Space Weather PowerPoint

Suggested Script

Presentation Notes
This presentation can take from 15 minutes up to an hour, depending on how many slides are used. Feel free to tailor this to your presentation needs.
Recommended for 7th grade to adult.

Slide 1: Opening Slide

Opening slide. Show while the audience enters and during introductions.
You may want to include the presenter's name and the location and date of the talk.

Presenter notes
You may want to start with slide #2 so you don't give away the punch line, or create your own title slide.

Slide 2: A massive blackout

So, imagine this scenario…

Shown:
Large power outage in northeast North America in 2003

Slide 3: Communications

Satellite signals are disrupted around the world. Communications are disrupted from the ground to airplanes and ships.

Presenter notes
Airplanes and ships use the ionosphere to reflect shortwave radio signals

Shown:
Images of airplanes, ships, satellites, and satellite dishes

Slide 4: GPS Signals
You can't use Google Maps!

Shown:
A smartphone with an image of a compass
Graphic of lost man looking at a map

Slide 5: The Aurorae
And the northern lights, or aurorae, are brilliantly shimmering as far south as the Caribbean!

Shown:
Three images of the aurorae
Upper Left: NASA/Warren Gammel
Lower Left: NASA/Shawn Malone
Upper Right: NASA

Slide 6: What could be causing this?

Shown:
A checklist of many items:
- ❑ Terrorist attacks?
- ❑ Earthquakes?
- ❑ Tornados?
- ❑ Hurricanes?
- ❑ Alien Invasion?

Slide 7: It's the Sun!
The Sun may look peaceful from here.
It turns out there's a bigger story.
What do you see on this image? *(Dark spots?)*
Right! Those dark patches are called sunspots. Would you believe all of that chaos is related to these innocent looking sunspots?
Let's explore the Sun together and find out what's lurking behind that peaceful surface.

Shown:
Visible light image of the Sun with sunspots

Slide 8: Inside the Sun

We'll start at the center. <click>
Let's use a thick-bottomed pot sitting on a stove as a model for the interior of the Sun. The pot is filled with boiling water and some strands of spaghetti. You can think of the Sun's ***core*** <click> as the burner on the stove, generating energy.
The core blends into the ***radiative zone*** <click> where energy continues to be transferred outwards through radiation. Like the thick bottom of the pot, the material is still very dense – too dense to "boil" – but the heat still transfers up through the bottom of the pot.
Now we move out into the ***convective zone*** <click> where the density is low enough to allow the material to "boil," like water boiling in that thick pot. It's deep in the Sun's boiling *convective zone* where magnetic field lines are generated. The magnetic field gets twisted up, kind of like the strands of spaghetti in the boiling pot of water.
The Sun's ***Photosphere*** is represented by the surface of the boiling water. <click>
This is the part that we see through a filtered telescope and the layer where nearly all the visible light that illuminates our sky comes from.
Now imagine a strand of the boiling spaghetti looping up through the surface of the water. <click> Sometimes the Sun's magnetic field lines pop through the surface <click> – and at those points is where we see ***sunspots***.
So it's the convective zone that has the primary role in generating those sunspots and also the Sun's **magnetic activity**.

<u>(Optional) Extending the analogy:</u>
Convection cells visible on the sun's surface are like the little bubbles on the surface of the water. The steam rising out and away from the pot represents the Sun's Corona.

Add an activity:
Use the Explore the Sun cards to expand on this model and introduce other models of the Sun.

Shown:
Image of the inside of the Sun and a boiling pot

Slide 9: What Makes Sunspots?

Let's take a closer look.
This is schematic of a magnetic field line popping through the surface of the Sun.
We can't actually *see* magnetic field lines, but we do see their footprints.

Sunspots are the “footprints” of the coronal magnetic loops. They look dark compared to the surface of the Sun because they are not as hot as the rest of the surface.

Presenter’s notes:
An electrified gas (plasma) like that of the Sun will create magnetic fields, generated within the convective zone. The coronal loops are made of plasma trapped in a very strong magnetic field. The gas in these loops are glowing from being bombarded by charged particles trapped on the magnetic loops. These charged particles are energized by different processes involving the magnetic field and heat the Corona, especially in these magnetic field regions.
These same magnetic field loops penetrate down into a region just below the photosphere called the convection zone and inhibits the convection of gas in that region. The inhibition of convection causes the gas below the photosphere to cool faster than the surrounding region.
The average strength of the magnetic fields in sunspots is around 1,000 Gauss (Gauss is a unit of magnetic field strength). The average field strength on the surface of Earth is about 0.5 Gauss, the average magnetic field strength on the surface of the Sun is about 1 Gauss, and the average magnetic field in the solar wind is 0.00005 Gauss (50 microGauss). The magnetic fields in sunspots are extremely strong.

