

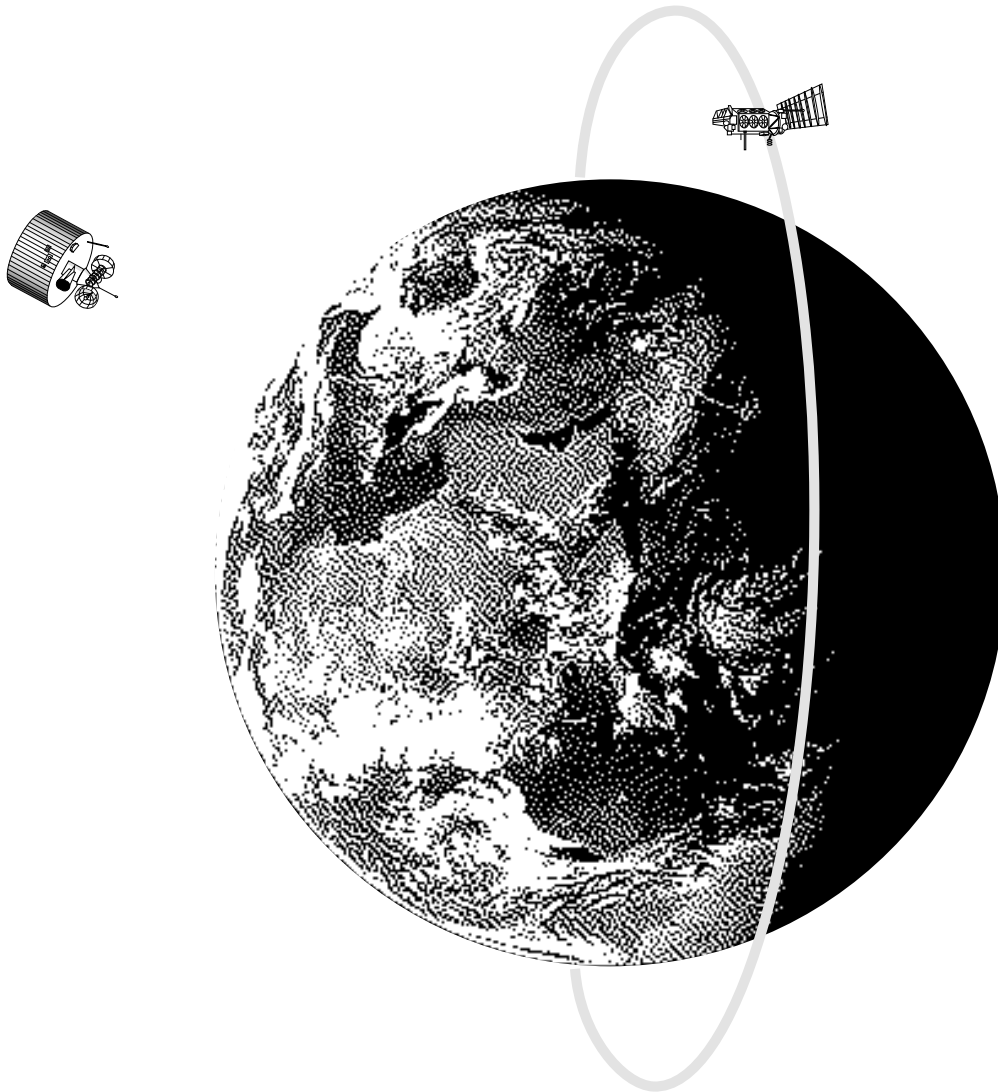
National Aeronautics and
Space Administration
**Office of Mission to
Planet Earth**

Educational Reference

Teachers

Grades 7-12

LOOKING AT EARTH FROM SPACE



GLOSSARY OF TERMS

This series of publications is printed in black and white to facilitate copying and distribution to the broadest audience possible.

Words that are italicized are listed in the Glossary.

Introduction

NASA's Office of Mission to Planet Earth is responsible for mounting a global-scale examination of the Earth's environment and how it is changing. Researchers will use data from satellites carrying specialized instruments to study all components of the Earth system—air, water, land, and biota—and their interactions. NASA will archive, analyze, and distribute these data through a comprehensive data and information system. These efforts will help to increase our understanding of the global environment and how human activities affect our planet.

The NASA series of publications entitled "Looking at Earth From Space" was developed to familiarize educators with global change issues and Mission to Planet Earth, and to enable teachers to enhance classroom studies with hands-on activities using satellite images. The series, available through the NASA Teacher Resource Center network, includes:

- Direct Readout from Environmental Satellites (January 1994);
- Guide to Equipment and Vendors, which reviews hardware requirements for environmental satellite ground stations and identifies sources for the equipment (January 1994);
- Glossary of Terms which includes science and technology terms relevant to Mission to Planet Earth, remote sensing, and direct readout (August 1994);
- Teacher's Guide to Global Change, which includes background information and lessons for high school classrooms on topics related to the science issues of global climate change (Fall 1994);
- Training Manual, designed to help teachers (elementary grades through high school) use an environmental satellite Earth station and understand the atmospheric conditions displayed in the images (Fall 1994); and
- Teacher's Resource Guide to Direct Readout, which contains lesson plans for grades 4–12 (Fall 1994).

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August 1994.

CONCEPTS AND TERMS

A

absolute humidity

In a system of moist air, the ratio of the mass of water vapor present to the volume occupied by the mixture; that is, the density of the water vapor component. Absolute humidity is normally expressed in grams of water vapor in a cubic meter of air (25 g/m³).

$$\text{absolute humidity} = \frac{\text{mass of water vapor}}{\text{volume of air}}$$

absorption

The process in which radiant energy is retained by a substance. A further process always results from absorption, that is, the irreversible conversion of the absorbed *radiation* into some other form of energy within and according to the nature of the absorbing medium. The absorbing medium itself may emit radiation, but only after an energy conversion has occurred.

acid rain

Acids form when certain atmospheric gases (primarily carbon dioxide, sulfur dioxide, and nitrogen oxides) come in contact with water in the atmosphere or on the ground and are chemically converted to acidic substances. Oxidants play a major role in several of these acid-forming processes. Carbon dioxide dissolved in rain is converted to a weak acid (carbonic acid). Other gases, primarily oxides of sulfur and nitrogen, are converted to strong acids (sulfuric and nitric acids).

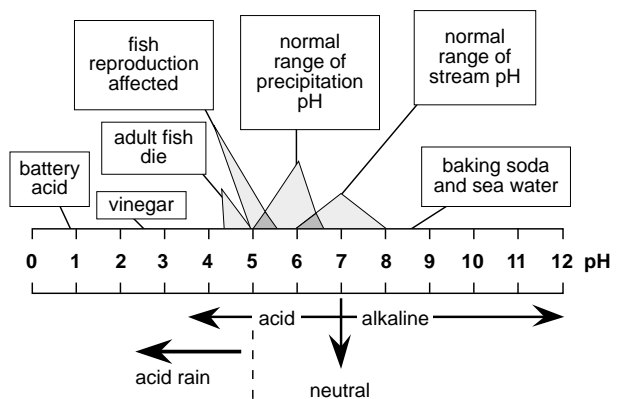
Although rain is naturally slightly acidic because of carbon dioxide, natural emissions of sulfur and nitrogen oxides, and certain organic acids, human activities can make it much more acidic. Occasional *pH* readings of well below 2.4 (the acidity of vinegar) have been reported in industrialized areas.

The principal natural phenomena that contribute acid-producing gases to the *atmosphere* are emissions from volcanoes and from biological processes that occur on the land, in

wetlands, and in the oceans. The effects of acidic deposits have been detected in glacial ice thousands of years old in remote parts of the globe. Principal human sources are industrial and power-generating plants and transportation vehicles. The gases may be carried hundreds of miles in the atmosphere before they are converted to acids and deposited.

Since the industrial revolution, emissions of sulfur and nitrogen oxides to the atmosphere have increased. Industrial and energy-generating facilities that burn fossil fuels, primarily coal, are the principal sources of increased sulfur oxides. These sources, plus the transportation sector, are the major originators of increased nitrogen oxides.

The problem of acid rain not only has increased with population and industrial growth, it has become more widespread. The use of tall smokestacks to reduce local pollution has contributed to the spread of acid rain by releasing gases into regional atmospheric circulation. The same remote glaciers that provide evidence of natural variability in acidic deposition show, in their more recently formed layers, the increased deposition caused by human activity during the past half century.



Acquisition of Signal (AOS)

The time you begin receiving a signal from a spacecraft. For *polar-orbiting* satellites, radio reception of the *APT* signal can begin only when the polar-orbiting satellite is above the horizon of a particular location. This is determined by both the satellite and its particular path during orbit across the reception range of a *ground station*.

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active system (active sensor)

A remote-sensing system that transmits its own *radiation* to detect an object or area for observation and receives the reflected or transmitted radiation. Radar is an example of an active system. Compare with *passive system*.

A/D

Analog to Digital. Used to refer to the conversion of analog data to its digital equivalent.

Advanced Very High Resolution Radiometer (AVHRR)

A five-channel scanning instrument that quantitatively measures *electromagnetic radiation*, flown on NOAA environmental satellites. AVHRR remotely determines cloud cover and surface temperature. Visible and infrared detectors observe vegetation, clouds, lakes, shorelines, snow, and ice. TIROS *Automatic Picture Transmissions (APT)* are derived from this instrument. See *TIROS*.

aerosol

Particles of liquid or solid dispersed as a suspension in gas.

afforestation

The act or process of establishing a forest, especially on land not previously forested.

AI

See *artificial intelligence*.

AIR

Airborne Imaging Radar.

air mass

Large body of air, often hundreds or thousands of miles across, containing air of a similar temperature and humidity. Sometimes the differences between air masses are hardly noticeable, but if colliding air masses have very different temperatures and *humidity* values, storms can erupt. See *front*.

air pollution

The existence in the air of substances in concentrations that are determined unacceptable to human health and the environment. Contaminants in the air we breathe come mainly from manufacturing industries, electric power plants, exhaust from automobiles, buses, and trucks.

Primary Air Pollutants

sulfur dioxide
carbon monoxide
nitrogen dioxide
ground-level ozone
lead
carbon particles

air pressure

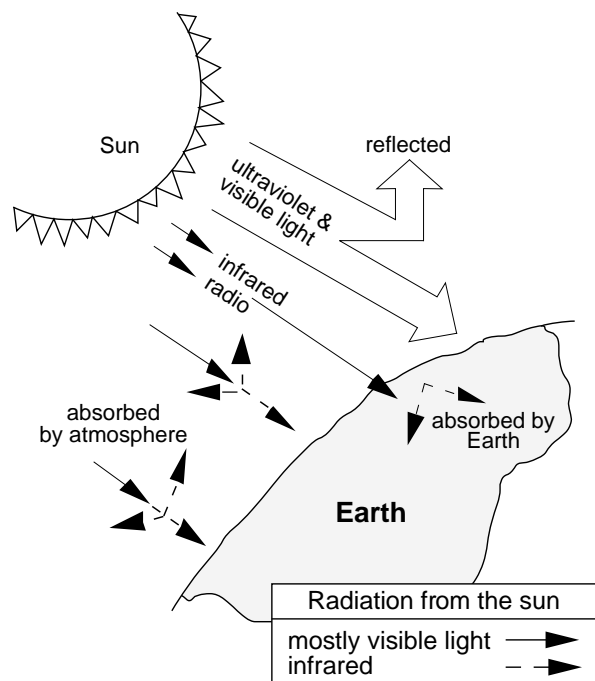
The weight of the *atmosphere* over a particular point, also called barometric pressure. Average air exerts approximately 14.7 pounds (6.8 kg) of force on every square inch (or 101,325 newtons on every square meter) at sea level.

aka

Also known as.

albedo

The ratio of the outgoing solar *radiation* reflected by an object to the incoming solar radiation incident upon it.



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algorithm

A mathematical relation between an observed quantity and a variable used in a step-by-step mathematical process to calculate a quantity.

In the context of *remote sensing*, algorithms generally specify how to determine higher-level data products from lower-level source data. For example, algorithms prescribe how atmospheric temperature and moisture profiles are determined from a set of *radiation* observations originally sensed by satellite sounding instruments.

alkaline

Substance capable of neutralizing acid, with a pH greater than 7.0. See *pH*.

altimeter

An active instrument (see *active system*) used to measure the altitude of an object above a fixed level. For example, a laser altimeter can measure height from a spacecraft to an ice-sheet. That measurement, coupled with radial orbit knowledge, will enable determination of the topography.

altitude

Height above the Earth's surface.

AM

See *amplitude modulation*.

ampere (amp)

Standard unit to measure the strength of an electric current. One amp is the amount of current produced by an electromotive force of one *volt* acting through the resistance of one *ohm*. The ampere is 10^{-1} of the theoretical *electromagnetic* unit of current. Named for the French physicist Andre Marie Ampere. See *ohm*.

amplitude

The magnitude of the displacement of a *wave* from a mean value. For a simple harmonic wave, it is the maximum displacement from the mean. For more complex wave motion, amplitude is usually taken as one-half of the mean distance (or difference) between maxima and minima.

amplitude modulation (AM)

One of three ways to modify a *sine wave* signal in order to make it "carry" information.

The strength (amplitude) of a signal varies (modulates) to correspond to the transmitted information. As applied to *APT*, an audible tone of 2400 *Hz* is amplitude modulated, with the maximum signal corresponding to light areas of a photograph, the minimum levels black, and the intermediate strengths various shades of gray. See *grayscale*.

analog

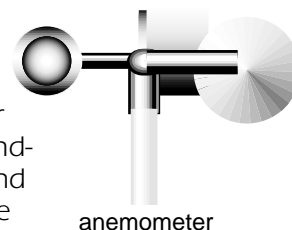
Transmission of a continuously variable signal as opposed to a discretely variable signal. Compare with *digital*. A system of transmitting and receiving information in which one value (i.e., voltage, current, resistance, or, in the *APT* system, the volume level of the video tone) can be compared directly to the information (in the *APT* system, the white, black, and gray values) in the image.

ancillary data

Data other than instrument data required to perform an instrument's data processing. Ancillary data includes such information as orbit and/or attitude data, time information, spacecraft engineering data, and calibration information.

anemometer

Instrument used to measure wind speed, usually measured either from the rotation of wind-driven cups or from wind pressure through a tube pointed into the wind.



anemometer

anomaly

1. The deviation of (usually) temperature or *precipitation* in a given region over a specified period from the normal value for the same region.
2. The angular distance of an Earth satellite (or planet) from its *perigee* (or perihelion) as seen from the center of the Earth (sun). See *Keplerian elements* for examples of use.

antenna

A wire or set of wires used to send and receive *electromagnetic waves*. Two primary features must be considered when selecting antennas: *beamwidth*, or the "width" of the

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antenna pattern (wide beamwidth suggests the ability to receive signals from a number of different directions), and *gain*, or the increase in signal level. Generally beamwidth or gain can be increased only at the expense of the other. Gain can be increased by multiplying the number of antenna elements, although this adds “directionality” that reduces beamwidth.

