ESS 7
Lecture 2
March 31, 2010
A Little History
**Terrestrial Weather and Space Weather**

- Space weather is interested in the space environment around the Earth all of the way to the Sun.
- Space physics is concerned with the physics of gases of charged particles called a plasma.
- Its roots are in the Sun.
- **Difference 1**
  - Terrestrial weather occurs in the troposphere.
  - Space weather starts in the thermosphere which is about 100km above the Earth.
The Boundary Between the Atmosphere and Space

• The sharp contrast between the atmosphere and space is at about 100km.
Terrestrial Weather and Space Weather

• Difference 2
  – The Sun emits two types of energy – electromagnetic and particle.
  – Visible light, radio waves, microwaves, infrared, ultraviolet, X-rays and gamma rays make up the electromagnetic radiation.
  – About 1400 watts/m² hit the upper atmosphere
  – Heats the lower atmosphere unevenly driving winds.
  – The Sun also emits particles – charged atoms, protons, electrons – the stream of particles is the solar wind.
  – The solar wind is driven by temperature difference in the Sun’s upper atmosphere.
  – The solar wind changes continuously. Occasionally it erupts and sends a large part of its atmosphere our way.
Coronal Mass Ejection

$10^{12}$ kg of material is ejected at 1000km/s (2.5 million miles/hr.).
A Little Greek

• Spheres – concentric regions around planets.
  – Litho – stone – the rocky surface of the Earth
  – Hydro- water
  – Bio- life
  – Atmos – vapors
• Boundaries between spheres are called pauses.
• Tropo – mixing 0-10 km – weather
• Strato – 10 – 50 km – ozone layer
• Meso – 50-80 km – coldest layer
• Thermo 100 km – space
• Iono – 100 km – aurora – greatly influences space weather.
The Aurorae

• Aurorae probably are the longest studied space weather phenomenon – They have been observed for thousands of years even in Los Angeles.
Historical References to Aurorae

- Old Testament references to auroras.
- Greek literature (Aristotle – 384BC -322BC) speaks of “moving accumulations of burning clouds”
- Chinese literature has references to auroras prior to 2000BC
Systematic Study of Aurorae

- Systematic study of aurorae began in the 16th century primarily in northern Europe.
Early Ideas on the Cause of Aurorae

- Galileo theorized that aurora is caused by air rising out of the Earth’s shadow to where it could be illuminated by sunlight. (Note he also coined the name *aurora borealis* meaning “northern dawn”.)
- Pierre Gassendi who was working with Galileo concluded that the aurorae had to occur at high altitude because they can be seen in widely separated locations.
- Descartes thought they are reflections from ice crystals.
- Halley suggested that auroral phenomena are ordered by the Earth’s magnetic field.
- In 1731 the French philosopher de Mairan suggested they are connected to the solar atmosphere.
- Cavendish in 1790 used triangulation to deduce that they occurred at 80km -112km – confirmed by Størmer in 1900.
The Auroral Oval

- Scientists began carrying out observational studies designed to determine where the aurorae were found.
- Elias Loomis (1869) collected observations of aurora and published the first map of their occurrence. They are not found at the pole but in a ring around it.
- By the end of the 19th century scientists had systematically determined that they occur at high altitudes and in a ring around the pole – understanding was next.
Geomagnetism

- By the 11th century the Chinese had learned that a magnetic needle points north-south.
- By the 12th century the European records mention the compass.
- That there was a difference between magnetic north and the direction of the compass needle (declination) was known by the 16th century.
- William Gilbert (1600) realized that the field was dipolar.
- In 1698 Edmund Halley organized the first scientific expedition to map the field in the Atlantic Ocean.
William Gilbert’s Magnetic Field
William Gilbert’s Magnetic Field

• The dipole is the simplest magnetic field you can have. Gauss (1839) showed that the magnetic field was divergenceless. This that the magnetic lines of force (everywhere tangent to the magnetic field vector) must close.
Gravity Sucks

Gravity always pulls toward the center.

This is a very profound influence in the universe, explaining much more than why a little puppy cannot stand up.