Shown:
Illustration of magnetic field loop emerging through the surface of the Sun, leaving sunspot footprints where they hit the surface

Slide 10: The Visible Sun
And that’s what we see when we look at the Sun through a backyard telescope with a solar filter, like this.
We’re looking at the Sun’s visible “surface” or the Photosphere.
Dark sunspots are visible in telescope images. Images in white light are otherwise featureless.
But the magnetic field is lurking. Let’s take a different look.

Presenter’s Notes:
The “surface” of the Sun is where visible light streams freely away from the Sun. The density here is far less than that of Earth’s atmosphere. Temperatures are around 5,800 C (10,000° F) and the gas is mostly ionized.

Add an activity:
Use the Sun in a Different Light banner and model to highlight features, show the Sun in 3D, and answer questions about the Sun’s magnetic activity.

Shown:
Image of the Sun in Visible light with sunspots

Slide 11: The Sun in H-alpha

This image was taken on the same day, but in a specific color of red light.
Looking at the Sun in different wavelengths reveals different parts of the Sun.
In this view of the Sun, we see the Chromosphere. You'll notice the loops on the side, called prominences.
When prominences are seen from above from our point of view, we call them filaments, as you can see in the picture in the bottom right. They look like dark lines on the surface of the Sun. Just like sunspots, filaments appear dark against the surface because they are cooler than the surrounding material.
They are made from material from the Sun getting lifted off the surface by the magnetic activity of the Sun.
You can see these details through a special filter on a backyard telescope, called a hydrogen alpha filter.
Now keep an eye on one of those sunspot areas as we move to UV wavelengths.

<u>Presenter's Notes</u>
Sunspots and plage (rhymes with garage) also visible along with *prominences* and *filaments*
Sunspots usually appear dark in H-alpha images and the bright plage surrounding them are more prominent.
The chromosphere is just above the photosphere. It is transparent to visible light, but can be seen in a specific, red, color of visible light given off by hydrogen gas (H-alpha).
Visible light (H-α)
Wavelength = 656.3 nm

Shown:
2 red H-alpha images of the Sun, one showing the prominence/filament connection described in the script

Slide 12: The Ultraviolet Sun

What do you see in the places where we previously saw sunspots? *(Bright loops!)*
The Ultraviolet or UV wavelength reveals the super hot gas in the atmosphere of the Sun.
The brightest spots are above sunspots. These loops are hot gas trapped in the magnetic field lines above the sunspots.
Let's see how these are connected…

Presenter's Notes

Views like this of the Sun are only possible from space since the Earth's atmosphere absorbs high energy UV light from the Sun. This image is from NASA's Space Dynamics Observatory (SDO) and shows gases heated to extreme temperatures in the atmosphere of the Sun, called the corona. These gases are suspended in magnetic fields and trace them out like iron filings around a bar magnet.
Extreme Ultraviolet light
Wavelength = 17.1 nm

Shown:
Blue UV image of the Sun taken by SDO

Slide 13: The Dynamic Sun

Here you see a movie of four different views of the Sun over a period of 3 days.
As we saw in the last few slides, you can see sunspots on the chromosphere. Do you see what's happening where those spots are in the other views of the Sun?
At the end of the movie, you see a large solar storm on the top left side of the images.

Presenter's Notes

Set the movie to repeat if your computer allows this.

Shown:
Video of 4 images of the Sun taken over 3 days

Slide 14: The Magnetic Sun

Here again on the left we see the schematic of a magnetic field line popping through the surface of the Sun.
We don't see the magnetic field lines, but we do see the charged material from the corona gathering around the magnetic loops.
That's what we're looking at in the image on the right. Sunspots are the "footprints" of the coronal magnetic loops.

Presenter's Notes

On the right is an image of a coronal loop acquired from the TRACE satellite.
An electrified gas (plasma) like that of the Sun will create magnetic fields, generated within the convective zone.

Shown:
Images described above

Slide 15: The Different Parts of the Sun

Let's review the different parts of the Sun. That visible surface of the Sun where we see sunspots is called the photosphere.
I know we've been seeing the sun in different colors – mainly to enhance the image to bring out certain features. But the true color of the Sun is white, like in this image.