Important antenna considerations include the following:

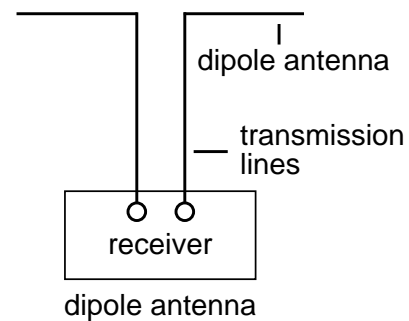
- 1) The physical size of antenna components is determined by the *frequency* of the transmissions it will receive—the higher the frequency, the shorter the elements. At high frequencies, use of a *satellite dish* will compensate for the reduced amount of energy intercepted by shortened components.
- 2) The antenna design should fit the type of *radio frequency (RF)* signal polarization it will receive. The orientation of radio waves in space is a function of the orientation of the elements of the transmitting antenna. A circularly polarized wave rotates as it propagates through space. Antennas can be designed for either right or left-handed circular polarization. Earth-based communication antennas are either vertical or horizontal in polarization, and not suited for space communication. Police and cellular phone transmissions use vertical polarization because a simple vertical whip antenna is the easiest sort of omnidirectional antenna to mount on a vehicle.
- 3) The antenna needs to produce sufficient signal gain to produce noise-free reception.
- 4) The antenna should be clear of conductive objects such as power lines, phone wires, etc., so height above the ground becomes important.

Basic antenna components are:

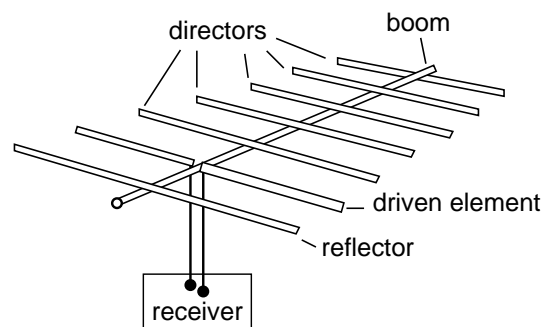
- 1) Driven element—the parts connected to and receiving power from the receiver/transmitter;
- 2) Parasitic elements—the parts dependent upon resonance rather than connection to a power source;

- A director or parasitic element that reinforces radiation on a line pointing to it from the driven element;
- A reflector or parasitic element that reinforces radiation on a line pointing from it to the driven element.

A fundamental form of antenna is a single wire whose length approximately equals half the transmitting wavelength. Known as a dipole antenna, it is the unit from which many more complex forms of antennas are constructed.



One of the most common forms of *VHF* antenna is the Yagi/beam, named for the Japanese scientist who first described the principles of combining a basic dipole (driven element) and parasitic elements. A common TV antenna is an example of this type. A Yagi/beam antenna is directional and therefore includes a rotator to aim (direct) the antenna. See *yagi*.



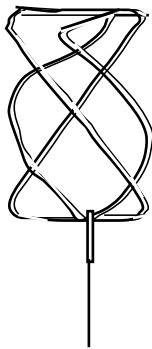
Yagi/beam antenna

An omnidirectional antenna has a wide beamwidth and consequently does not require “tracking” (aiming the antenna toward the signal source). An example of an omnidirectional

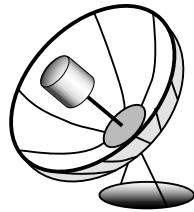
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antenna is the turnstile antenna, a variation of the standard dipole antenna well suited for space communications. The quadrifilar helix antenna is omnidirectional and an inherently excellent antenna for ground station use. Quadrifilars are also used on NOAA's *polar-orbiting* environmental satellites.

The parabolic reflector or *satellite dish* antenna collects RF signals on a passive dish-shaped surface. A *feedhorn* antenna—a simple dipole antenna mounted in a resonant tube structure (cylinder with one open end)—transfers the RF energy to a transmission line. The bigger the dish, the greater the amount of RF energy intercepted, and therefore the greater the *gain* from the signal.



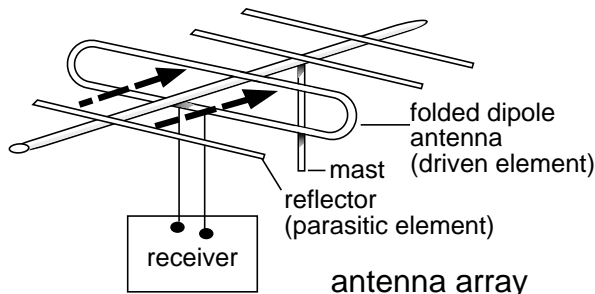
quadrifilar helix



parabolic reflector

antenna array

An ordered assembly of elementary antennae spaced apart and fed in such a manner that the resulting *radiation* is concentrated in one or more directions.



antenna array

antenna beam

The focused pattern of *electromagnetic radiation* that is either received or transmitted by an antenna.

anticyclone

A high pressure area where winds blow clockwise in the Northern Hemisphere and counter-clockwise in the Southern Hemisphere. See *cyclone, wind*.

AOS

See *Acquisition of Signal*.

apogee (aka apoapsis or apifocus)

On an elliptical orbit path, point at which a satellite is farthest from the Earth. See *perigee* diagram

APT

See *Automatic Picture Transmission*.

aquifer

Layer of water-bearing permeable rock, sand, or gravel capable of providing significant amounts of water.

ARGOS

French random-access Doppler data collection system. Used on NOAA's Polar-Orbiting Environmental Satellites (*POES*), ARGOS receives platform and buoy transmissions on 401.65 MHz. This data collection system now monitors more than 4,000 platforms worldwide, outputs data via VHF link, and stores them on tape for relay to a central processing facility.

argument of perigee (aka ARGP or w)

One of the six *Keplerian elements*, it gives the rotation of the satellite on the orbit. The argument (argument meaning angle) of perigee—perigee is the point on an orbital path when the satellite is closest to the Earth—is the angle (measured from the center of the Earth) from the *ascending node* to perigee. Example: When ARGP = 0 degrees, the perigee occurs at the same place as the ascending node. That means that the satellite would be closest to Earth just as it rises up over the equator. When ARGP = 180 degrees, apogee would occur at the same place as the descending node. This means that the satellite would be farthest from Earth just as it rises over the equator. See *Keplerian elements* for diagram.

Arctic circle

The parallel of latitude that is approximately 66.5 degrees north of the equator and that circumscribes the northern frigid zone.

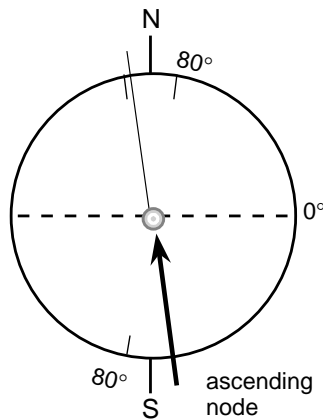
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artificial intelligence

Neural networks. The branch of computer science that attempts to program computers to respond as if they were thinking—capable of reasoning, adapting to new situations, and learning new skills. Examples of artificial intelligence programs include those that can locate minerals underground and understand human speech.

ascending node

The point in an orbit (*longitude*) at which a satellite crosses the equatorial plane from south to north.



aspect ratio

The ratio of image width to image height. *Weather Facsimile (WEFAX)* images have a 1:1 aspect ratio (square); a conventional TV aspect ratio is 4:3 (rectangle).

Astronomical Unit (AU)

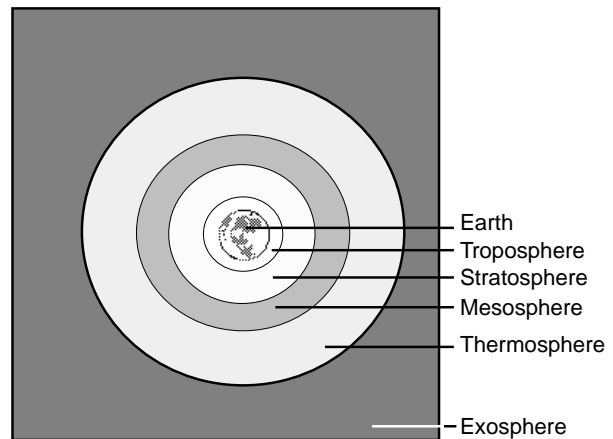
The distance from the Earth to the sun. On average, the sun is 149,599,000 kilometers from Earth.

ATLAS (Atmospheric Laboratory for Applications and Science) mission

The focus of ATLAS is to study the chemistry of the Earth's upper *atmosphere* (mainly the *stratosphere/mesosphere*) and the solar radiation incident on the Earth system (both total solar irradiance and spectrally resolved radiance, especially ultraviolet). Science operations onboard ATLAS 1 (March 1992) and ATLAS 2 (March-April, 1993) began a comprehensive and systematic collection of data that will help establish benchmarks for atmospheric conditions and the sun's stability.

atmosphere

The air surrounding the Earth, described as a series of shells or layers of different characteristics. The atmosphere, composed mainly of nitrogen and oxygen with traces of *carbon dioxide*, water vapor, and other gases, acts as a buffer between Earth and the sun. The layers, troposphere, stratosphere, mesosphere, thermosphere, and the exosphere, vary around the globe and in response to seasonal changes.

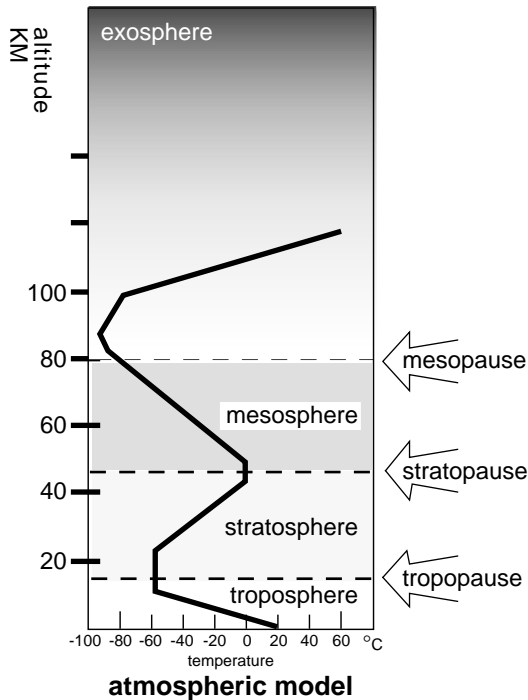


Troposphere stems from the Greek word *tropos*, which means turning or mixing. The troposphere is the lowest layer of the Earth's atmosphere, extending to a height of 8-15 km, depending on latitude. This region, constantly in motion, is the most dense layer of the atmosphere and the region that essentially contains all of Earth's weather. Molecules of nitrogen and oxygen compose the bulk of the troposphere.

The tropopause marks the limit of the troposphere and the beginning of the stratosphere. The temperature above the tropopause increases slowly with height up to about 50 km.

The stratosphere and stratopause stretch above the troposphere to a height of 50 km. It is a region of intense interactions among radiative, dynamical, and chemical processes, in which horizontal mixing of gaseous components proceeds much more rapidly than vertical mixing. The stratosphere is warmer than the upper troposphere, primarily because of a stratospheric *ozone* layer that absorbs solar *ultraviolet* energy.

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The mesosphere, 50 to 80 km above the Earth, has diminished ozone concentration and radiative cooling becomes relatively more important. The temperature begins to decline again (as it does in the troposphere) with altitude. Temperatures in the upper mesosphere fall to -70° to -140° Celsius, depending upon latitude and season. Millions of meteors burn up daily in the mesosphere as a result of collisions with some of the billions of gas particles contained in that layer. The collisions create enough heat to burn the falling objects long before they reach the ground.

The stratosphere and mesosphere are referred to as the middle atmosphere. The mesopause, at an altitude of about 80 km, separates the mesosphere from the thermosphere—the outermost layer of the Earth's atmosphere.

The thermosphere, from the Greek thermo for heat, begins about 80 km above the Earth. At these high altitudes, the residual atmospheric gases sort into strata according to molecular mass. Thermospheric temperatures increase with altitude due to absorption of highly energetic solar radiation by the small amount of residual oxygen still present. Temperatures can rise to $2,000^{\circ}$ C. Radiation causes the scattered

air particles in this layer to become charged electrically, enabling radio waves to bounce off and be received beyond the horizon.

At the exosphere, beginning at 500 to 1,000 km above the Earth's surface, the atmosphere blends into space. The few particles of gas here can reach $4,500^{\circ}$ F ($2,500^{\circ}$ C) during the day.

Atmospheric Infrared Sounder

Advanced sounding instrument selected to fly on the *EOS-PM1* mission (intermediate-sized, sun-synchronous, morning satellite) in the year 2000. It will retrieve vertical temperature and moisture profiles in the troposphere and stratosphere. Designed to achieve temperature retrieval accuracy of 1° C with a 1 km vertical resolution, it will fly with two operational microwave sounders. The three instruments will constitute an advanced operational sounding system, relative to the TIROS Operational Vertical Sounder (TOVS) currently flying on NOAA polar-orbiting satellites. See *Earth Observing System, TIROS-N/NOAA Satellites*.

atmospheric pressure

The amount of force exerted over a surface area, caused by the weight of air molecules above it. As elevation increases, fewer air molecules are present. Therefore, atmospheric pressure always decreases with increasing height. A column of air, 1 square inch in cross section, measured from sea level to the top of the atmosphere would weigh approximately 14.7 lb/in². The standard value for atmospheric pressure at sea level is:

29.92 inches or 760 mm of mercury
1013.25 millibars (mb) or 101,325 pascals (Pa)

Atmospheric Radiation Measurements Program (ARM)

U.S. Department of Energy program for the continual, ground-based measurements of atmospheric and meteorological parameters over approximately a ten-year period. The program will study radiative forcing and feedbacks, particularly the role of clouds. The general program goal is to improve the performance of climate models, particularly general circulation models of the atmosphere.

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atmospheric response variables

Variables that reflect the response of the atmosphere to external forcing (e.g., temperature, pressure, circulation, and precipitation).

atmospheric windows

The range of wavelengths at which water vapor, carbon dioxide, or other atmospheric gases only slightly absorb radiation. Atmospheric windows allow the Earth's radiation to escape into space unless clouds absorb the radiation. See *greenhouse effect*.

atoll

A coral island consisting of a ring of coral surrounding a central lagoon. Atolls are common in the Indian and Pacific Oceans.

attenuation

The decrease in the magnitude of current, voltage, or power of a signal in transmission between points. Attenuation may be expressed in *decibels*, and can be caused by interferences such as rain, *clouds*, or *radio frequency* signals.

audio frequencies

Frequencies that the human ear can hear (usually 30 to 20,000 cycles per second).

auroras

See *solar wind*.

