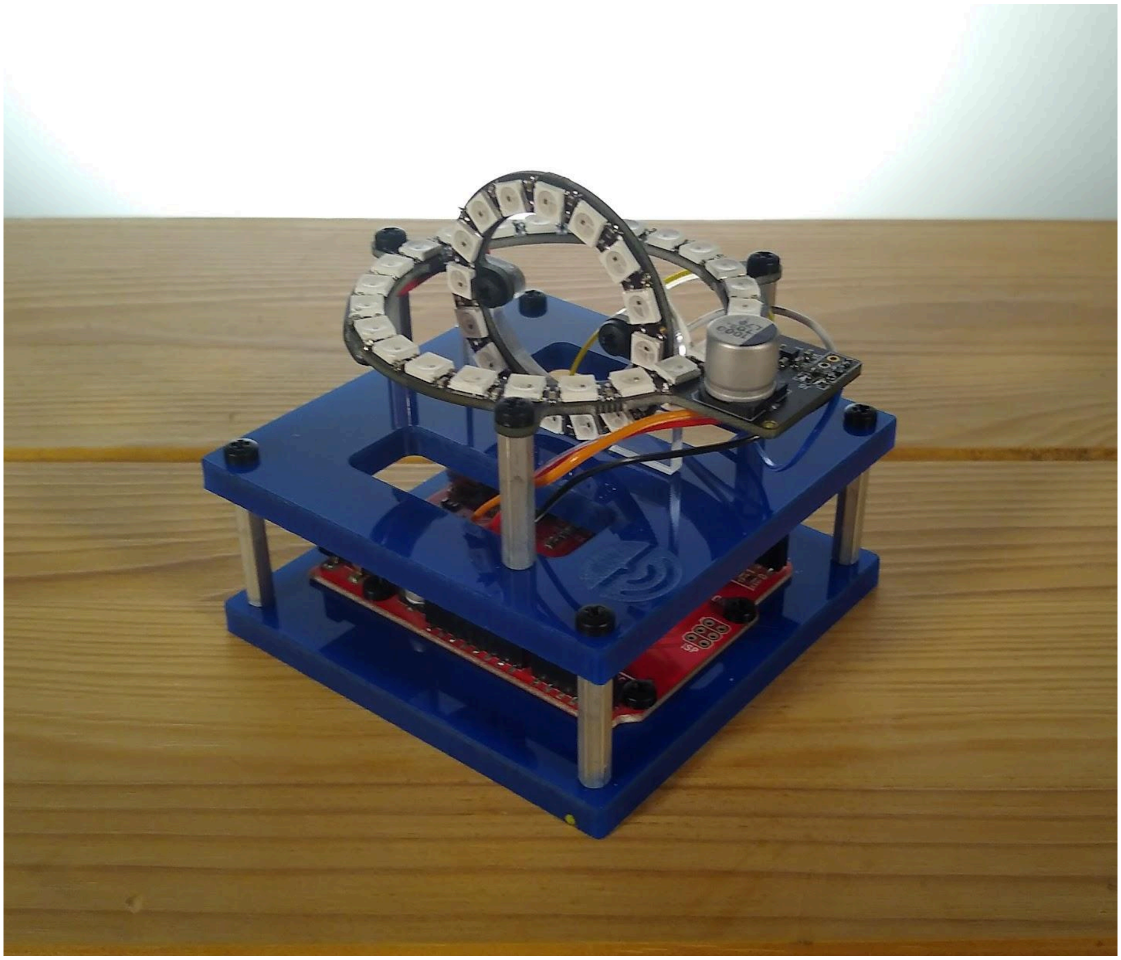
LEEMANGEOPHYSICAL LLC
CONSULTING & INSTRUMENTATION

# 3D Compass Lab Activity

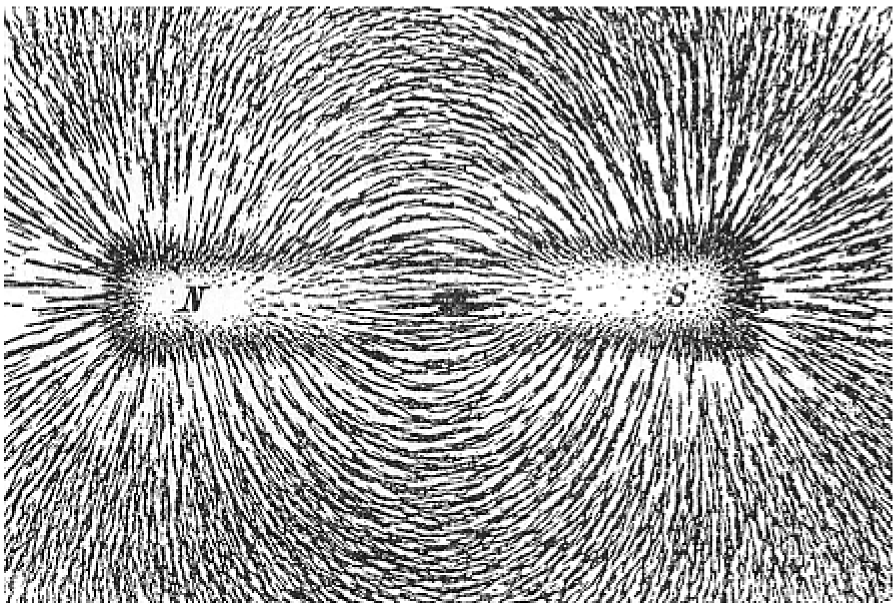


**⚠ WARNING:**
This product can expose you to chemicals, which are known to the State of California to cause cancer. For more information, visit www.P65Warnings.ca.gov.

**⚠ WARNING:**
CHOKING HAZARD - Small parts
Not for children under 3 yrs.

# Introduction

Magnets create a magnetic field that surrounds them with lines of magnetic flux going from the North Pole