<u>Presenter's Notes</u>
The temperature of the photosphere is about 6000 C (11,000 ° F)

Shown:
This image is a composite of the Sun's corona seen during a total eclipse by the Moon and the Sun's photosphere as seen by NASA's Space Dynamics Observatory.

Slide 16: The Different Parts of the Sun

The chromosphere is where we saw the prominences and filaments in the red image.
If the Sun were the size of an apple, the chromosphere would be thinner than the apple skin.
You can actually see this layer during a solar eclipse when the Moon covers the Sun.

<u>Presenter's Notes</u>
The chromosphere is very thin 10,000 miles (16,000 km) thick and very hot, around 10,000 C (18,000° F).

Shown:
Same image as previous slide, with arrow indicating layer of chromosphere

Slide 17: The Different Parts of the Sun

One of the most amazing things you can see during an eclipse is the Sun's corona, or outer atmosphere.
The Sun's corona is over a million degrees, so hot that the atoms are ripped apart. The negatively charged electrons are separated from the positively charged nucleus, creating a charged solar wind called plasma.
This shows the charged solar wind – the gentle breeze that constantly streams away from the sun – we live in it!

Presenter notes
This is extremely hot, over 1 million C (or 2 million degrees F)

Shown:
Same image as previous slide, with arrow indicating the extended corona

Slide 18: Solar Storms

Sometimes the Sun is not so calm and peaceful.
Rather than simply gentle breezes, explosions on the surface of the Sun can create solar storms.
One type of explosion is called a flare. Let's see what that looks like.
<Play movie with click>
A flare releases a bright flash of visible light, as well as high-energy radiation, like X-rays.
Sometimes these are directed towards Earth. But down here on Earth's surface, we don't have to worry too much about it. We see the flash, but our atmosphere protects us from this high-energy radiation.
But for astronauts on the Moon or doing work outside the space station, this large dose of radiation can be very dangerous.
And there's no warning when a flare happens so astronauts can't protect themselves. The radiation from a flare takes only 8 minutes to travel from the Sun to Earth because it's traveling at the speed of light.
Let's take a look at the flare from the side.

Shown:
Video described above

Slide 19: Solar Storms

Sometimes these storms are so big and forceful that, in addition to light and radiation, they actually eject solar material from the Sun out into space. We call this a Coronal Mass Ejection, or CME for short. This solar material is so hot that the atoms' negative electrons are stripped from the positive nucleus.
In a matter of seconds, tons of charged gas is thrown out into space, as seen in this video. And it's traveling very fast.

Shown:
The movie here is from the SOHO spacecraft. The sun in the center is blocked so we can see the much dimmer corona, much like in the solar eclipse we saw earlier. The white circle indicates the size of the Sun and the black area to the lower left is the arm that holds the occulting disk out in front of the camera. The bright, saturated object near the Sun is the planet Mercury.

Slide 20: Solar Storms and Earth

Sometimes that stream of light and matter is directed at the Earth. The light from the Sun takes only 8 minutes to reach us, so we can see when a big storm is happening almost immediately. It can take a couple of days for the stream of particles to hit us.
<play video>
In this video you will see a Solar Storm seem to surround the Sun (Oct 26th) and then a few days later the field of view becomes snowy (Oct 29th). This is a Solar Storm directed right at Earth. The first explosion was the light reaching us, 8 minutes after the explosion. The snow is caused by high-energy particles from the storm impacting the telescope a few days after the storm occurred on the Sun.
So how does that affect us here on Earth?

Shown:

This is a composite of observations from several NASA instruments taken over a period of a couple weeks in late 2003. The Sun was extremely active during these two weeks, hurling many CMEs and producing some of the strongest solar flares ever observed.
Images from STEREO

Slide 21: Solar Storms and Earth

Let's watch as a big Solar Storm hits Earth. <play> This animation shows the charged particles ejected form the Sun and traveling towards Earth.
Those lines around Earth are our magnetic field. The solar storm warps the Earth's magnetic field. Moving magnetic fields generate a current that can enhance the beautiful aurorae. This works much like a neon sign, where electrons bang into the oxygen and nitrogen atoms, causing them to emit lights of different colors.

<u>Presenter's Notes</u>
When a solar storm passes Earth, it can "drag" the magnetic tail far out into space. Stretched magnetic lines can break and then reconnect into a different shape. Moving magnetic fields generate an electrical current that excite the atoms in our atmosphere, enhancing the aurora.