Automatic Picture Transmission (APT)

System developed to make real-time reception of satellite images possible whenever an APT-equipped satellite passes within range of an environmental satellite ground station. Transmission (*analog* video format) consists of an *amplitude-modulated* audible tone that can be displayed as an image on a computer monitor when received by an appropriate ground station.

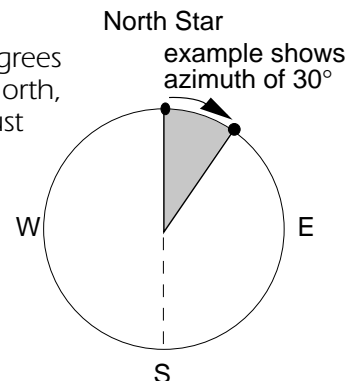
APT images are transmitted by polar-orbiting satellites such as the *TIROS-N/NOAA* satellites, Russia's *METEOR*, and the Chinese *Feng Yun*, which orbit 500-900 miles above the Earth, and offer both visible and infrared images. An APT image has thousands of squares called picture elements or *pixels*. Each pixel represents a four-km square.

AVHRR

See *Advanced Very High Resolution Radiometer*.

azimuth

The direction, in degrees referenced to true north, that an antenna must be pointed to receive a satellite signal (compass direction). The angular distance is measured in a clockwise direction.



B

band

1. In radio, a continuous sequence of broadcasting *frequencies* within given limits.
2. In radiometry, a relatively narrow region of the *electromagnetic spectrum* to which a remote sensor responds; a multispectral sensor makes measurements in a number of spectral bands.
3. In spectroscopy, spectral regions where atmospheric gases absorb (and emit) radiation, e.g., the 15 μm carbon dioxide absorption band, the 6.3 μm water vapor absorption band, and the 9.6 μm ozone absorption band.

bandwidth

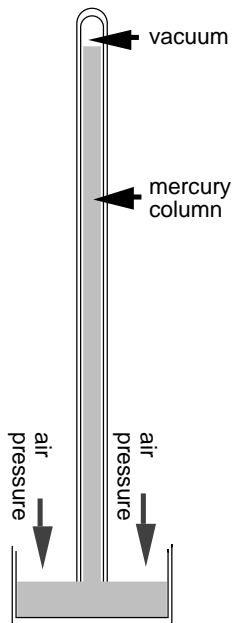
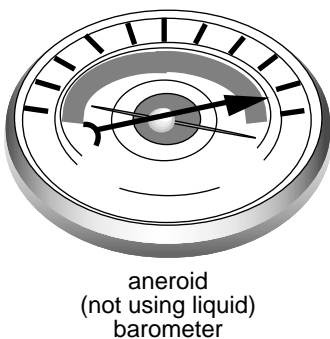
The total range of *frequency* required to pass a specific modulated signal without distortion or loss of data. The ideal bandwidth allows the signal to pass under conditions of maximum *AM* or *FM* adjustment. (Too narrow a bandwidth will result in loss of data during modulation peaks. Too wide a bandwidth will pass excessive noise along with the signal.) In *FM*, radio frequency signal bandwidth is determined by the frequency deviation of the signal.

barometer

An instrument used to measure *atmospheric pressure*. A standard mercury barometer has a glass column about 30 inches long, closed at

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one end, with a mercury-filled reservoir. Mercury in the tube adjusts until the weight of the mercury column balances the atmospheric force exerted on the reservoir. High atmospheric pressure forces the mercury higher in the column. Low pressure allows the mercury to drop to a lower level in the column. An aneroid barometer uses a small, flexible metal box called an aneroid cell. The box is tightly sealed after some of the air is removed, so that small changes in external air pressure cause the cell to expand or contract.



base

A substance that forms a salt when it reacts with acid. A base is a substance that removes hydrogen ions (protons) from an acid and combines with them in a chemical reaction.

BASIC

See *Beginners All-purpose Symbolic Instruction Code*.

baud

Unit of signaling speed. The speed in bauds is the number of discrete conditions or signal events per second. If each signal event represents only one *bit* condition, baud is the same as bits per second.

bay

A wide area of water extending into land from a sea or lake.

beamwidth

The measure of the "width" of an antenna pattern, measured in degrees of arc. Generally

an antenna with low *gain* has a wide pattern, receiving signals well from a number of different directions. See *antenna*.

bearing

The combination of *antenna azimuth* and *elevation* required to point (aim) an antenna at a spacecraft. The bearing for *geostationary* (i.e., GOES) satellites is constant. The bearing for *polar-orbiting satellites* varies continuously.

Beginners All-purpose Symbolic Instruction Code (BASIC)

A most popular and widespread "high level" language for microcomputers. BASIC uses a sequence of English-like commands and statements.

binary

A numbering system that uses only 1 and 0 (e.g., 1 is one, 10 is two, 11 is three). In digital integrated circuits, a 0 is indicated by a logic low and a 1 by a logic high.

bioassay

A measurement of the effects of a substance on living organisms.

biodegradation

Decomposition of material by microorganisms.

biogeochemical cycles

Movements through the *Earth system* of key chemical constituents essential to life, such as carbon, nitrogen, oxygen, and phosphorus.

biomass

The amount of living material in unit area or volume, usually expressed as mass or weight.

biome

Well-defined terrestrial environment (e.g., desert, tundra, or tropical forest). The complex of living organisms found in an ecological region.

biosphere

Part of the *Earth system* in which life can exist, between the outer portion of the *geosphere* and the inner portion of the *atmosphere*.

biota

The plant and animal life of a region or area.

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bit

A contraction of “*binary digit*.” The basic element of a two-element (binary) computer language.

bit rate

The speed at which bits are transmitted, usually expressed in bits per second. See *baud*.

blizzard

A severe weather condition characterized by low temperatures and strong winds (greater than 35 mph) bearing a great amount of snow, either falling or blowing. When these conditions persist after snow has stopped falling, it is called a ground blizzard.

boundaries

Lines indicating the limits of countries, states, or other political jurisdictions, or different air masses.

British Thermal Unit (BTU)

The amount of heat needed to raise the temperature of one pound of water by one degree Fahrenheit. Compare with *calorie*.

bus

The basic frame of a satellite system that includes the propulsion and stabilization systems, but not the instruments or data systems.

byte

A unit of eight *bits* of data or memory in microcomputer systems.

**calibration**

Act of comparing an instrument's measuring accuracy to a known standard.

calorie

The amount of heat needed to raise the temperature of one gram of water at 15° centigrade one degree centigrade. Compare with *British Thermal Unit*.

canal

A man-made watercourse designed to carry goods or water.

canopy

The layer formed naturally by the leaves and branches of trees and plants.

canyon

A large but narrow gorge with deep sides.

cape (or point)

A piece of land extending into water.

carbon cycle

All parts (reservoirs) and fluxes of carbon. The cycle is usually thought of as four main reservoirs of carbon interconnected by pathways of exchange. The reservoirs are the *atmosphere*, terrestrial *biosphere* (usually includes freshwater systems), oceans, and sediments (includes fossil fuels). The annual movements of carbon, the carbon exchanges between reservoirs, occur because of various chemical, physical, geological, and biological processes. The ocean contains the largest pool of carbon near the surface of the Earth, but most of that pool is not involved with rapid exchange with the atmosphere. See appendix for diagram, page 71.

carbon dioxide (CO₂)

A minor but very important component of the *atmosphere*, carbon dioxide traps *infrared radiation*. Atmospheric CO₂ has increased about 25 percent since the early 1800s, with an estimated increase of 10 percent since 1958 (burning fossil fuels is the leading cause of increased CO₂, deforestation the second major cause). The increased amounts of CO₂ in the atmosphere enhance the *greenhouse effect*, blocking heat from escaping into space and contributing to the warming of Earth's lower atmosphere.

carrier

Radio frequency capable of being modulated with some type of information. See *modulation*.

carrying capacity

The steady-state density of a given species that a particular habitat can support.

catalog number

A five-digit number assigned to a cataloged orbiting object. This number may be found in the NASA Satellite Situation Report and on the *NASA Prediction Bulletins*.

CONCEPTS AND TERMS

cathode ray tube (CRT)

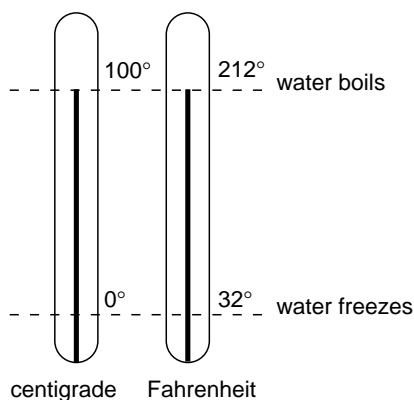
A television picture tube for image display.

CD-ROM

See *Compact Disk–Read Only Memory*.

centigrade

Temperature scale proposed by Swedish astronomer Anders Celsius in 1742. A mixture of ice and water is zero on the scale; boiling water is designated as 100 degrees. A degree is defined as one hundredth of the difference between the two reference points, resulting in the term centigrade (100th part).



To convert centigrade to Fahrenheit: multiply the centigrade temperature by 1.8 and add 32°. $F = 9/5 C + 32$

To convert Fahrenheit to centigrade: subtract 32° from the Fahrenheit temperature and divide the quantity by 1.8. $C = (F - 32) / 1.8$.

central processing unit (CPU)

Main part of a computer consisting of an arithmetic logic unit and a control unit. See *micro-processor*.

CFC

See *chlorofluorocarbon*.

chlorofluorocarbon (CFC)

A family of compounds of chlorine, fluorine, and carbon, entirely of industrial origin. CFCs include refrigerants, propellants for spray cans (this usage is banned in the U.S., although some other countries permit it) and for blowing plastic-foam insulation, styrofoam packaging, and solvents for cleaning electronic circuit

boards. The compounds' lifetimes vary over a wide range, exceeding 100 years in some cases.

CFCs' ability to destroy stratospheric ozone through catalytic cycles is contributing to the depletion of ozone worldwide. Because CFCs are such stable molecules, they do not react easily with other chemicals in the lower atmosphere. One of the few forces that can break up CFC molecules is *ultraviolet radiation*, however the ozone layer protects the CFCs from ultraviolet radiation in the lower atmosphere. CFC molecules are then able to migrate intact into the stratosphere, where the molecules are bombarded by ultraviolet rays, causing the CFCs to break up and release their chlorine atoms. The released chlorine atoms participate in ozone destruction, with a single atom of chlorine able to destroy ozone molecules over and over again.

International attention to CFCs resulted in a meeting of diplomats from around the world in Montreal in 1987. They forged a treaty that called for drastic reductions in the production of CFCs. In 1990, diplomats met in London and voted to significantly strengthen the Montreal Protocol by calling for a complete elimination of CFCs by the year 2000. See Montreal Protocol.

Circadian Rhythm

The cyclical changes in physiological processes and functions that are related to the 24-hour *diurnal* cycle.

circuit

The complete path of an electric current; an assemblage of electronic elements; a means of two-way communication between two points—comprised of associated "go" and "return" channels.

circularly polarized RF

Radio frequency transmissions where the wave energy is divided equally between a vertically- and a horizontally-polarized component.

Clarke Belt

A belt 22,245 miles (35,800 kilometers) directly above the equator where a satellite orbits the Earth at the same speed the Earth is

CONCEPTS AND TERMS

rotating. Science fiction writer and scientist Arthur C. Clarke wrote about this belt in 1945, hence the name.

climate

The average weather conditions in an area determined over a period of years.

climatology

Science dealing with *climate* and climate phenomena.

clone

A person or thing very much like another, e.g., a copy of another manufacturer's computer.

cloudburst

Any sudden, heavy rain shower.

clouds

A visible mass of *water vapor* suspended in the *atmosphere* above Earth's surface. Clouds form in areas where air rises and cools. The condensing water vapor forms small droplets of water (0.012 mm) that, when combined with billions of other droplets, form clouds. Clouds can form along warm and cold fronts, where air flows up the side of the mountain and cools as it rises higher into the atmosphere, and when warm air blows over a colder surface, such as a cool body of water.

Clouds fall into two general categories: sheet-like or layer-looking stratus clouds (stratus means layer) and cumulus clouds (cumulus means piled up). These two cloud types are divided into four more groups that describe the cloud's altitude.

High clouds form above 20,000 feet in the cold region of the troposphere, and are denoted by the prefix CIRRO or CIRRUS. At this altitude water almost always freezes so clouds are composed of ice crystals. The clouds tend to be wispy, are often transparent, and include *cirrus*, *cirrocumulus*, and *cirrostratus*.

Middle clouds form between 6,500 and 20,000 feet and are denoted by the prefix ALTO. They are made of water droplets and include *altostratus* and *altocumulus*.

Low clouds are found up to 6,500 feet and include the *stratocumulus* and *nimbostratus*

clouds. When stratus clouds contact the ground they are called fog.

Vertical clouds, such as cumulus, rise far above their bases and can form at many heights. *Cumulonimbus* clouds, or thunderheads, can start near the ground and soar up to 75,000 feet.

cloud streets

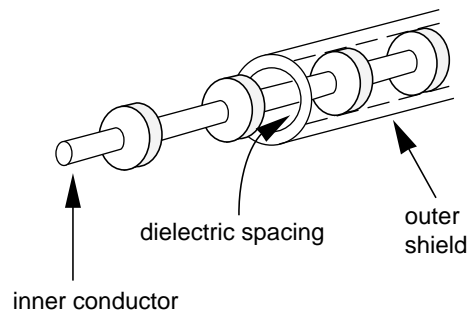
Lines or rows of cumuliform clouds.

Coastal Zone Color Scanner (CZCS)

The first spacecraft instrument devoted to measurement of ocean color. Although instruments on other satellites have sensed ocean color, their *spectral bands*, spatial resolution, and dynamic range were optimized for geographical or meteorological use. In the CZCS, every parameter is optimized for use over water to the exclusion of any other type of sensing. The CZCS flew on the *Nimbus-7* spacecraft.

coaxial cable

A hollow copper cylinder, or other cylindrical conductor, surrounding a single-wire conductor having a common axis (hence coaxial). The space between the cylindrical shell and the inner conductor is filled with an insulator which may be plastic or mostly air, with supports separating the shell and the inner conductor every inch or so. The cable is used to carry radio frequency signals to or from antennas, etc.



COBOL

See *Common Business Oriented Language*.

comma cloud

Band of organized cumuliform clouds that look like a comma from a satellite's perspective. Comma clouds are indicators of heavy storms.

