Major magnetic storm events also lead to spectacular auroral displays even at low geographic latitudes.

Substorms were first documented in 1964 by Syun-Ichi Akasofu of the University of Alaska using a network of all-sky cameras. They are generally less dramatic than magnetic storms, and may come and go within a few hours or so, always with accompanying auroral displays seen in the upper latitudes in Canada, Scandinavia and Alaska. Although there is considerable variation on a central theme, the evolution of substorm aurora (also called auroral substorms) follows a non-random basic script. Beginning with quiet auroral curtains, they brighten and pick up streaks or rays. Then a series of sweeping folds or spirals appear near the eastern horizon and surge westward as the 'expansion phase' begins. The sky brightens again and dissolves into myriad rapidly moving forms, followed by a 'recovery phase' where conditions return to a vague diffuse cloudiness, with patches of diffuse glow pulsating on and off with a period of a few seconds.

Substorms are thought to be produced by minor changes in the orientation of the solar wind magnetic field as it collides with the geomagnetic field. If magnetic 'kinks' in the solar wind field meet up with the geomagnetic field, rapid polarity changes can lead to reconnection and current disruption events in the magnetopause and magnetotail regions. These events can cause particles to be accelerated to high energy and flow into the atmosphere to produce aurora. Substorms cannot be anticipated in advance because the interplanetary magnetic field is a complex phenomenon that is largely invisible. Major magnetic storms, however, are known to follow the Sun spot cycle; a fact uncovered by Edward Sabine in 1839, but not formally recognized by the scientific community until the turn of the 20th century. The best time to observe magnetic storms is when the solar surface is active, or has large sunspot groups transiting its surface.

III. The THEMIS mission

3.1 Scientific Objectives

The Time History of Events and Macroscale Interactions during Substorms (**THEMIS**) program consists of a five-satellite constellation with the job of determining the causes of the global reconfigurations of the Earth's magnetosphere observed during the abrupt beginning of 'onset' of an auroral substorm. Each satellite carries identical electric, magnetic, and particle detectors that will be put in carefully coordinated orbits. Every four days, the satellites will line up like pearls on a string along the Earth's magnetic tail, allowing them to track disturbances from this distant region, all the way to Earth's outer atmosphere. The satellite data will be combined with observations of the aurora from a network of observatories across Canada and Alaska, as well as additional magnetic observatories located in schools in the northern U.S. states.

"Basically, we hope to solve the mystery surrounding the transport and explosive release of solar wind energy within Earth's space environment," said Michael J. Cully, Director of Civil and Commercial Programs for Swales Aeospace. "In addition, we believe THEMIS will also be able to answers some critical questions about radiation belt physics as that science relates to solar winds." The launch of the THEMIS mission aboard a Delta II rocket happened successfully on February 17, 2007. (Updates at http://ds9.ssl.berkeley.edu/themis/news.html)

The data collected by THEMIS will allow scientists to determine which magnetotail process is responsible for the start of a magnetic substorm. Is it caused by a local disruption of the currents flowing in the plasma sheet, a bed of hot electrons and ions located in the magnetotail? Or is a magnetic substorm the result of the rapid influx of plasma from magnetic reconnection events occurring deep within the magnetotail at a distance of ~25Re?