of the magnet to the South Pole of the magnet. We can see this with a bar magnet and some iron filings, but visualizing the magnetic field surrounding the Earth is a little more difficult! Much like a bar magnet, lines of magnetic flux run from the north magnetic pole of the Earth to the south magnetic pole.

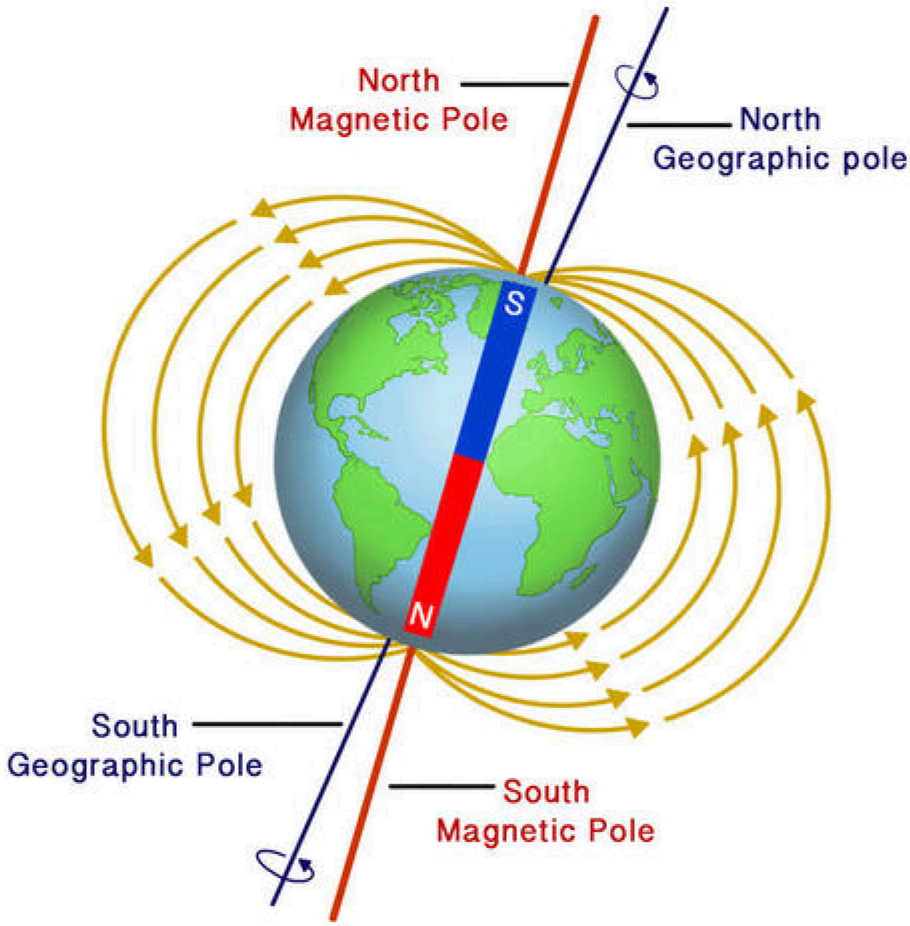



*Iron filings trace out magnetic field lines around a bar magnet.* Image: Newton Henry Black, Harvey N. Davis (1913) Practical Physics, The MacMillan Co., USA, p. 242, fig. 200