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Common Business Oriented Language (COBOL)

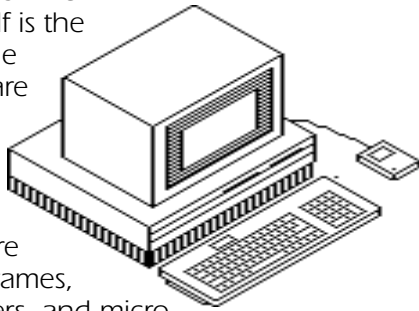
A computer programming language written for business application.

Compact Disk–Read Only Memory (CD-ROM)

Type of computer memory that reads and uses information, but does not allow information to be added, changed, or erased. Digital information is read by laser. CD-ROM does not depend upon any proprietary hardware or software, making it an accessible vehicle for electronic publishing.

computer

Electronic machine capable of performing calculations and other manipulations of various types of data, under the control of a stored set of instructions. The machine itself is the hardware; the instructions are the program or software. Depending upon size, computers are called mainframes, minicomputers, and microcomputers. Microcomputers include desk-top and portable personal computers.



condensation

Change of a substance to a denser form, such as gas to a liquid. The opposite of *evaporation*.

conduction

The transfer of heat from one substance to another by direct contact. Denser substances are better conductors; the transfer is always from warmer to colder substances.

contrails

Condensation trails. Artificial clouds made by the exhaust of jet aircraft.

convection

The rising of warm air and the sinking of cool air. Heat mixes and moves air. When a layer of air receives enough heat from the Earth's surface, it expands and moves upward. Colder,

heavier air flows under it which is then warmed, expands, and rises. The warm rising air cools as it reaches higher, cooler regions of the atmosphere and begins to sink.

Convection causes local breezes, winds, and thunderstorms.

Coordinated Universal Time (UTC)

(aka *Greenwich Mean Time [GMT]*) Local time at zero degrees longitude at the Greenwich Observatory, England. UTC uses a 24-hour clock, i.e., 2:00 a.m. is 0200 hours, 2:00 p.m. is 1400 hours, midnight is 2400 or 0000 hundred hours.

continent

One of the large, continuous areas of the Earth into which the land surface is divided. The six geographically defined continents are politically defined as seven; Africa, Asia, Australia, Europe, North America, South America, and Antarctica.

continental drift

See *plate tectonics*.

Coriolis force

The apparent tendency of a freely moving particle to swing to one side when its motion is referred to a set of axes that is itself rotating in space, such as Earth. The acceleration is perpendicular to the direction of the speed of the article relative to the Earth's surface and is directed to the right in the northern hemisphere. Winds are affected by rotation of the Earth so that instead of a wind blowing in the direction it starts, it turns to the right of that direction in the northern hemisphere; left in the southern hemisphere.

coupled system

Two or more processes that affect one another.

CPU

See *central processing unit*.

crop calendar

The schedule of the maturing and harvesting of seasonal crops.

CRT

See *cathode ray tube*.

CONCEPTS AND TERMS

cryosphere

One of the interrelated components of the *Earth's system*, the cryosphere is frozen water in the form of snow, permanently frozen ground (permafrost), floating ice, and glaciers. Fluctuations in the volume of the cryosphere cause changes in ocean sea-level, which directly impact the atmosphere and biosphere.

culmination

The point at which a satellite reaches its highest position or elevation in the sky, relative to an observer (aka the closest point of approach).

cyclone

An area of low pressure where winds blow counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere. See *anticyclone*, *wind*.

CZCS

See *Coastal Zone Color Scanner*.

D

data collection system (DCS)

DCS units are flown on both *GOES* and NOAA *polar-orbiting* spacecraft. They gather and relay data from both mobile and stationary platforms at various locations. DCS units on NOAA satellites can also determine the precise location of moving platforms at the time the data were acquired. See *TIROS-N/NOAA satellites*.

data rate

The amount of information transmitted per unit time.

decay

See *period decay*.

decibel (dB)

A tenth of a bel. A unit used to measure the volume of a sound, equal to ten times the common *logarithm* of the ratio of the intensity of the sound to the intensity of an arbitrarily chosen standard sound. The decibel also is used to measure relative strengths of *antenna* and amplified signals and always refers to a ratio or difference between two values.

declination

The angular distance from the equator to the satellite, measured as positive north and negative south.

Defense Meteorological Satellite Program (DMSP)

A U.S. Air Force-managed meteorological satellite program with satellites circling in *sun-synchronous* orbit. Imagery is collected in the *visible-* to *near-infrared* band (0.4 to 1.1 *micrometers*) and in the *thermal-infrared* band (about 8 to 13 micrometers) at a resolution of about three kilometers. DMSP data is available directly from the satellite for local use aboard ships and at military deployment locations, but is also usually available to civilian users.

degree

A unit of angular measure represented by the symbol $^{\circ}$. The circumference of a circle contains 360 degrees. When applied to the roughly spherical shape of the Earth for geographic and cartographic purposes, degrees are each divided into 60 minutes.

delta

The fan-shaped area at the mouth or lower end of a river, formed by eroded material that has been carried downstream and dropped in quantities larger than can be carried off by tides or currents.

demodulation

The process of retrieving information (data) from a modulated carrier wave, the reverse of *modulation*.

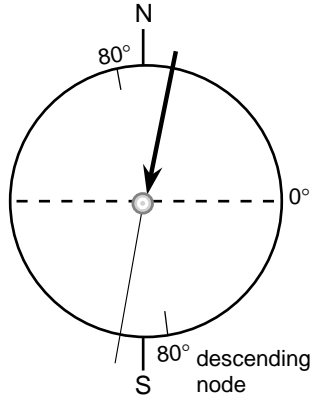
Department of the Interior (DOI)

Responsible for our nationally-owned public lands and natural resources, the DOI is chartered to foster the wisest use of our land and water resources, protect fish and wildlife, preserve the environmental and cultural values of national parks and historical places, and provide for the enjoyment of life through outdoor recreation. The department assesses energy and mineral resources and is responsible for assuring that their development is in the best interest of all citizens. The *U.S. Geological Survey (USGS)* is part of the DOI.

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descending node

The point in a satellite's orbit at which it crosses the equatorial plane from north to south. See diagram, *Keplerian elements*.



desert

A land area so dry that little or no plant or animal life can survive.

desertification

The man-made or natural formation of desert from usable land.

detector

A device in a *radiometer* that senses the presence and intensity of radiation. The incoming radiation is usually modified by filters or other optical components that restrict the radiation to a specific *spectral band*. The information can either be transmitted immediately or recorded for transmittal at a later time.

dew

Atmospheric moisture that condenses after a warm day and appears during the night on cool surfaces as small drops. The cool surfaces cause the water vapor in the air to cool to the point where the water vapor condenses.

dew point

The temperature to which air must be cooled for saturation to occur, exclusive of air pressure or moisture content change. At that temperature dew begins to form, and water vapor condenses into liquid.

digital image

An *analog* image converted to numerical form so that it can be stored and used in a computer. The image is divided into a matrix of small regions called picture elements or *pixels*. At *sub-satellite point* each pixel represents a

specific amount of area. For example, in *APT* each pixel represents 4.1 kilometers. Each pixel has a numerical value or data number value, quantifying the radiance of the image at that spot. The data number value of each pixel usually represents a value between black and white, i.e., shades of gray.

False color can be applied to the image by assigning a graduated color palette to represent the gray shades. The color is "false" because it represents an assigned, not actual, color.

digital system

A system in which information is transmitted in a series of pulses. The source is periodically sampled, analyzed, and converted or coded into numerical values and transmitted. Digital transmissions typically use the *binary* coding used by computers so most data is in appropriate form, but verbal and visual communication must be converted. Many satellite transmissions use digital formats because noise will not interfere with the quality of the end product, producing clear and higher-resolution imagery.

direct readout

The capability to acquire data directly from environmental satellites via an *Earth station*. Data can be acquired from *NOAA* and other nations' environmental satellites, which offer weather information from *geostationary* and *polar-orbiting satellites*.

director

Parasitic element(s) of a VHF antenna located forward of the driven element. See *antenna*.

DIS

Data and Information System.

diurnal

Performed in twenty-four hours, such as the diurnal revolution of the Earth.

diurnal arc

The apparent arc described by heavenly bodies from their rising to their setting.

Dobson Unit (DU)

The standard way to express *ozone* amounts in the *atmosphere*. One DU is 2.7×10^{16} ozone molecules per square centimeter. One Dobson unit refers to a layer of ozone that would be 0.001 cm thick under conditions of

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standard temperature (0° C) and pressure (the average pressure at the surface of the Earth). For example, 300 Dobson units of ozone brought down to the surface of the Earth at 0° C would occupy a layer only 0.3 cm thick in a column. Dobson was a researcher at Oxford University who, in the 1920s, built the first instrument (now called the Dobson meter) to measure total ozone from the ground.

doldrums

Region near the equator characterized by low pressure and light shifting winds. See *wind*.

Doppler effect (aka Doppler shift)

The apparent change in frequency of sound or light waves, varying with the relative velocity of the source and the observer. If the source and observer draw closer together, the frequency is increased. Named for Christian Doppler, Austrian mathematician and physicist (1803–1853).

Doppler radar

The weather radar system that uses the Doppler shift of radio waves to detect air motion that can result in tornadoes and precipitation, as previously-developed weather radar systems do. It can also measure the speed and direction of rain and ice, as well as detect the formation of tornadoes sooner than older radars.

downconverter

Any radio frequency circuit that converts a higher frequency to a lower frequency. This enables signal processing by a receiver. A typical downconverter will feature one or more stages of *RF* preamplification, a mixer where the frequency conversion occurs, a local oscillator chain, and often one or more intermediate frequency preamplifiers to minimize the effect of line losses between the converter and the receiver.

drag (aka N1)

A retarding force caused by the Earth's atmosphere. Thus by definition, drag will act opposite to the vehicle's instantaneous velocity vector with respect to the atmosphere. The magnitude of the drag force is directly proportional to the product of the vehicle's cross-sectional area, its drag coefficient, its velocity, and the atmospheric density, and inversely

proportional to its mass. The effect of drag is to cause the orbit to decay, or spiral downward. A satellite of very high mass and very low cross-sectional area, and in a very high orbit, may be very little affected by drag, whereas a large satellite of low mass, in a low altitude orbit may be affected very strongly by drag. Drag is the predominant force affecting satellite lifetime.

driven element

See *antenna*.

dynamics

The study of the action of forces on bodies and the changes in motion they produce.

E

Earth Observing System (EOS)

A series of small- to intermediate-sized spacecraft that is the centerpiece of NASA's *Mission to Planet Earth (MTPE)*. Planned for launch beginning in 1998, each of the EOS spacecraft will carry a suite of instruments designed

EOS Research

Spacecraft	Research purpose
EOS-AM1 (1998)	characterization of land and ocean surfaces sea-surface temperature terrestrial and ocean productivity clouds, aerosols, and radiative balance
EOS-COLOR (1998)	ocean color and productivity
EOS-AERO1 (2000)	atmospheric aerosols and ozone
EOS-PM1 (2000)	clouds, precipitation, radiative balance, terrestrial snow, and sea ice sea surface temperature terrestrial and ocean productivity atmospheric temperature and moisture
EOS-ALT1 (2002)	ocean circulation, ice sheet mass balance, and land-surface topography
EOS-CHEM1 (2002)	atmospheric chemical species and their transformations solar radiation

projected year of launch shown in parentheses

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to study global climate change. MTPE will use space-, aircraft-, and ground-based measurements to study our environment as an integrated system. Designing and implementing the MTPE is, of necessity, an international effort. The MTPE program involves the cooperation of the U.S., the European Space Agency (ESA), and the Japanese National Space Development Agency (NASDA). The MTPE program is part of the U.S. interagency effort, the *Global Change Research Program*.

Earth Observing System Data & Information System (EOSDIS)

The system that will manage a dataset of Earth science observations to be collected over a 15-year period. Existing data indicates that the Earth is changing, and that human activity increasingly contributes to this change. To monitor these changes, a baseline of “normal” performance characteristics must be obtained. For the Earth, these baseline characteristics must cover a global scale and a long enough period that the variation caused by seasonal changes and other cyclical or periodic events (e.g., *El Niño* and the *solar cycle*) may be included in the analyses. The baseline characteristics also must enable scientists to quantify processes that govern the Earth’s system. Functionally, EOSDIS will provide computing and networking facilities supporting EOS research activities, including data interpretation and modeling; processing, distribution, and archiving of EOS data; and command and control of EOS observatories.

Earth Probes

Discipline-specific satellites and instruments that will be used by NASA to obtain observations before the launch of EOS spacecraft. Generally smaller than the EOS satellites and instruments, Earth Probes are planned to complement the broad environmental measurements from EOS with highly focused studies in areas such as tropical rainfall (*TRMM*), ocean productivity (SeaWiFS), atmospheric ozone (*TOMS*), and ocean surface winds (*NSCAT*).

Earth Radiation Budget Experiment (ERBE)

An experiment to obtain data to study the average *radiation budget* of the Earth and determine the energy transport gradient from

the equator to the poles. Three satellites were flown in different orbits to obtain the data: the Earth Radiation Budget Satellite, ERBS (launched in October 1984), NOAA-9 (launched in December 1984), and NOAA-10 (launched in September 1986). See *Television and Infrared Observation Satellite (TIROS)*.

Earth station (aka ground station)

Hardware necessary to acquire data directly from environmental satellites. The *WEFAX* Earth station diagram illustrates a basic ground station configuration for obtaining direct readout data from *geostationary* environmental (weather) satellites. (See diagram page 19.)

Earth system

The Earth regarded as a unified system of interacting components, including *geosphere* (land), *atmosphere* (air), *hydrosphere* (water and ice), and *biosphere* (life).