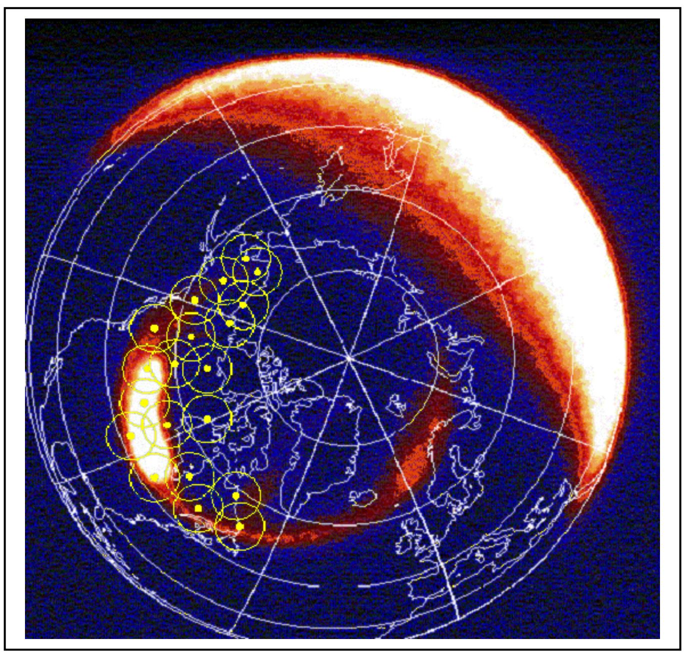

Figure 25 - The Earth imaged in ultraviolet light with a map overlaid to show where the bright emissions are located. The upper right white is from the upper atmosphere glowing with the Sun's daytime light. The white 'peanut' shape is an aurora during substorm onset.

Three inner probes at ~10Re will monitor current disruption onset, while two outer probes, at 20 and 30Re respectively, will remotely monitor plasma acceleration due to reconnection events. In addition to addressing its primary objective, THEMIS answers critical questions in radiation belt physics and solar wind-magnetosphere energy transfer.

The image in Figure 25 of an auroral oval shows an intense substorm event occurring over Canada. The circles show the locations of Canadian magnetometer stations.

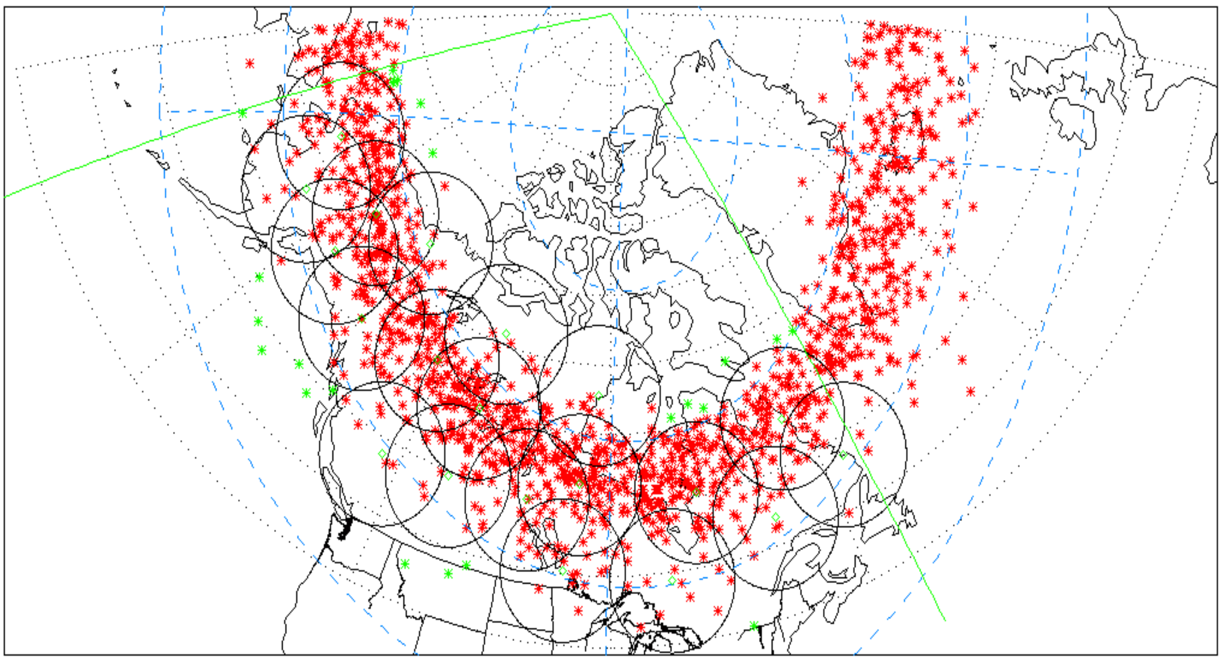

Figure 26 - Field-of-view of THEMIS all-sky imagers are shown as circles, with the stars indicating where substorm events have been seen during the IMAGE satellite mission between 2000-2005.