Add an Activity:

For small groups, use the Magnetic Connection activity to illustrate a solar storm passing Earth.

Shown:

Video of CME directed at Earth and its effects on Earth's magnetic field

Slide 22: Solar Storms

So that explains the aurora we were talking about in the beginning.
The magnetism on the Sun generates solar storms, which can intensify the aurora and make them appear at lower latitudes.
But what about the other less appealing scenarios we talked about earlier?

Shown:
3 Images of Aurorae
Upper Left: NASA/Warren Gammel
Lower Left: NASA/Shawn Malone
Upper Right: NASA

Slide 23: Solar Storms

Solar storms can also increase electric currents in the ground, tripping the fuses of large power grids. This can and has plunged cities into darkness.
In March of 1989, a large solar storm tripped circuit breakers and a caused a power outage in eastern Canada for 9 very cold hours.
That blackout caused power companies around the world to implement monitoring systems and programs to reduce the likelihood of this happening again.

Shown:
Image of eastern North America is not from a solar storm, but just an example of a large power outage from 2003. Same image as Slide 2

Slide 24: Solar Storms

This bombardment of fast moving particles in a solar storm can affect our communication with satellites.
As you can imagine, this is especially important for aircraft communications.

Shown:
Same images of airplanes, ships, satellites, and satellite dishes from Slide 3

Slide 25: Solar Storms

And last but certainly not least - we will all be lost!
The GPS that locates our phones can be thrown off by these solar storms.
Google maps would not work and we'd all be lost.
Now that would be a tragedy!

Shown:
Same image as slide 4 of a smartphone with a compass on it

Slide 26: The Sun's Magnetic Field

This isn't going on all the time. The Sun goes through cycles…
The Sun has an overall magnetic field much as Earth does. That's what you see in the image on the left.
But because the Sun is gaseous, it does not rotate as a solid body like the Earth does. The equator rotates faster than the poles.
So the magnetic field gets twisted and wrapped up as a result of the different rotation rates of the Sun's material. <click>
It can look something like this illustration. (pause)
Eventually, the field becomes so twisted that it essentially breaks and reforms back to its simpler north-south configuration.
This process is what is thought to be behind the observed solar cycle.

Shown:
Illustration of Sun's magnetic field twisting and deforming over time
Overlay illustration shows convoluted magnetic field lines extending out all over the sun.
Credit: NASA/SVS

Slide 27: The Solar Cycle

This graph charts the number of sunspots seen each month
At the solar minimum we see very few sunspots.
But at Solar Maximum you can often see many sunspots at once.
The number of sunspots increase and decrease on an approximately 11-year cycle.
Here we see the increasing and decreasing magnetic activity over a solar cycle. More sunspots and solar storms occur during the solar maximum, at the top of the graph.
The white areas are indicators of strong magnetic intensity.
(May want to mention where we are in the solar cycle now- we are near a maximum when this was released, in 2012)
So as we approach the next solar maximum, is there no way to avoid catastrophe?

<u>Presenter's Notes:</u>
The polarity of the Sun's magnetic field flips about every 11 years, and so the complete solar cycle is actually around 22 years for the Sun to return to its original state.
Monthly numbers from NASA Marshall Space Flight Center from 1984-2007
The red images are captured using He II 304 emissions showing the solar corona at a temperature of about 60,000 degrees K. Many more sunspots, solar flares, and coronal mass ejections occur during the solar maximum. The increase in activity can

be seen in the number of white areas in the images, i.e., indicators of strong magnetic intensity.

Shown:
Graph of sunspot activity over a 25-year period
Additional images show examples of the sun at various points on the graph

Slide 27: NASA's Heliophysics Missions

Never fear!
We can't avoid solar storms…
But we can minimize the effects.
Our world is increasingly dependent on satellites for internet, TV, and phone communications.
And solar storms could affect all of these, as well as power grids, as we saw.
But scientists around the world are working on predicting solar weather so that we can better prepare ourselves for solar storms.
NASA currently operates over a dozen missions studying the physics of the Sun (Heliophysics). They are studying the Sun's effects on Earth and the Solar System. This suite of instruments has given us a full 360-degree view of the Sun and allows us to come very close to predicting Space Weather events and avoiding the damaging effects of solar storms.

Shown:
Illustration of many of NASA's missions studying the Sun
Image credit: NASA GSFC

End of Presentation as written. Add additional slides as needed. Each slide has its own notes.