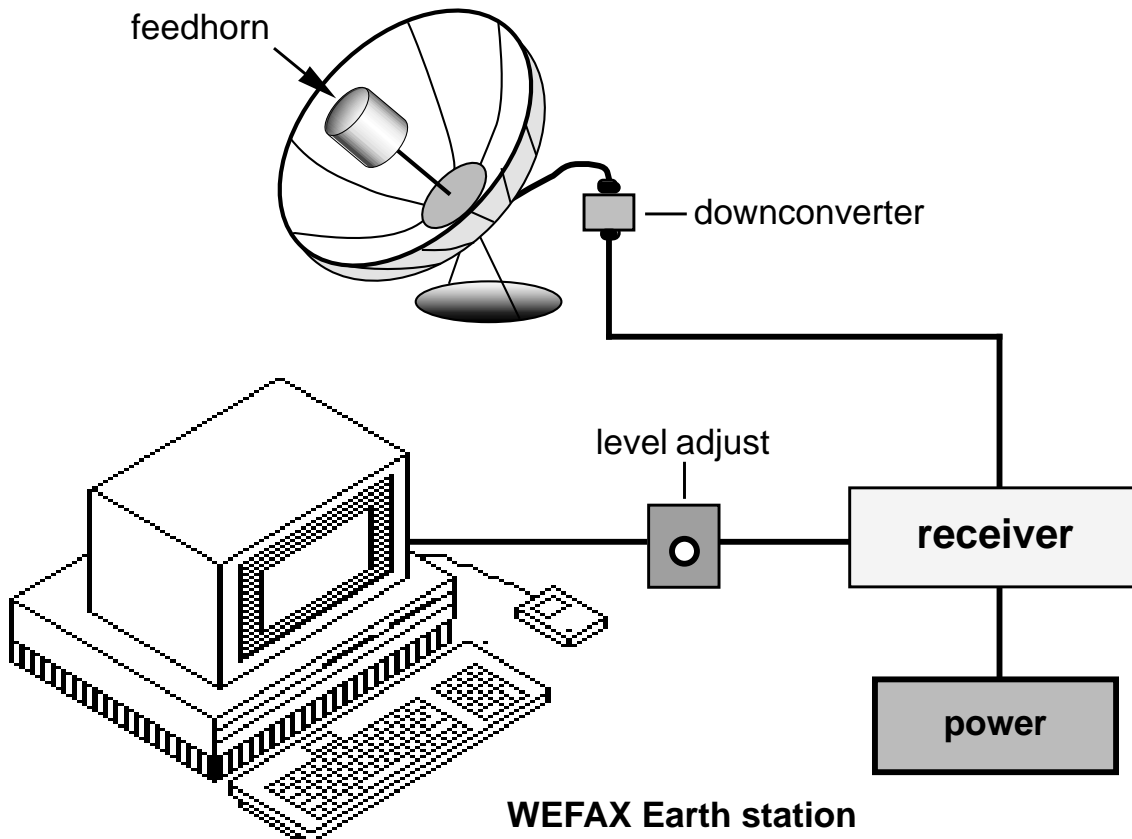
Earth’s Interacting Components

geosphere	Physical elements of the Earth’s surface, crust, and interior. Processes in the geosphere include continental drift, volcanic eruptions, and earthquakes.
atmosphere	Thin layer of gas or air that surrounds the Earth. Processes in the atmosphere include winds, weather, and the exchange of gases with living organisms.
hydrosphere	Water and ice on or near the surface of the Earth. Includes water vapor in clouds; ice caps and glaciers; and water in the oceans, rivers, lakes, and aquifers. Processes in the hydrosphere include the flow of rivers, evaporation, and rain.
biosphere	The wealth and diversity of living organisms on the Earth. Processes in the biosphere include life and death, evolution, and extinction.

Earth system science

An integrated approach to the study of the Earth that stresses investigations of the interactions among the Earth’s components in order to explain Earth dynamics, evolution, and global change.

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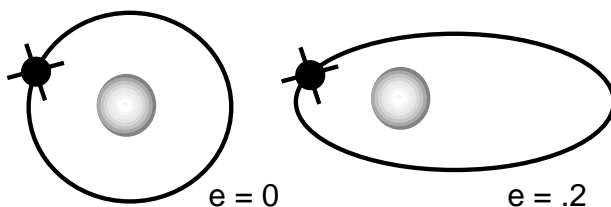


WEFAX Earth station

eccentricity

(aka ecce or E0 or e) One of six *Keplerian elements*, it describes the shape of an orbit. In the Keplerian orbit model, the satellite orbit is an ellipse, with eccentricity defining the "shape" of the ellipse. When $e=0$, the ellipse is a circle. When e is very near 1, the ellipse is very long and skinny.

eccentricity
$e = 0 \Rightarrow$ circular orbit
$0 < e < 1 \Rightarrow$ elliptical orbit
$e = 1 \Rightarrow$ parabolic orbit
$e > 1 \Rightarrow$ hyperbolic orbit



eclipse

The partial or total apparent darkening of the sun when the moon comes between the sun and the Earth (solar eclipse), or the darkening of the moon when the full moon is in the Earth's shadow (lunar eclipse).

eclipse blindness

Focus-point type of vision loss caused by looking at the sun for too long a time, which can burn a hole in the retina of the eye.

ecology

Science dealing with the interrelationships between living organisms and their environments.

ecosystem

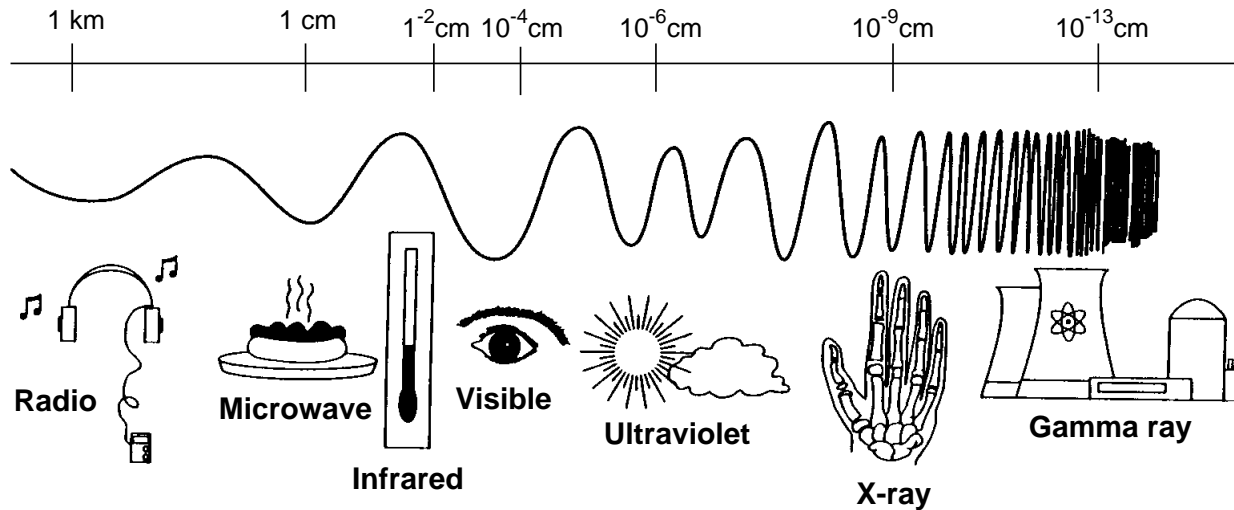
Any natural unit or entity including living and non-living parts that interact to produce a stable system through cyclic exchange of materials.

electromagnetic radiation

Energy propagated as time-varying electric and magnetic fields. These two fields are inextricably linked as a single entity since time-varying electric fields produce time-varying

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Electromagnetic Spectrum



magnetic fields and vice versa. Light and radar are examples of electromagnetic radiation differing only in their wavelengths (or frequency). Electric and magnetic fields propagate through space at the speed of light.

electromagnetic spectrum

The entire range of radiant energies or wave frequencies from the longest to the shortest wavelengths—the categorization of *solar radiation*. Satellite sensors collect this energy, but what the detectors capture is only a small portion of the entire electromagnetic spectrum. The spectrum usually is divided into seven sections: radio, microwave, infrared, visible, ultraviolet, x-ray, and gamma-ray radiation. See diagram above.

electromagnetic wave

Method of travel for radiant energy (all energy is both particles and waves), so called because radiant energy has both magnetic and electrical properties. Electromagnetic waves are produced when electric charges change their motion. Whether the frequency is high or low, all electromagnetic waves travel at 300,000,000 meters per second.

electromotive

Producing an electric current through differences in potential.

electromotive force

The force that can alter the motion of electricity, measured in terms of the energy per unit charge imparted to electricity passing through the source of this force. Electromotive force causes current flow in a circuit.

element set (aka Keplerian elements, classical elements, satellite elements)

Specific information used to define and locate a particular satellite. The set includes the catalog number; epoch year, day, and fraction of day; period decay rate; argument of perigee; inclination; eccentricity; right ascension of the ascending node; mean anomaly; mean motion; revolution number at epoch; and element set number. This data is contained in the two-line orbital elements provided by NASA in the *NASA Prediction Bulletin*. See *Keplerian elements*.

elevation

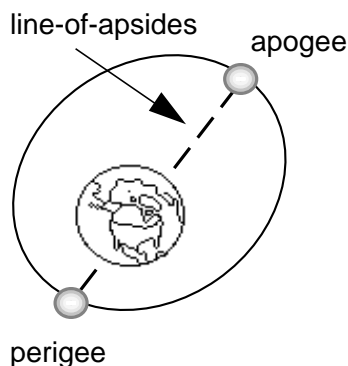
The angle at which an antenna must be pointed above the horizon for optimal reception from a spacecraft.

elliptical orbits

Bodies in space orbit in elliptical rather than circular orbits because of factors such as *gravity* and *drag*. The point where the orbiting satellite is closest to Earth is the *perigee*, sometimes

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called peri-apsis or perifocus. The point where the satellite is farthest from Earth is called *apogee*, apoapsis, or apifocus. A line drawn from perigee to *apogee* is the line-of-apsides, sometimes called the major-axis of the ellipse. It's simply a line drawn through the ellipse the long way.



El Niño

A warming of the surface waters of the eastern equatorial Pacific that occurs at irregular intervals of 2–7 years, usually lasting 1–2 years. Along the west coast of South America, southerly winds promote the upwelling of cold, nutrient-rich water that sustains large fish populations, that sustain abundant sea birds, whose droppings support the fertilizer industry. Near the end of each calendar year, a warm current of nutrient-poor tropical water replaces the cold, nutrient-rich surface water. Because this condition often occurs around Christmas, it was named El Niño (Spanish for boy child, referring to the Christ child). In most years the warming lasts only a few weeks or a month, after which the weather patterns return to normal and fishing improves. However, when El Niño conditions last for many months, more extensive ocean warming occurs and economic results can be disastrous. El Niño has been linked to wetter, colder winters in the United States; drier, hotter summers in South America and Europe; and drought in Africa. See *ENSO*.

ELT

Emergency Locator Transmitter. See *Search and Rescue*.

energy budget

A quantitative description of the energy exchange for a physical or ecological system. The budget includes terms for *radiation*, *conduction*, *convection*, latent heat, and for sources and sinks of energy.

ENSO (El Niño-Southern Oscillation)

Interacting parts of a single global system of climate fluctuations. ENSO is the most prominent known source of interannual variability in weather and climate around the world, though not all areas are affected. The Southern Oscillation (SO) is a global-scale seesaw in atmospheric pressure between Indonesia /North Australia, and the southeast Pacific. In major warm events *El Niño* warming extends over much of the tropical Pacific and becomes clearly linked to the SO pattern. Many of the countries most affected by ENSO events are developing countries with economies that are largely dependent upon their agricultural and fishery sectors as a major source of food supply, employment, and foreign exchange. New capabilities to predict the onset of ENSO events can have a global impact. While ENSO is a natural part of the Earth's climate, whether its intensity or frequency may change as a result of global warming is an important concern.

environment

The complex of physical, chemical, and biological factors in which a living organism or community exists.

EOS

See *Earth Observing System*.

EOSDIS

See *Earth Observing System Data and Information System*.

EPA (Environmental Protection Agency)

U.S. agency that ensures: Federal environmental laws are implemented and enforced effectively; U.S. policy—both foreign and domestic—fosters the integration of economic development and environmental protection so that economic growth can be sustained over the long term; public and private decisions affecting energy, transportation, agriculture, industry, international trade, and natural resources fully integrate considerations of environmental quality; national efforts to reduce environmental risk are based on the best available scientific information communicated clearly to the public; everyone in our

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society recognizes the value of preventing pollution before it is created; people have the information and incentives they need to make environmentally-responsible choices in their daily lives; and schools and community institutions promote environmental stewardship as a national ethic.

ephemeris

A tabulation of a series of points that define the position and motion of a satellite. See *Keplerian elements*.

EPIRB

Emergency Position Indicating Radio Beacon. See *Search and Rescue*.

epoch (aka Epoch Time or T0)

Epoch specifies the time of a particular description of a satellite orbit. See *Keplerian elements*.

equator

An imaginary circle around the Earth that is everywhere equally distant (90°) from the North Pole and the South Pole. The equator is a great circle and defines latitude 0°.

ERBE

See *Earth Radiation Budget Experiment*.

ESA

European Space Agency.

eutrophication

The process whereby a body of water becomes rich in dissolved nutrients through natural or man-made processes. This often results in a deficiency of dissolved oxygen, producing an environment that favors plant over animal life.

evaporation

Change from a liquid (more dense) to a vapor or gas (less dense) form. When water is heated it becomes a vapor that increases *humidity*. Evaporation is the opposite of *condensation*.

exosphere

The uppermost layer of the *atmosphere*, its lower boundary is estimated at 500 km to 1000 km above the Earth's surface. It is only from the exosphere that atmospheric gases can, to any appreciable extent, escape into outer space.

external forcing

Influence on the *Earth system* (or one of its components) by an external agent such as *solar radiation* or the impact of extraterrestrial bodies such as meteorites.

F

FAA

Federal Aviation Administration.

facsimile (FAX)

A process by which graphic or photographic information is transmitted or recorded by electronic means.

false color

See *digital image*.

Fahrenheit

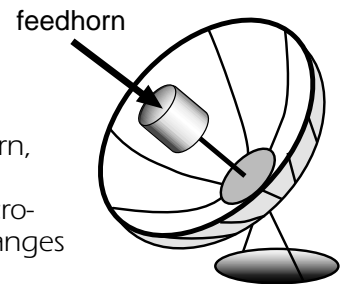
Temperature scale designed by the German scientist Gabriel Fahrenheit in 1709, based upon water freezing at 32 °F and water boiling at 212 °F under standard atmospheric pressure. Compare with *centigrade*.

far infrared

Electromagnetic radiation, longer than the thermal infrared, with wavelengths between about 25 and 1000 micrometers. See *electromagnetic spectrum*.

feedhorn

A metallic cylinder closed at one end, used to obtain and direct *radio frequency (RF)* energy reflected from a *satellite dish*. It acts as a wave guide at microwave frequencies. RF energy inside the horn is picked up by a small probe; once inside the horn, the wavelength (energy) of the microwave radiation changes to a *guided wave*.



FEMA

U.S. Federal Emergency Management Agency.

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Feng Yun

Chinese geostationary environmental satellite that was destroyed by an explosion before launch in April 1994. The name Feng Yun, meaning *Wind and Cloud*, was originally applied to the Chinese *polar-orbiting* environmental satellite launched in September 1991 (Feng Yun 1-2), which offered direct readout services. The Chinese polar-orbiter program has since been abandoned.

field

The set of influences (electricity, magnetism, gravity) that extend throughout space.

field of view

The range of angles that are scanned or sensed by a system or instrument, measured in degrees of arc.

filter

Device that while selectively passing desired frequencies removes undesired ones.

FM

See *frequency modulation*.