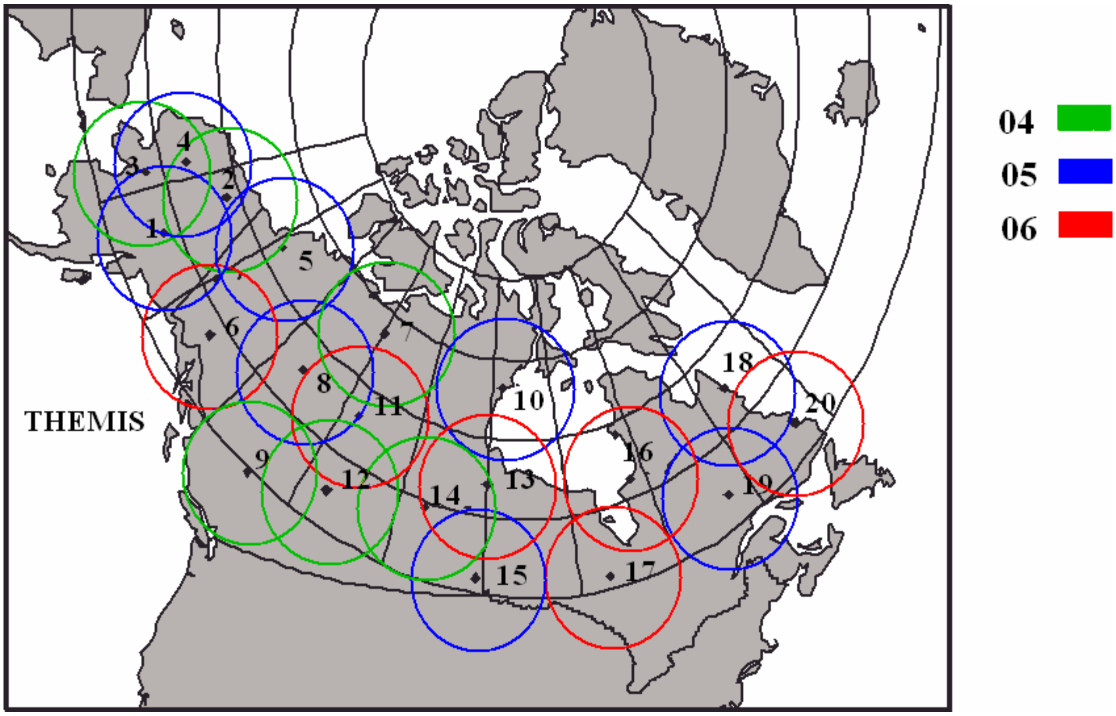

Figure 27 - Field-of-view of the 20 THEMIS all-sky imagers and the year in which they were installed indicated by color.

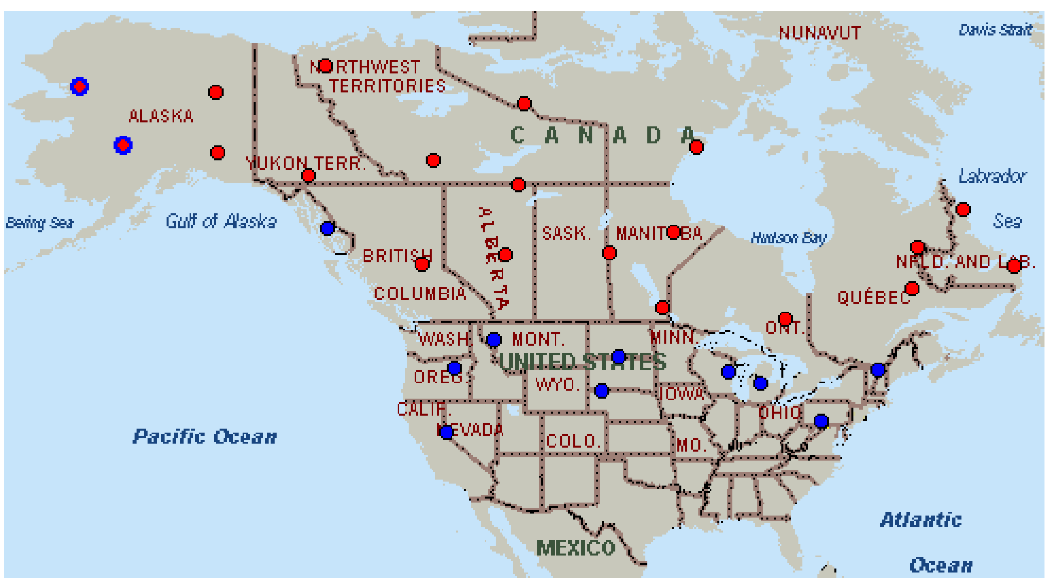

Figure 28 - A map with the locations of the THEMIS observatories .The blue dots indicate schools with magnetometers. The red dots indicate the ground-based observatories used by scientific researchers.