The magnetic field of the Earth is created by the swirling liquid metal of the outer core revolving around the solid metal inner core. This creates the “geodynamo” of the Earth. Scientists are still working to understand exactly how the geodynamo works and model its behavior. The magnetic field around the Earth is about 80% a dipole field like that surrounding a magnet, but the remaining 20% difference is due to the turbulent swirling and churning of the liquid metal. The flow is convective, similar to a thunderstorm but with metal clouds!

At times, the magnetic poles even switch - compasses would point south instead of north! This process has occurred many times in the history of the Earth (over 180) and measuring the magnetic field locked into rocks when they formed has helped us understand when and where the rocks were made. The pole reversal could take anywhere from hundreds to thousands of years, but we haven’t been here to observe one as the most recent polar reversal occurred about 780,000 years ago!

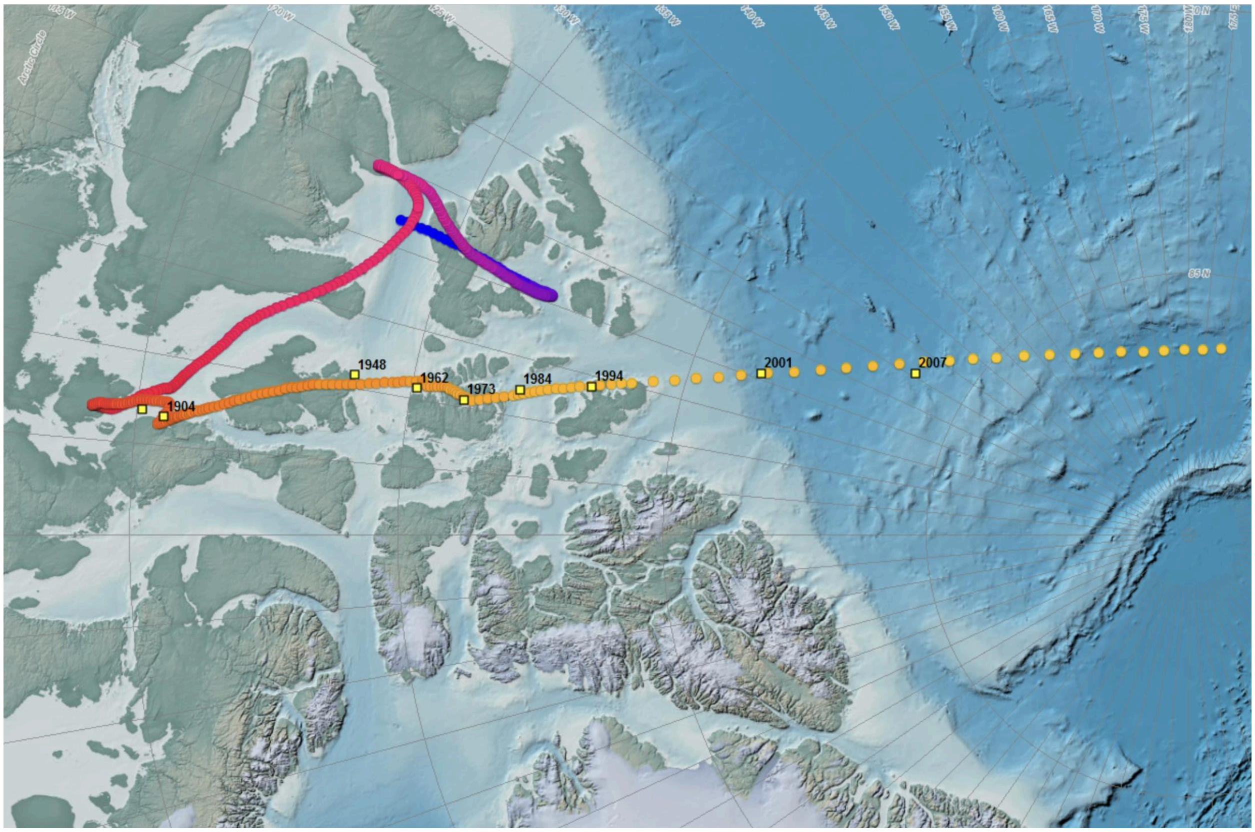
Speaking of the poles, the Earth has two sets of poles. There is the geographic pole where the axis of the planet's rotation is, then there is the magnetic pole. The magnetic pole is where the bar magnet would come through the surface. The magnetic pole drifts around and changes position.




