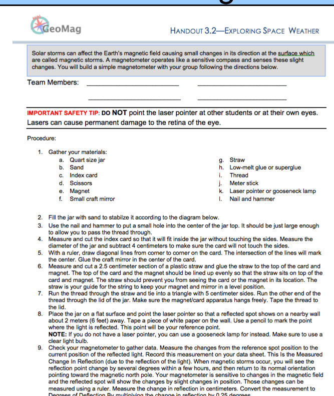

HANDOUT 2.4—NAVIGATION WITH AN 1823 PIRATE MAP
This handout combines working with declination and navigation. Have fun find a buried treasure!

Lesson D -- Handout 2.4

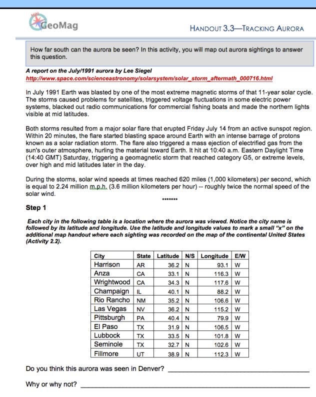
Session Three – Solar Activity and the Earth's Magnetic Field


HANDOUT 3.1—AURORA AND EARTH'S MAGNETIC FIELD
Legends of the Aurora

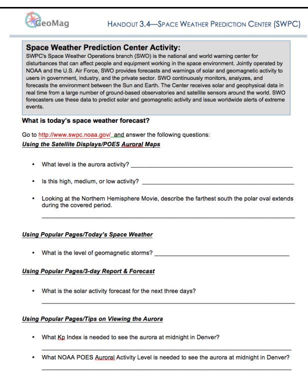
Lesson A -- Handout 3.1


HANDOUT 3.2—EXPLORING SPACE WEATHER

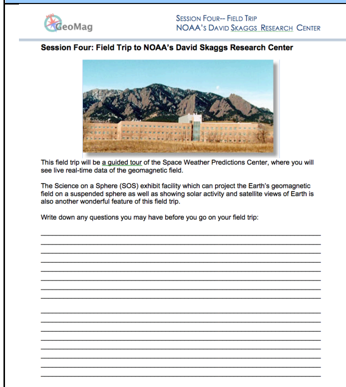
Lesson B -- Handout 3.2


HANDOUT 3.3—TRACKING AURORA

Lesson C -- Handout 3.3


HANDOUT 3.4—SPACE WEATHER PREDICTION CENTER (SWPC)
Space Weather Prediction Center Activity:
What is today's space weather forecast?

Lesson D -- Handout 3.4

Session Four – Field Trip to Boulder's NOAA David Skaggs Research Center		
 Session Four-- Field Trip NOAA's David Skaggs Research Center **Session Four: Field Trip to NOAA's David Skaggs Research Center** This field trip will be a guided tour of the Space Weather Predictions Center, where you will see live real-time data of the geomagnetic field. The Science on a Sphere (SOS) exhibit facility which can project the Earth's geomagnetic field on a suspended sphere as well as showing solar activity and satellite views of Earth is also another wonderful feature of this field trip. Write down any questions you may have before you go on your field trip:		
Lesson A -- Handout 4.1		

You can explore the concepts and ideas in the GeoMag kit further with these great Apps!

Apps	Information
3D Sun	A major solar flare erupts on the sun. Before long, your phone chirps in your pocket to let you know! Pulling out your phone, you see a 3D view of the sun — a digital reconstruction of satellite images freshly downloaded from NASA's "STEREO" satellites, orbiting millions of miles away.
Aurora Forecast	Aurora Forecast application lets you easily plan to see the Northern Lights. If you are a serious aurora watcher, plan to spend the night with Aurora Forecast application. It's time to see the Northern Lights. Recent auroral activity and forecast data is provided by NOAA POES and Geophysical Institute at UAF.
Geo Bucket	Do you like geocaching? Want an iPad, iPhone, iPod geocaching application that can be used offline for paperless geocaching? Geo Bucket is just the thing for you.
Geocaching Intro	Geocaching is a global treasure hunting game where participants locate hidden physical containers, called geocaches, outdoors and then share their experience online. Find out more about geocaching at Geocaching.com.
Geocaching Toolkit iGCT	Geocaching is a worldwide game of hiding and seeking treasure. A multi-cache involves two or more locations. Sometimes the calculations are easy, but this toolkit can help when calculations become tedious while out there in the field.
SDO	SDO App brings you real-time images from The Solar Dynamics Observatory. SDO is the first mission to be launched for NASA's Living With a Star (LWS) Program, a program designed to understand the causes of solar variability and its impacts on Earth. SDO is designed to help us understand the Sun's influence on Earth and Near-Earth space by studying the solar atmosphere on small scales of space and time and in many wavelengths simultaneously.

USGS Comic: Journey along a Fieldline
http://geomag.usgs.gov/publications/comicbook/GeomagComic.pdf

Education & Outreach

For more information please visit:
http://cires.colorado.edu/education/outreach/

Questions or Comments can be sent to:
outreach@cires.colorado.edu

https://www.facebook.com/CIRESEducationOutreach
https://vimeo.com/user1459836
https://itunes.apple.com/us/itunes-u/icee-inspiring-climate-education/id398026184
http://www.youtube.com/user/CIRESvideos