Table 2: Participating Schools:

School	Location	Teacher
Petersburg City Schools	Petersburg, AK	Victor Trautman
McGrath School	McGrath, AK	Ray Benson
Chippewa Hills HS	Remus, MI	Chris DeWolf
Hot Springs HS	Hot Springs, MT	Sean Estill
Western Nevada CC	Carson City, NV	Terry Parent, Jim Bean
Fort Yates Public School	Fort Yates, ND	Frank Martin, Harriet Howe
Ukiah School	Ukiah, OR	Laura Orr
Northern Bedford County HS	Loysburg ,PN	Keith Little
Red Cloud HS	Pine Ridge ,SD	Wendell Gehman
Shawano Community HS	Shawano ,WI	Wendy Esch
North County Union JHS	Derby ,VT	Holly Wiley, Manju Prakash *(located in ME, using VT mag.)*

3.2 The magnetic field coordinates

The typical THEMIS ground-based magnetometer (GMAG) is a three-channel flux-gate magnetometer that measures the strength (magnitude) of Earth's local field along three perpendicular axes. To find the average components of the magnetic field where you live, visit the International Geomagnetic Reference Field Model

http://nssdc.gsfc.nasa.gov/space/model/models/igrf.html

and enter the date, your geographic latitude, longitude and elevation. You can find the geographic coordinates for a specific location at

http://geonames.usgs.gov/pls/gnis/web_query.gnis_web_query_form.
Select 'Civil' for a town name.

Table 3 - Magnetic components of some familiar cities

City	Longitude	Latitude	Bx	By	Bz	Total B
Chicago	87 54 55	41 50 05	26454	1271	48893	55605
Boston	71 05 00	42 18 00	25251	2234	46676	53116
Miami	80 32 00	25 37 00	36274	0.0	28396	46067
Anchorage	149 15 02	61 10 00	16320	-3553	53774	56308

Table 3 shows the components for 2004 at sea level for different geographic coordinates. The vector components whose magnitudes are the numbers Bx, By and Bz are defined in units of nano-teslas (nT), B is the total field strength also in units of nT. You can use this information to calculate D, the declination angle between geographic and magnetic north, and I, the inclination or Dip Angle, in degrees below the local horizontal plane from Equations 7 and 8 in Section 1.7. The Declination angle, D, is the angle you will find on a geographic map that gives the compass correction to True North.

For example, in Chicago the components of the field are 26,454 nT, 1271 nT and 55,605 nT. The total magnitude of the field at the surface is then 55,605 nT or since there are 10,000 Gauss units per tesla, this equals 0.556 Gauss. The angle between geographic north and magnetic north at this location is 2.8 degrees, so that your compass will point 2.8 degrees west of true north. The needle of the compass will dip 61.6 degrees from the horizontal plane. You can actually see this if you have a compass with a needle suspended at its middle point.

IV. Magnetism Measurement Techniques

4.1 The Soda Bottle Magnetometer

Compasses are great for measuring the direction of a magnetic field locally, but don't provide enough detailed information to make these measurements precise enough for scientific study. They also don't tell us the actual strength of the magnetic field. To gather this data, we have to develop sensitive instruments. One simple instrument that is the next step up from a compass is the Soda Bottle or 'Jam Jar' magnetometer. It provides a greatly amplified measurement of the compass needle motion, and the direction changes of the ground-level magnetic field.

This instrument is nothing more than a magnet suspended by a thread in a compass-like manner, which merely indicates the local direction of the horizontal component of the magnetic field. Details for constructing and using this instrument may be found at the IMAGE education web site:

http://image.gsfc.nasa.gov/poetry