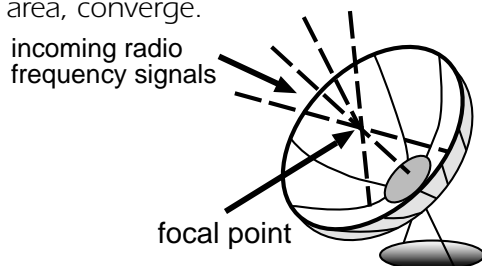
focal length

1) In optics, the distance—usually expressed in millimeters—from the principal point of a lens or concave mirror to its *focal point*.

2) The distance, measured from the center of the surface of a parabolic or spherical reflector (e.g., *satellite dish*) where *RF* energy is brought to essential point focus.

focal point

The area where weak signals collected by a *satellite dish*, concentrated into a smaller receiving area, converge.



fog

A cloud on the ground.

fossil

Hardened remains or traces of plant or animal life from a previous geological period preserved in the Earth's crust.

fossil fuel

Any hydrocarbon deposit that can be burned for heat or power, such as petroleum, coal, and natural gas.

frame

A single image or picture. A single complete vertical scan of the *cathode ray tube (CRT)*.

free radicals

Atomic or molecular species with unpaired electrons or an otherwise open shell configuration, usually very reactive. Specific to atmospheric chemistry, free radicals are: short-lived, highly reactive, intermediate species produced by dissociation of the source molecules by solar ultraviolet radiation or by reactions with other stratospheric constituents. Free radicals are the key to intermediate species in many important *stratospheric* chain reactions in which an *ozone* molecule is destroyed and the radical is regenerated. See *ozone*.

frequency (F)

Number of cycles and parts of cycles completed per second. $F=1/T$, where T is the length of one cycle in seconds.

frequency division multiplexing

The combining of a number of signals to share a medium by dividing it into different frequency bands for each signal. See *signal*.

frequency modulation (FM)

The instantaneous variation of the frequency of a carrier wave in response to changes in the amplitude of a modulating signal. As applied to *APT*, the radio signal from the satellite is broadcast on an FM transmitter and received on the ground on an FM radio receiver. See *frequency division multiplexing*, signal.

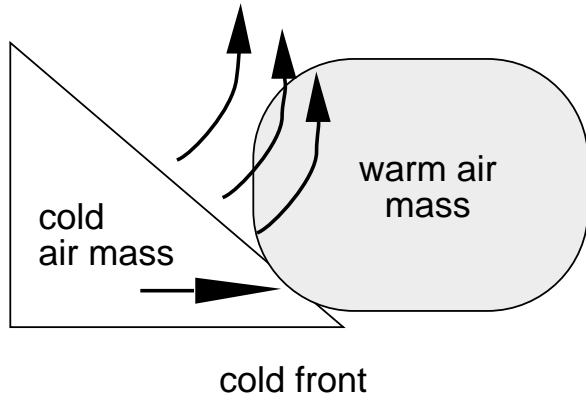
front

A boundary between two different air masses. The difference between two air masses sometimes is unnoticeable. But when the colliding air masses have very different temperatures and amounts of water in them, turbulent weather can erupt.

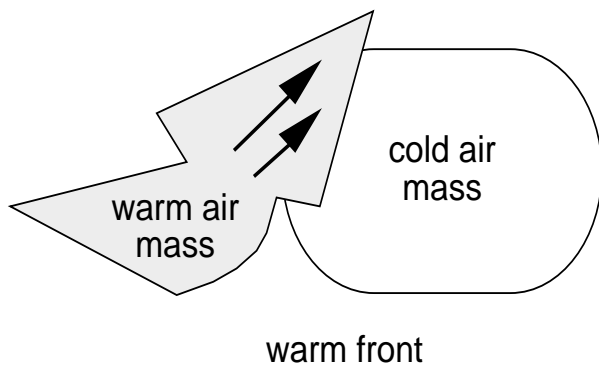
A cold front occurs when a cold air mass moves into an area occupied by a warmer air mass. Moving at an average speed of about 20 mph, the heavier cold air moves in a

CONCEPTS AND TERMS

wedge shape along the ground. Cold fronts bring lower temperatures and can create narrow bands of violent thunderstorms. In North America, cold fronts form on the eastern edges of high pressure systems.



A warm front occurs when a warm air mass moves into an area occupied by a colder air mass. The warm air is lighter, so it flows up the slope of the cold air below it. Warm fronts usually form on the eastern sides of low pressure systems, create wide areas of clouds and rain, and move at an average speed of 15 mph.



When a cold front follows and then overtakes a warm front (warm fronts move more slowly than cold fronts) lifting the warm air off the ground, an *occluded front* forms.

frost

Water *condensation* occurring on surfaces below freezing. Condensing water turns to ice.

G

Gaia hypothesis

The hypothesis that the Earth's *atmosphere*, *biosphere*, and its living organisms behave as a single system striving to maintain a stability that is conducive to the existence of life.

gain

The increase in signal power produced by an amplifier, usually expressed in *decibels* as the ratio of the output to the input. A measure of the effectiveness of a directional antenna as compared to a non-directional antenna. See *antenna*.

geodesy

A branch of applied mathematics concerned with measuring the shape of the Earth and describing variations in the Earth's gravity field.

Geographic Information System (GIS)

A system for archiving, retrieving, and manipulating data that has been stored and indexed according to the geographic coordinates of its elements. The system generally can utilize a variety of data types, such as imagery, maps, tables, etc.

geoid

A surface of constant gravitational potential around the Earth—an averaged surface perpendicular to the force of gravity.

geosphere

The physical elements of the Earth's surface, crust, and interior.

geostationary

Describes an orbit in which a satellite is always in the same position (appears stationary) with respect to the rotating Earth. The satellite travels around the Earth in the same direction, at an altitude of approximately 35,790 km (22,240 statute miles) because that produces an orbital period equal to the period of rotation of the Earth (actually 23 hours, 56 minutes, 04.09 seconds). A worldwide network of operational geostationary meteorological satellites provides visible and infrared images of Earth's surface and atmosphere. The satellite

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systems include the U.S. *GOES*, *METEOSAT* (launched by the European Space Agency and operated by the European Weather Satellite Organization–EUMETSAT), the Japanese *GMS*, and most commercial, telecommunications satellites. See *Clarke Belt*.

Geostationary Meteorological Satellite (GMS)

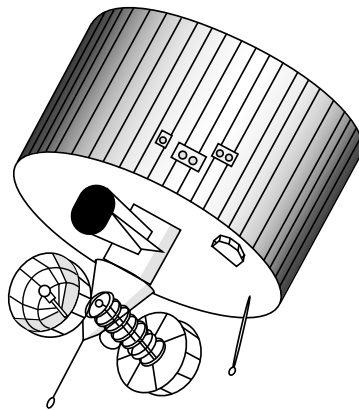
Japan's geostationary weather satellite.

Geostationary Operational Environmental Satellite (GOES)

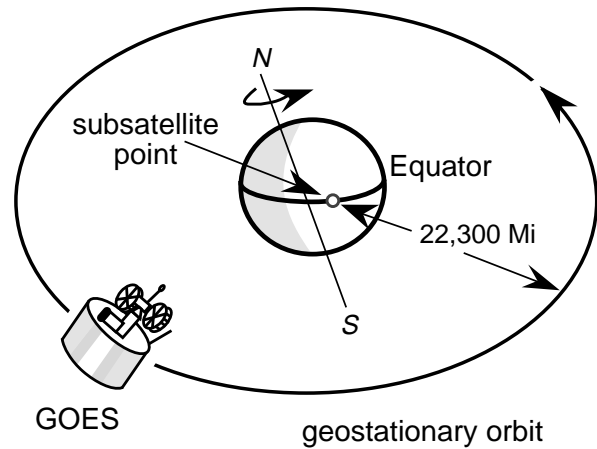
NASA-developed, NOAA-operated series of satellites that:

- provide continuous day and night weather observations;
- monitor severe weather events such as hurricanes, thunderstorms, and flash floods;
- relay environmental data from surface collection platforms to a processing center;
- perform facsimile transmissions of processed weather data to low-cost receiving stations;
- monitor the Earth's magnetic field, the energetic particle flux in the satellite's vicinity, and x-ray emissions from the sun;
- detect distress signals from downed aircraft and ships.

GOES observes the U.S. and adjacent ocean areas from vantage points 35,790 km (22,240 miles) above the equator at 75° west and 135° west. GOES satellites have an equatorial, Earth-synchronous orbit with a 24-hour period, a resolution of 8 km, an IR resolution of 4 km, and a scan rate of 1864 statute miles in about three minutes. See *geostationary*. The transmission of processed



weather data (both visible and infrared) by GOES is called weather facsimile (*WEFAX*). GOES WEFAX transmits at 1691+ MHz and is accessible via a ground station with a satellite dish antenna.



GOES carries the following five major sensor systems:

- 1) The imager is a multispectral instrument capable of sweeping simultaneously one visible and four infrared channels in a north-to-south swath across an east-to-west path, providing full disk imagery once every thirty minutes.
- 2) The sounder has more spectral bands than the imager for producing high-quality atmospheric profiles of temperature and moisture. It is capable of stepping one visible and eighteen infrared channels in a north-to-south swath across an east-to-west path.
- 3) The Space Environment Monitor (SEM) measures the condition of the Earth's magnetic field, the solar activity and radiation around the spacecraft, and transmits these data to a central processing facility.
- 4) The Data Collection System (DCS) receives transmitted meteorological data from remotely located platforms and relays the data to the end users.
- 5) The Search and Rescue Transponder can relay distress signals at all times, but cannot locate them. While only the polar-orbiting satellite can locate distress signals, the two types of satellites work together to create a comprehensive search and rescue system.

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geosynchronous (aka GEO)

Synchronous with respect to the rotation of the Earth. See *geostationary*.

glacier

A multi-year surplus accumulation of snowfall in excess of snowmelt on land and resulting in a mass of ice at least 0.1 km² in area that shows some evidence of movement in response to gravity. A glacier may terminate on land or in water. Glacier ice is the largest reservoir of fresh water on Earth, and second only to the oceans as the largest reservoir of total water. Glaciers are found on every continent except Australia.

Global Change Research Program (GCRP)

The USGCRP is a government-wide program whose goal is "to establish a scientific basis for national and international policy-making relating to natural and human-induced changes in the global Earth system." *Mission to Planet Earth* is NASA's central contribution to the U.S. Global Change Research Program.

The Global Change Research Program coordinates and guides the efforts of federal agencies. The program examines such questions as, is the Earth experiencing global warming? Is the depletion of the ozone layer expanding? How do we determine and understand the causes of global climate changes? Are they reversible? What are the implications for human needs and activities?

global measurement

All of the activities required to specify a global variable, such as *ozone*. These activities range from data acquisition to the generation of a data-analysis product, and include estimates of the uncertainties in that product. A global measurement often will consist of a combination of observations from a spacecraft instrument (required for global coverage) and measurements *in situ* (needed to provide reference points for long-term accuracy).

global variables

Functions of space and time that describe the large scale state and evolution of the Earth system. The Earth system's *geosphere*, *hydrosphere*, *atmosphere*, and *biosphere* and their components are, or potentially are, global variables.

GMS

See *Geostationary Meteorological Satellite*.

GOES

See *Geostationary Operational Environmental Satellite*.

GOES I/GOES 8

NOAA geostationary satellite launched in April 1994 (alphabetical designators are used while on the ground and before geostationary orbit, after it achieves geostationary orbit it became GOES 8). GOES 8 is the first in a series of five new geostationary satellites that will ensure dual-satellite coverage of the U.S. into the next century, and will provide better advanced warnings of thunderstorms, flash floods, hurricanes, and other severe weather. GOES 8 will also contribute important information to a new flood and water management system which will assist decision-makers with the allocation of precious western water resources.

GOES NEXT

The next generation of NOAA geostationary satellites, scheduled for launch beginning sometime after 2003. Currently in the planning phase, these satellites will follow the series of five geostationary satellites which are being launched beginning in 1994. See *GOES I*

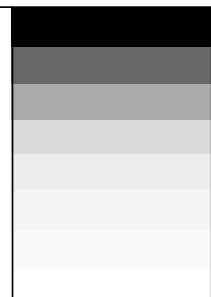
grayscale

Environmental satellite scanners, rather than photographing a scene, scan a scene line-by-line measuring light or heat levels and transmitting this information as a video image via an amplitude modulated (*AM*) subcarrier contained in the satellite's *FM* signal. The video image—a 2400 Hz tone—is amplitude modulated to correspond to the light and dark areas sensed, with the louder portion of the tone representing the lighter areas of the

0 represents pure black

all values in between
are shades of gray

255 represents pure white



CONCEPTS AND TERMS

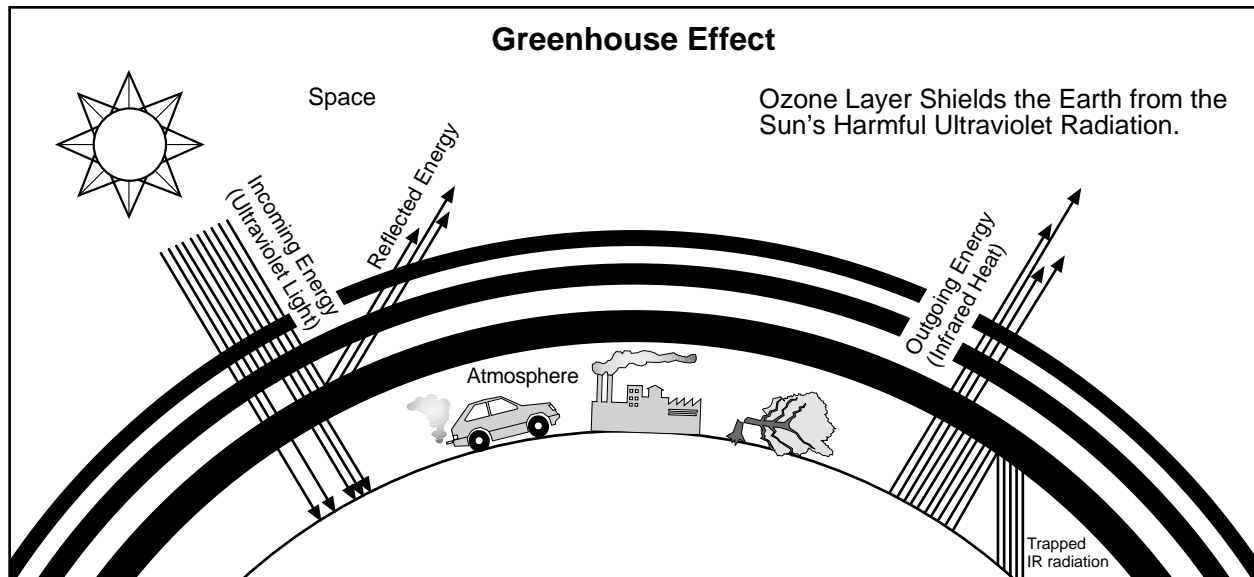


image and the lower portion of the tone representing the darker areas of the image. Intermediate volumes form the shades of the *grayscale* (up to 256 shades) needed to complete the image. This is an *analog* type of data transmission, and enables the assessment of such features as heat, light, temperature, and cloud heights.

greenhouse effect

Process by which significant changes in the chemistry of Earth's atmosphere may enhance the natural process that warms our planet and elevates temperatures. If the effect is intensified and Earth's average temperatures change, a number of plant and animal species could be threatened with extinction.