It explains why stars are tiny points in a vast empty space – they pulled things toward them to empty the space!

cuteoverload.com (result of web search “gravity sucks”)
Magnetic Fields Don’t Suck!

Although you likely think of magnets as attracting things, they do so in a much more complex way than gravity does.

In fact, there is no such thing as a pure attraction in magnetism the way there is with gravity. There are no single “poles” in magnetism, they always come in pairs that we call “North” and “South”.

Electric forces are like gravity but can either repel or attract to charges.
Sunspots (Dark Areas on the Sun)

• In 1610 Galileo used his telescope to observe sunspots for the first time. Note he did not look at the Sun instead he focused the image on a piece of paper – like a pin hole camera.

• There was debate over whether they were planets moving across the Sun or actual features on the Sun.

• Schwabe systematically looked for a planet or planets that could account for sunspots but failed.

• He discovered that the sunspots had an 11 year periodicity.
Galileo’s Sunspots
Making the Connection

• In 1859 Carrington noticed a white light flare was followed by geomagnetic activity on the Earth.
• It was controversial – Lord Kelvin – solar magnetic field couldn’t possibly effect the Earth’s field – “connexion between magnetic storms and Sun-spots is unreal…”
• Becquerel (Nobel laureate) in 1878 suggested the either magnetic fields or matter provided the connection.
• Corpuscular radiation (Crookes) was responsible (Sir Oliver Lodge) (J. J. Thompson (Nobel laureate) showed that corpuscular radiation was electrons).
• Marconi (Nobel laureate) showed that radio messages could go across the Atlantic prompting Kennelly and Heaviside to postulate the ionosphere. Appleton won a Nobel Prize for showing they were correct,
The Carrington Event
150 years ago, first manifested by a very bright solar flare, followed by particles which took 18 hours to get to Earth and then caused huge auroras and disruption to the advanced technical systems of the day – telegraphs.

What would such an event do to our technological civilization, with assets in unprotected space?
Dawn of an age of Space Physics and Space Industry

• Marconi (Nobel laureate) showed that radio messages could go across the Atlantic prompting Kennelly and Heaviside to postulate the ionosphere, the lowest layer of plasma near Earth (and reflective of radio waves)

• Image (Wikipedia): receiving antenna in St. John’s, Newfoundland (now part of Canada)

• Kristian Olaf Birkeland (1867 – 1917) was a Norwegian who initiated scientific studies of the aurora in both the field and laboratory. He financed his work through electromagnetic inventions. Electric currents in space, that he deduced to exist, are named for him.

• Image (Wikipedia): Birkeland working with a model Earth/aurora system (terrella) in his laboratory.
A Digression on Units

• SI units will be used in this class – mostly.
• The four fundamental units are
  – Time – seconds
  – Length – meters
  – Mass – kilograms
  – Electrical charge – coulomb
• All other units are combinations of these units – if you use the SI units exclusively you will get the correct answer.
• It is convenient to depart from SI in a few areas.
  – 1AU – 150,000,000 km (or 1.5X10^8 km) the mean distance from the Sun to the Earth
  – 1RE – 6371 km – the radius of the Earth.
A Digression on Scientific Notation

- For really big numbers (like the distance to the Sun) it is useful to express multiples of 10 as exponents ($1.5 \times 10^8$ km).
- This make arithmetic easier.
  - Multiplication becomes addition ($10^2 \times 10^5 = 10^7$)
  - Division becomes subtraction ($10^2 / 10^5 = 10^{-3}$)
- Numbers with exponents less than zero are one over the number ($10^{-3}$ is $1/1000$).
Assignment

• Read Chapter 2

• Chapter 1 problems 1.2, 1.4, 1.5 –
  • Write the following amounts in SI units (m, kg, s) using scientific notation.
    • 1261 km    b. 13 cm   c. 0.0000061 m   d. 3.2 g   e. one year
  • The gas associated with the Carrington event took 18 hours to travel from the Sun to the Earth. Calculate the speed it travelled at, in km/s.

• Due 4/5/10