*The geographic and magnetic poles of the Earth don't exactly line up and the polar location wanders through time.*
Image: Laura Guerin, CK-12 Foundation, CC BY-NC 3.0

When boats are sailing or airplanes are flying they must correct the difference between the direction indicated by a magnetic compass and true north. This is called the magnetic declination. If the declination is east, then it is subtracted from the compass reading to get the true heading and it is added if the declination is west.

The magnetic field isn't just good for navigation though, it is actually crucial for life on Earth. The magnetic field creates a shield that protects the planet from harmful solar radiation. Without it, life as we know it wouldn't be here!




*Map of the magnetic north pole location.* Image courtesy of NOAA/NGDC

Finally, the lines of magnetic field exist in 3D - they have not only a portion of the magnetic field vector pointing to the north magnetic pole, but also pointing up or down. This is called the angle of magnetic dip. At the magnetic poles the dip angle is ninth degrees, or straight into/out of the ground. At the magnetic equator the dip angle is zero degrees and the magnetic field is parallel to the ground, entirely in the north-south direction. Your 3D compass is a unique instrument as it can show you not only which direction is north, but what the actual 3D direction of the magnetic field is where you are standing!

# 3D Compass Lab Activity

## Materials Needed

- Assembled 3D compass
- Pencil
- Small magnet

The 3D compass is powered by a standard USB mini-B cable (included) that can be plugged into a computer, USB charger, or USB battery pack. We have included a USB charger to make powering it up easy. If plugged into a computer the device may reset a couple of times while the computer establishes a connection to the compass. When connected to a computer, the x, y, and z components of the magnetic field can be recorded for later analysis.

As soon as the compass is plugged in, the large LED ring will start filling with green light. While this is happening, rotate the compass around in the air so that it points in all directions. Be sure to turn it upside down too! During this time the compass is learning about any metal objects near it and trying to correct for them so that you will get an accurate picture of just the Earth's magnetic field. This may not be able to work when close to large magnetic objects though, to try it away from metal desks and magnetic things.

Once the green lights fill the large ring, they will be replaced by red and blue lights. The compass is now ready to use! The lights turn more and more red as they get closer to the direction of the field, so the bright red lights of the large ring point to the north and the red lights of the small ring point in the direction of magnetic dip up or down. Explore around with your compass!

Name:____________________________

1. Turn the compass around - does the direction of north stay pointing where north is for your location?

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   ______________________________________________________________

2. Now tilt the compass up and down - the dip angle remains constant with zero degrees being parallel to the floor and ninth degrees being straight into or out of the floor. What do you think the dip angle is for your location?

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3. Look at the dip map. What is the predicted dip for where you are? How does that compare to the angle you see on the lights?

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4. Look at the map of magnetic declination. What is the declination for your location? (There is an interactive map online at https://maps.ngdc.noaa.gov/viewers/historical_declination/)

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5. If you wanted to fly an airplane to the geographic east of your location (90 degrees heading) - what is the magnetic heading you would need to fly towards?

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6. For every degree of heading you are off, you drift from your desired destination by 0.17 km for every 10km travelled. If your destination is straight to the west by 1000km, but you forget to correct for magnetic declination - how far off will you be from your desired destination?

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7. Take a magnet and move it around the magnetic field sensor of the compass - what happens? What happens when you flip the magnet over? Why?

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8. When scientists explore the north and south poles of Earth, they have a problem with their compasses. They need to add weight to one end of the compass needle or it hits the glass of the compass and won't spin. Why? (Remember the compass needle points along the magnetic field lines.)

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9. What do you think would happen to the Earth's magnetic field if the outer core cooled and the liquid metal became solid? Why?

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10. What are other uses of magnetic fields that you can think of?