Certain gaseous components of the atmosphere, called *greenhouse gases*, transmit the visible portion of solar radiation but absorb specific *spectral bands* of thermal radiation emitted by the Earth. The theory is that terrain absorbs radiation, heats up, and emits longer wavelength thermal radiation that is prevented from escaping into space by the blanket of carbon dioxide and other greenhouse gases in the atmosphere. As a result, the climate warms.

Because atmospheric and oceanic circulations play a central role in the climate of the Earth, improving our knowledge about their interaction becomes essential.

greenhouse gas

A gaseous component of the *atmosphere* contributing to the *greenhouse effect*. Greenhouse gases are transparent to certain wavelengths of the sun's radiant energy, allowing them to penetrate deep into the atmosphere or all the way into the Earth's surface. Greenhouse gases and clouds prevent some of infrared radiation from escaping, trapping the heat near the Earth's surface where it warms the lower atmosphere. Alteration of this natural barrier of atmospheric gases can raise or lower the mean global temperature of the Earth.

Greenhouse gases include *carbon dioxide*, methane, nitrous oxide, *chlorofluorocarbons*, and water vapor. Carbon dioxide, methane, and nitrous oxide have significant natural and human sources while only industries produce

Key Greenhouse Gases

water vapor
ozone
carbon dioxide
methane
nitrous oxide
chlorofluorocarbons (CFCs)

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chlorofluorocarbons. Water vapor has the largest greenhouse effect, but its concentration in the *troposphere* is determined within the climate system. Water vapor will increase in response to global warming, which in turn may further enhance global warming.

Greenwich Mean Time (GMT)

See *Coordinated Universal Time*.

gross feature map

Map that displays geographic characteristics rather than political boundaries.

ground control (points)

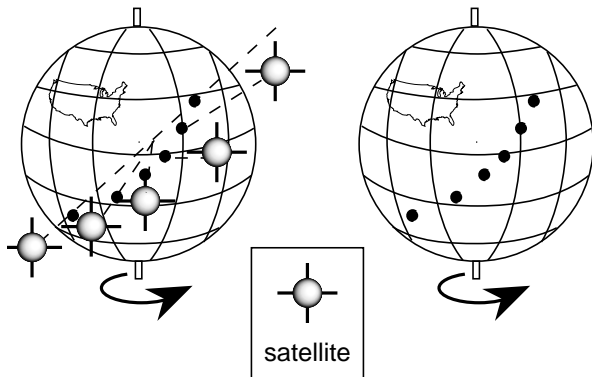
Identifiable points on the ground whose locations on the surface of the Earth are accurately known for use as geodetic references in mapping, charting, and other related mensuration applications.

ground station

See *Earth station*.

ground track

The inclination of a satellite, together with its orbital altitude and the period of its orbit, creates a track defined by an imaginary line connecting the satellite and the Earth's center. The intersection on the line with the Earth's surface is the subsatellite point. As the Earth turns on its axis and the satellite orbits overhead, a line is created by the satellite's apparent path over the ground (the series of subsatellite points connected). A geostationary satellite has an inclination of essentially zero, and, because its orbital period exactly matches the Earth's rotation, its ground track is reduced to an apparent stationary point on the equator.



GSFC

NASA Goddard Space Flight Center, located in Greenbelt, Maryland. See *NASA Centers*.

guided wave

Electromagnetic or acoustic wave that is constrained within certain boundaries, as in a wave guide (transmission line).

gulf

A large arm of an ocean or sea extending into a land mass.

gulf stream

A warm, swift ocean current that flows along the coast of the Eastern United States and makes Ireland, Great Britain, and the Scandinavian countries warmer than they would be otherwise.



habitat

The area or region where a particular type of plant or animal lives and grows.

hail

Precipitation composed of balls or irregular lumps of ice. Hail is produced when large frozen raindrops, or almost any particles, in cumulonimbus clouds act as embryos that grow by accumulating supercooled liquid droplets. Violent updrafts in the cloud carry the particles in freezing air, allowing the frozen core to accumulate more ice. When the piece of hail becomes too heavy to be carried by upsurging air currents it falls to the ground.

hardware

The electrical and mechanical components of a system, as opposed to *software*.

haze

Fine dry or wet particles of dust, salt, or other impurities that can concentrate in a layer next to the Earth when air is stable.

heat balance

The equilibrium existing between the radiation received and emitted by a planetary system.

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Heat Capacity Mapping Mission (HCMM)

A two-channel *radiometer* launched by NASA to measure the thermal properties of the terrestrial surface. It had an application to identify and locate rocks and minerals. One radiometer channel was in the visible to near infrared (0.5–1.1 *micrometers*), and the other in the thermal infrared (10.5–12.5 *micrometers*). The *instantaneous field of view (IFOV)* was about 600 meters.

hemisphere

Half of the Earth, usually conceived as resulting from the division of the globe into two equal parts, north and south or east and west.

hertz (Hz)

The international unit of frequency equal to one cycle per second. Radio frequencies are usually expressed in kilohertz/kHz (1,000 cycles per second) or megahertz/MHz (1,000,000 cycles per second).

Hertzian waves

Radio waves or other electromagnetic radiation resulting from the oscillations of electricity in a conductor.

high

A digital logic state corresponding to a *binary* "1." See *low*.

High Resolution Doppler Imager (HRDI)

Carried on *UARS*, it measures stratospheric winds.

High-Resolution Infrared Radiation Sounder (HIRS)

Instrument carried by *NOAA* polar-orbiting satellites that detects and measures energy emitted by the atmosphere to construct a vertical temperature profile from the Earth's surface to an altitude of about 40 km.

Measurements are made in 20 spectral regions in the infrared band.

High-Resolution Picture Transmission (HRPT)

Real-time, 1.1-kilometer *resolution*, digital images provided by *NOAA's* polar-orbiting environmental satellites, containing all five spectral channels and *telemetry* data transmitted as high-speed digital transmissions. The

Advanced Very High Resolution Radiometer (AVHRR) provides the primary imaging system for *APT* and *HRPT*. See *TIROS*.

horse latitudes

The subtropical latitudes (30–35 degrees), where winds are light and weather is hot and dry. According to legend, ships traveling to the New World often stagnated in this region and had to throw dead horses overboard or eat them to survive, hence the name horse latitudes. See *wind*.

HRDI

See *High Resolution Doppler Imager*.

HRPT

See *High Resolution Picture Transmission*.

humidity

The amount of water vapor in the air. The higher the temperature, the greater the number of water molecules the air can hold. For example: at 60 °F (15 °C), a cube of air one yard on each side can hold up to 4.48 ounces of water. At 104 °F (40 °C), the same cube of air can hold up to 17.9 ounces of water.

Relative humidity describes the amount of water in the air compared with how much the air can hold at the current temperature. Example: 50% relative humidity means the air holds half the water vapor that it is capable of holding; 100% relative humidity means the air holds all the water vapor it can. At 100% humidity, no more evaporation can occur until the temperature rises, or until the water vapor leaves the air through *condensation*. Absolute humidity is the ratio of the mass of water vapor present in a system of moist air to the volume occupied by the mixture, that is, the density of water vapor.

hurricanes

Severe tropical storms whose winds exceed 74 mph. Hurricanes originate over the tropical and subtropical North Atlantic and North Pacific oceans, where there is high humidity and light wind. These conditions prevail mostly in the summer and early fall. Since hurricanes can take days or even weeks to form, time is usually available for preventive or protective measures.

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From space, hurricanes look like giant pinwheels, their winds circulating around an eye that is between 5 and 25 miles in diameter. The eye remains calm with light winds and often a clear sky.

Hurricanes may move as fast as 50 mph, and can become incredibly destructive when they hit land. Although hurricanes lose power rapidly as soon as they leave the ocean, they can cause high waves and tides up to 25 feet above normal. Waves and heavy flooding cause the most deaths during a hurricane. The strongest hurricanes can cause tornadoes.

hydrochlorofluorocarbon (HCFC)

One of a class of compounds used primarily as a CFC substitute. Work on CFC alternatives began in the late 1970s after the first warnings of CFC damage to stratospheric *ozone*. By adding hydrogen to the chemical formulation, chemists made CFCs less stable in the lower atmosphere enabling them to break down before reaching the ozone layer. However, HCFCs do release chlorine and have contributed more to atmospheric chlorine buildup than originally predicted. Development of non-chlorine based chemical compounds as a substitute for CFCs and HCFCs continues.

hydrologic cycle

The pathways through which water is cycled in the terrestrial biosphere.

hydrosphere

The totality of water encompassing the Earth, comprising all the bodies of water, ice, and water vapor in the atmosphere.

hygrometer

Instrument that measures water vapor content in the air and communicates changes in humidity visibly and immediately through a graph or a dial. There are three types of hygrometers:

- The hair hygrometer uses a human hair as the sensing instrument. The hair lengthens when the air is moist and contracts when the air is dry, but remains unaffected by air temperature. However, the hair hygrometer cannot respond to rapid fluctuations in humidity.

- An electric hygrometer uses a plate coated with carbon. Electrical resistance of the carbon coating changes as the moisture content of the air changes—changes that translate into relative humidity. This type of hygrometer is used frequently in the *radiosonde*.
- An infrared hygrometer uses a beam of light containing two separate wave lengths to gauge atmospheric humidity. One of the wavelengths is absorbed by water vapor, the other is unaffected, providing an extremely accurate index of water vapor for paths of a few inches or thousands of feet. See *psychrometer*.

Hz

See *Hertz*.



ice shelf

A thick mass of ice extending from a polar shore. The seaward edge is afloat and sometimes extends hundreds of miles into the sea.

IFOV

Instantaneous Field of View. See *Multispectral Scanner* for sample usage.

IGY

See *International Geophysical Year*.

image

Pictorial representation of data acquired by satellite systems, such as direct readout images from environmental satellites. An image is not a photograph. An image is composed of two-dimensional grids of individual picture elements (*pixels*). Each pixel has a numeric value that corresponds to the radiance or temperature of the specific ground area it depicts. See *grayscale*.

image resolution

The area represented by each *pixel* of a satellite image. The smaller the area represented by a pixel, the more accurate and detailed the image. For example, if a U.S. map and a world map are printed on identically sized

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sheets of paper, one square inch on the U.S. map will represent far less area and provide for more detail than one square inch on the world map. In this example the U.S. map has higher resolution. *APT* has a resolution of 4 km, *HRPT* has a resolution of 1.1 km and *WEFAX* resolution is 8 km.

imager

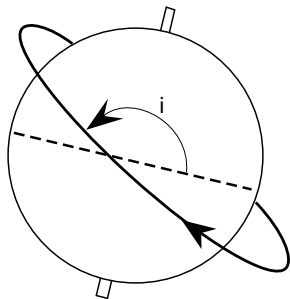
A satellite instrument that measures and maps the Earth and its atmosphere. Imager data are converted by computer into pictures.

inclination (aka i)

One of the six *Keplerian elements*, it indicates the angle of the orbit plane to the central body's equator. See *Keplerian elements* for diagram.

The elliptical path of a satellite orbit lies in a plane known as the orbital plane. The orbital plane always goes through the center of the Earth but may be tilted at any angle relative to the equator. Inclination is the angle between the equatorial plane and the orbital plane measured counter-clockwise at the ascending node.

A satellite in an orbit that exactly matches the equator has an inclination of 0° , whereas one whose orbit crosses the Earth's poles has an inclination of 90° . Because the angle is measured in a counterclockwise direction, it is quite possible for a satellite to have an inclination of more than 90° . An inclination of 180° would mean the satellite is orbiting the equator, but in the opposite direction of the Earth's rotation. Some *sun-synchronous* satellites that maintain the same *ground track* throughout the year have inclinations of as much as 98° . U.S. scientific satellites that study the sun are placed in orbits closer to the equator, frequently at 28° inclination. Most weather satellites are placed in high-inclination orbits so they can oversee weather conditions worldwide. See *orbital inclination*.



angle of inclination
(measured counterclockwise
at the ascending node)

information system

All of the means and mechanisms for data receipt, processing, storage, retrieval, and analysis. Information systems can be designed for storage and dissemination of a variety of data products—including primary data sets and both intermediate and final analyses—and for an interface providing connections to external computers, external data banks, and system users. To be effective, the design and operation of an information system must be carried out in close association with the primary producers of the data sets, as well as other groups producing integrated analyses or intermediate products.

infrared radiation (IR)

Infrared is *electromagnetic radiation* whose wavelength spans the region from about 0.7 to 1000 *micrometers* (longer than visible radiation, shorter than microwave radiation). *Remote-sensing* instruments work by sensing radiation that is naturally emitted or reflected by the Earth's surface or from the atmosphere, or by sensing signals transmitted from a satellite and reflected back to it. In the visible and near-infrared regions, surface chemical composition, vegetation cover, and biological properties of surface matter can be measured. In the mid-infrared region, geological formations can be detected due to the absorption properties related to the structure of silicates. In the far infrared, emissions from the Earth's atmosphere and surface offer information about atmospheric and surface temperatures and water vapor and other trace constituents in the atmosphere. Since IR data are based on temperatures rather than visible radiation, the data may be obtained day or night.

INSAT

Indian National Satellite.

in situ

Latin for "in original place." Refers to measurements made at the actual location of the object or material measured. Compare with *remote sensing*.

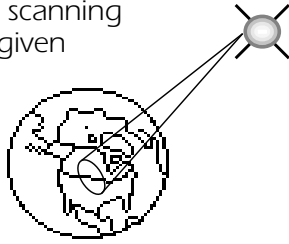
insolation

Solar radiation incident upon a unit horizontal surface on or above the Earth's surface.

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instantaneous field of view (IFOV)

The field of view of a scanning detector system at a given instant. The range of angles scanned by the system is then called the field of view, or *swath width*.



Instantaneous field of view

integrated circuit (IC)

A solid state electronic circuit that consists of several micro-components constructed to perform a special function.

international date line

An imaginary line of longitude 180° east or west of the *prime meridian*.

international designator

An internationally agreed-upon naming convention for satellites. The designator contains the last two digits of the launch year, the launch number of the year, and the part of the launch, i.e., "A" indicates payload, "B" the rocket booster, or second payload, etc.

International Geophysical Year (IGY)

(1957–58) The IGY was organized by the scientific community through the International Council of Scientific Unions (ICSU). It was highlighted by international cooperation in the exploration of world-wide geophysical phenomena and by the inauguration of the space age through the launching of the first satellites (USSR's Sputnik I and US Explorer 1) to study the upper atmosphere and Earth's nearby environment.

