

## Space Weather FX: Episode 1

[Animation of outburst from the Sun]

**VO:** One hundred fifty million kilometers away Earth, an outburst occurs on the surface of the Sun.

In just few a seconds, it sends out a seething cloud of charged particles and super hot gases. This massive “space weather” front travels on the solar wind, a stream of material that constantly blows away from the Sun.

When the storm front arrives at Earth, it energizes electrons and ions in our upper atmosphere.

[Google Earth fly in to MIT Haystack Observatory]

Out in the countryside near Boston Massachusetts, scientists at MIT’s Haystack Observatory study the geomagnetic storms triggered by solar outbursts. They’re working to understand the effects on Earth’s upper atmosphere when Sun stirs up a little space weather.

[Title Sequence]

[Video of atmospheric layers]

Our planet’s atmosphere is a blanket of air that is thick near the surface and gets thinner the higher up you go. We live and travel through the troposphere—the lowest part. Next is the stratosphere, which contains the ozone layer and high thin clouds. The mesosphere is where we see incoming meteors burn up.

Above that is the ionosphere, an electrified region where space weather has its greatest effect.

[Still graphic of ionosphere with label]

Haystack researchers analyze how the ionosphere is affected by the solar wind. They also measure how it interacts with the magnetosphere, the region of space around Earth influenced by the magnetic field.

[Sun video from SOHO]

The Sun is the source of all space weather that buffets the ionosphere and magnetosphere. Like every other star in the universe, it is an active seething sphere of hot gas.

[Zoom in to flare and plasma release]

When a cloud of gas and charged particles, called a plasma, escapes from the Sun, we find out about it pretty quickly.

[SOHO multi-instrument view of outburst]

The light from the outburst reaches our planet in about eight and a half minutes.

[Animation of plasma colliding with Earth's magnetosphere]

The plasma takes longer. It usually arrives within two to three days, and collides with our magnetic field. That action sparks huge electrical storms high in the ionosphere and creates blazing displays of northern and southern lights.

[Zoom in to Earth at night and power outages]

Space weather can have more serious consequences. In March 1989, a series of solar disturbances triggered violent geomagnetic storms. They knocked out the power for more than six million people across eastern Canada.

[Phil Erickson at desk]

For that reason, researchers want to understand space weather and how it can affect people and technology here on Earth.

[Phil Erickson walking outdoors by radars]

Dr. Philip Erickson is part of Haystack's team of space weather researchers. They use the Millstone Hill radar antennas to study the ionosphere.

[Phil in front of the radars]

**PHIL:** Right now, these big antennas behind me are tracking changes in Earth's ionosphere. They're telescopes, but they use radio waves instead of visible light.

We use the radar signals from these instruments to track the temperature and chemical composition of the gases in Earth's ionosphere.

[Radar dish; Phil on the dish for scale; top view of radar]

We also use our radar data to learn more about the ions and electrons in the atmosphere: how hot they are, how many there are, and how fast they are. We also measure the effects of the solar wind as it slams into the ionosphere. Our instruments are very accurate and can measure the ionosphere all along the eastern United States.

[Crossfade to Phil in his office and animation of data he studies]

We take the data our radar provides and get an idea of the physical state of the ionosphere. We can use this information to track changes in the ionosphere and relate them to changes in the solar wind and other space weather events.

[Phil and GPS unit]

These days, we've added a new instrument to our ionospheric study toolkit – GPS.

[Animation of GPS system and orbits; cuts to plane landing and boats in channel]

**VO:** Global positioning system satellites continually relay radio signals to ground receivers. Those signals contain timing information and data about the satellites' locations. That information is then analyzed and turned into other data that can be used by airplanes and boats for navigation.

[Automobile GPS system]

Automobile GPS systems also use same the information to help drivers find their destinations.

[MIT Credit Union and ATM user]

Banks and financial institutions depend on precise GPS signals to help them transfer money on time.

[cellular tower]

And, every cellular telephone network relies GPS timing data.

[Animation of solar outburst/crossfades to TEC animation]

So, how can space weather affect all of these systems? Solar storm fronts rapidly push clouds of ions and electrons into small regions of the ionosphere.

[GPS network animation]

This interferes with broadcast signals from communications satellites and radio signals from the GPS satellite network.

[Google Earth zoom in and power outage scene]

Solar storms can also stir up strong electrical currents could overload power grids shut off lights millions people.

[Power substation and long-distance transmission lines]

If communication networks and power companies have enough advance warning, they CAN take steps to protect their systems until the storm is over.

[Plane landing]

During such solar storms, ships and airplanes can switch to other navigation methods until reliable GPS signals are available.

[Haystack scientists discussing data at Phil's desk]

**PHIL:** Today at Haystack Observatory, we're using GPS data collected during solar storms to better understand how space weather changes our ionosphere. What we learn by analyzing the data together from our radar antennas and GPS units is of immense importance. Space weather isn't just "out there." It affects us right here on Earth.

[Closing sequence and credits]