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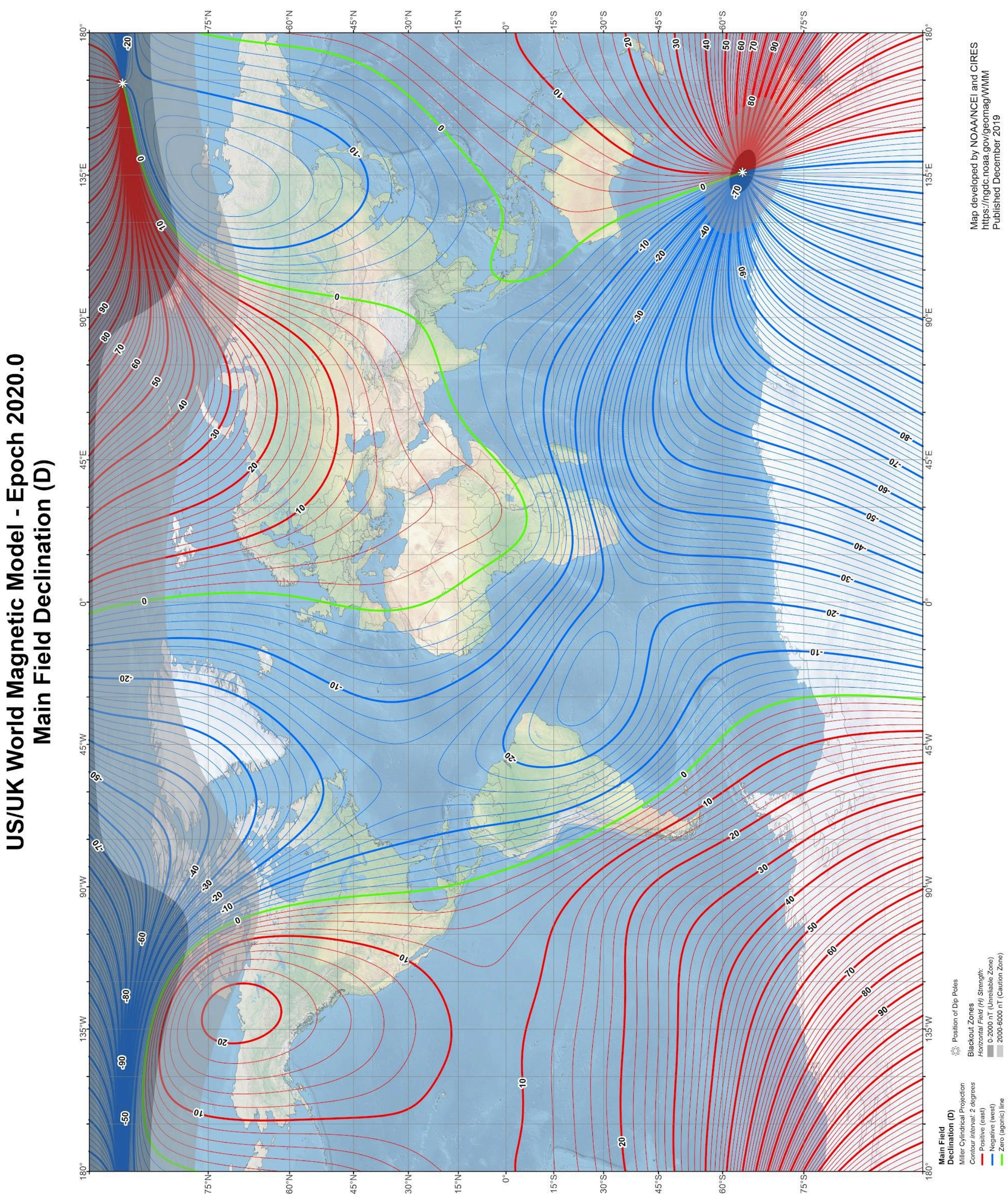
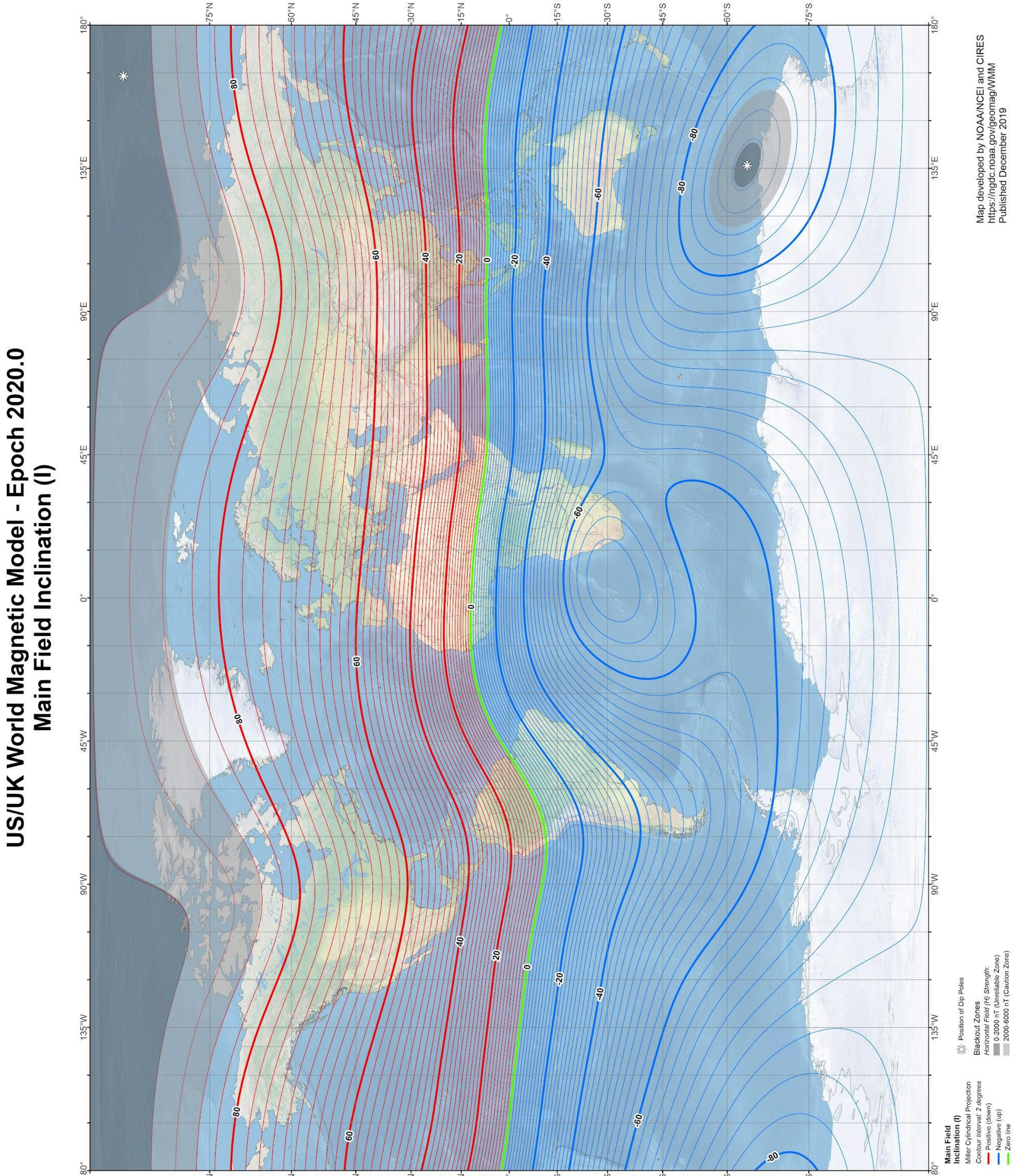

US/UK World Magnetic Model - Epoch 2020.0
Main Field Declination (D)
Map developed by NOAA/NCEI and CIRES
https://ngdc.noaa.gov/geomag/WMM
Published December 2019
Main Field Declination (D)
Miller Cylindrical Projection
Contour interval: 2 degrees
Positive (east)
Negative (west)
Zero (agonic line)
Position of Dip Poles
Blackout Zones
Horizontal Field (H) Strength:
0-2000 nT (Unreliable Zone)
2000-6000 nT (Caution Zone)


US/UK World Magnetic Model - Epoch 2020.0
Main Field Inclination (I)
Map developed by NOAA/NCEI and CIRES
https://ngdc.noaa.gov/geomag/WMM
Published December 2019
Main Field
Inclination (I)
Miller Cylindrical Projection
Contour interval: 2 degrees
Positive (down)
Negative (up)
Zero line
Position of Dip Poles
Blackout Zones
Horizontal Field (H) Strength:
0-2000 nT (Unreliable Zone)
2000-6000 nT (Caution Zone)