International Space Year (ISY)

(1992) Designated the first international celebration of humanity's future in the space age. Themes included the global perspective of the space age, discovery, exploration, and scientific inquiry. An important ISY scientific focus was *Mission to Planet Earth*. A wide range of educational programs and public events emphasized ISY's global perspective. 1992 also commemorated the 500th anniversary of Columbus' voyage to the New World and the 35th anniversary of the *International Geophysical Year*.

International System of Units (SI)

The International System of Units prescribes the symbols and prefixes shown in the table to form decimal multiples and submultiples of SI units.

SI prefixes		
Factor	Prefix	Symbol
10^1	deka	da
10^2	hecto	h
10^3	kilo	k
10^6	mega	M
10^9	giga	G
10^{12}	tera	T
10^{15}	peta	P
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

The following examples illustrate the use of these prefixes.

$$0.000,001 \text{ meters} = 10^{-6} \text{ meters} = 1 \text{ micrometer} = 1 \mu\text{m}$$

$$1000 \text{ meters} = 10^3 \text{ meters} = 1 \text{ kilometer} = 1 \text{ km}$$

$$1,000,000 \text{ cycles per second} = 10^6 \text{ hertz} = 1 \text{ megahertz} = 1 \text{ MHz}$$

CONCEPTS AND TERMS

ion

Atom or molecule that has acquired an electric charge by the loss/gain of one or more electrons.

IPS

Inches per second.

IR

See *infrared*.

isobars

Lines drawn on a weather map joining places of equal barometric pressure.

isothermal

Of or indicating equality of temperature.

isotherms

Lines connecting points of equal temperature on a weather map.

isthmus

Narrow strip of land located between two bodies of water, connecting two larger land areas.

ITOS (Improved TIROS Operational Satellite)

Second generation, polar-orbiting, environmental satellites utilized to augment NOAA's world-wide weather observation capabilities. ITOS were launched from 1970–1976, but eventually replaced by the third generation of polar-orbiting, environmental satellites TIROS-N (first launched in 1978). See *TIROS*.

J

Japanese National Space Development Agency (NASDA)

The agency reports to the Japanese Ministry of Science and Technology.

JPL (Jet Propulsion Laboratory)

See *NASA Centers*.

jet stream

Rivers of high-speed air in the atmosphere. Jet streams form along the boundaries of global air masses where there is a significant difference in atmospheric temperature. The jet streams may be several hundred miles across and 1–2 miles deep at an altitude of 8–12

miles. They generally move west to east, and are strongest in the winter with core wind speeds as high as 250 mph. Changes in the jet stream indicate changes in the motion of the atmosphere and weather.

Joint Education Initiative (JEI)

The JEI project was developed by *USGS*, *NOAA*, *NASA*, industry, and teachers to enable teachers and students to explore the massive quantities of Earth science data published by the U.S. Government on CD-ROM. JEI encourages a research and analysis approach to science education.

JSC (Johnson Space Center)

See *NASA Centers*.

K

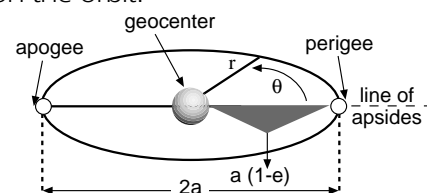
KSC (Kennedy Space Center)

See *NASA Centers*.

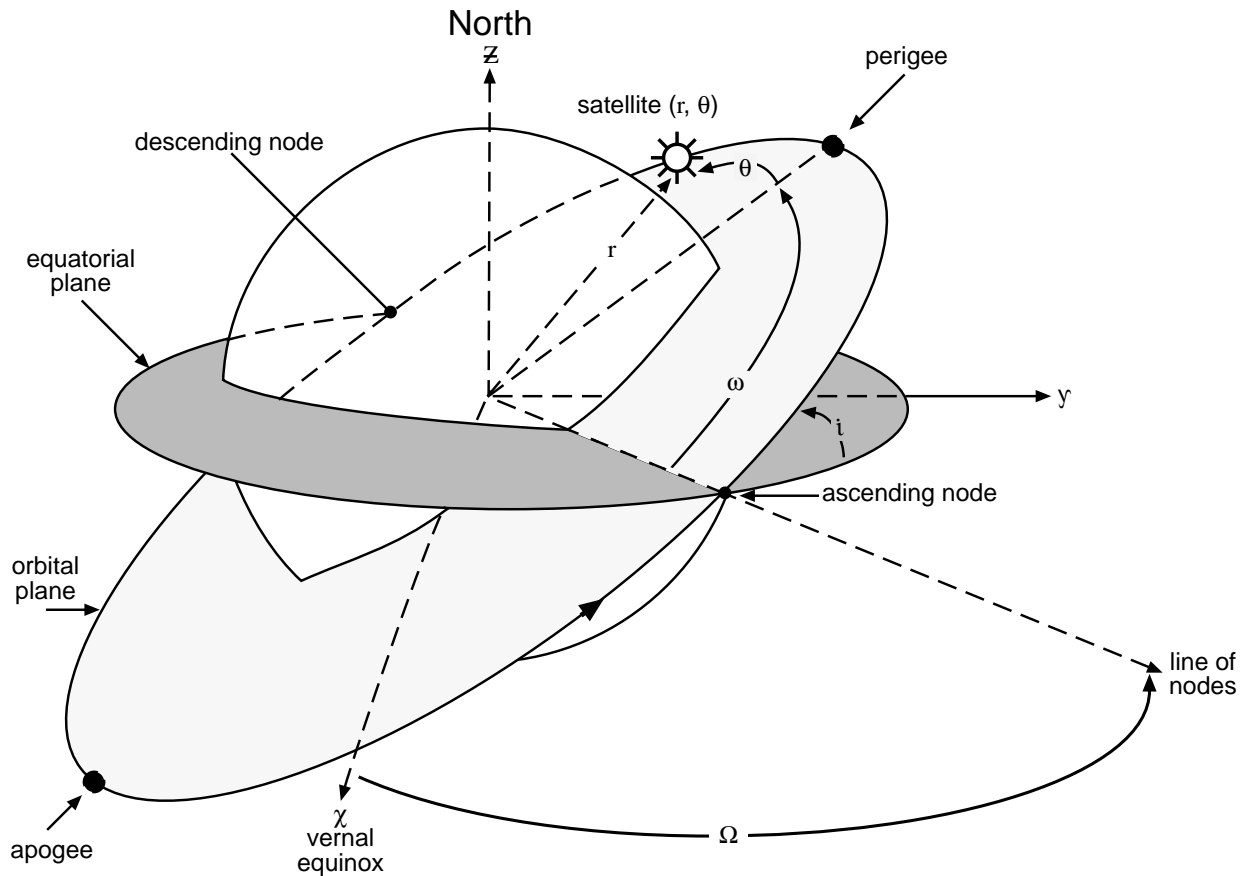
Keplerian elements (aka satellite orbital elements)

The set of six independent constants which define an orbit—named for Johannes Kepler [1571–1630]. The constants define the shape of an ellipse or hyperbola, orient it around its central body, and define the position of a satellite on the orbit. The classical orbital elements are:

- a: semi-major axis, gives the size of the orbit,
- e: eccentricity, gives the shape of the orbit,
- i: inclination angle, gives the angle of the orbit plane to the central body's equator
- Ω right ascension of the ascending node, which gives the rotation of the orbit plane from reference axis,
- ω argument of perigee is the angle from the ascending nodes to perigee point, measured along the orbit in the direction of the satellite's motion,
- θ true anomaly gives the location of the satellite on the orbit.



CONCEPTS AND TERMS



Kepler's three laws of motion

Any spacecraft launched into orbit obeys the same laws that govern the motions of the planets around our sun, and the moon around the Earth. Johannes Kepler formulated three laws that describe these motions:

1) Each planet revolves around the sun in an orbit that is an ellipse with the sun as its focus or primary body. Kepler postulated the lack of circular orbits—only elliptical ones—determined by gravitational perturbations and other factors. Gravitational pulls, according to Newton, extend to infinity, although their forces weaken with distance and eventually become impossible to detect. (See *Newton's law of universal gravitation*.) Spacecraft orbiting the Earth are primarily influenced by the Earth's gravity and anomalies in its composition, but they also are influenced by the moon and sun and possibly other planets.

orbital elements		
Element	Conventional Symbol	Symbol used in GSFC Computer Printouts
epoch	epoch	Epoch Time, TO
orbital inclination	i	Inclination, IO
right ascension of ascending node	Ω	R.A.A.N., O0
argument of perigee	ω	(ARGP) Arg Perigee, WO
eccentricity	e	(ecce) Eccentricity, EO or e
mean motion	n	Mean Motion, NO
mean anomaly	M	(MA, phase) Mean Anomaly, MO

CONCEPTS AND TERMS

2) The radius vector—such as the line from the center of the sun to the center of a planet, from the center of Earth to the center of the moon, or from the center of Earth to the center of gravity of a satellite—sweeps out equal areas in equal periods of time.

3) The square of a planet's orbital period is equal to the cube of its mean distance from the sun times a constant. As extended and generalized, this means that a satellite's orbital period increases with its mean distance from the planet. See *Newton's law of universal gravitation and laws of motion*.

kilohertz (kHz)

One thousand hertz, i.e., one thousand cycles per second.

kilometer (km)

Metric unit of distance equal to 3,280.8 feet or .621 statute miles.

knot

Unit of speed of one nautical mile (6,076.1 feet) an hour.



lake

A body of fresh or salt water entirely surrounded by land.

land breeze

A nocturnal coastal breeze that blows from land to sea. In the evening the water may be warmer than the land, causing pressure differences. The land breeze is the flow of air from land to sea equalizing these pressure differences. See *sea breeze*.

Landsat

Land Remote-Sensing Satellite, operated by the U.S. Earth Observation Satellite Company (EOSAT). Commercialized under the Land Remote-Sensing Commercialization Act of 1984, Landsat is a series of satellites (formerly called ERTS) designed to gather data on the Earth's resources in a regular and systematic

manner. Objectives of the mission are: land use inventory, geological/mineralogical exploration, crop and forestry assessment, and cartography. Landsat has a spatial resolution of 28.5 meters.

Restructured Federal agency responsibilities for the Landsat program are effective for the acquisition and operation of Landsat 7. New operating policy specifies that NOAA will be responsible for satellites after they are placed in orbit, NASA will be responsible for the development and launch of Landsat 7, and that the U.S. government will provide unenhanced data to users at no cost beyond the cost of fulfilling their data request.

landsats (aka Earth resources satellites)

Any land remote-sensing satellites. Includes the U.S. Landsat system and the French *SPOT*.

LaRC (Langley Research Center)

See *NASA Centers*.

laser (light amplification by stimulated emission of radiation)

Active instrument that produces discretely coherent pulses of light (light waves with no phase differences, or with predictable phase differences, are said to be coherent).

laser ranging

The use of lasers to measure distances.

latitude (aka the geodetic latitude)

The angle between a perpendicular at a location, and the equatorial plane of the Earth.

legend

A listing that contains symbols and other information about a map.

LeRC (Lewis Research Center)

See *NASA Centers*.

light

1) Form of radiant energy that acts upon the retina of the eye, optic nerve, etc., making sight possible. This energy is transmitted at a velocity of about 186,000 miles per second by wavelike or vibrational motion.

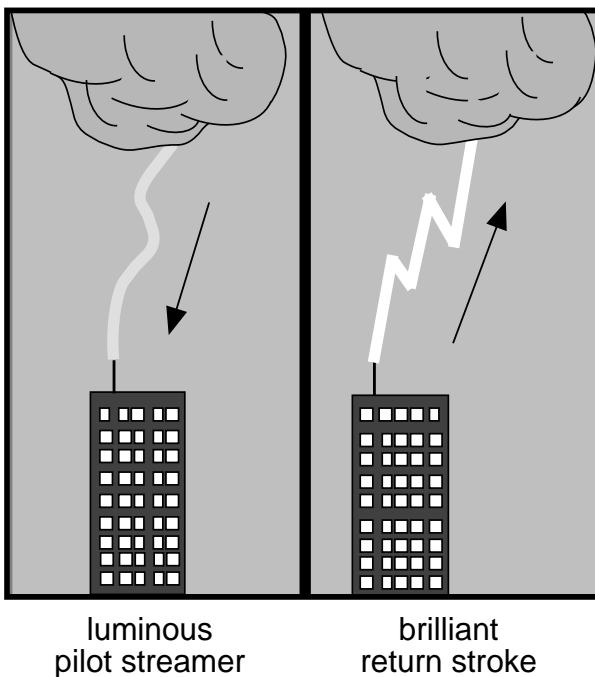
CONCEPTS AND TERMS

2) A form of radiant energy similar to this, but not acting on the normal retina, such as ultraviolet and infrared radiation.

Interplay between light rays and the atmosphere cause us to see the sky as blue, and can result in such phenomena as glows, halos, arcs, flashes, and streamers.

lightning

A discharge of atmospheric electricity accompanied by a vivid flash of light. During thunderstorms, static electricity builds up within the clouds. A positive charge builds in the upper part of the cloud, while a large negative charge builds in the lower portion. When the difference between the positive and negative charges becomes great, the electrical charge jumps from one area to another, creating a lightning bolt. Most lightning bolts strike from one cloud to another, but they also can strike the ground. These bolts occur when positive charges build up on the ground. A negative charge called the "faintly luminous streamer" or "leader" flows from the cloud toward the ground. Then a positively charged leader, called the return stroke, leaves the ground and runs into the cloud. What is seen as a lightning



bolt is actually a series of downward-striking leaders and upward-striking return strokes, all taking place in less than a second.

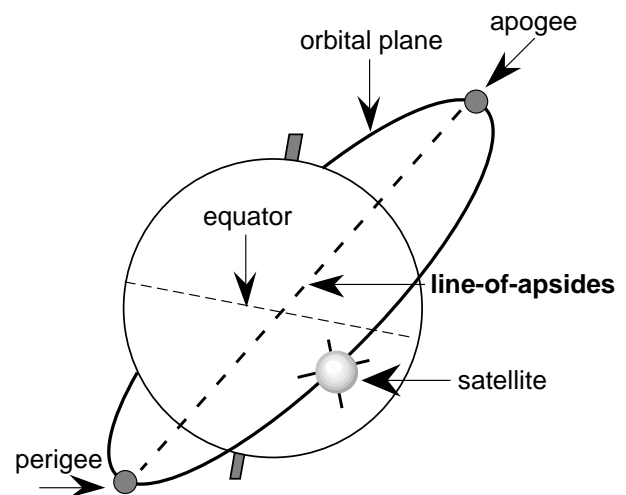
Lightning bolts can heat the air to temperatures hotter than the surface of the sun. This burst of heat makes the air around the bolt expand explosively, producing the sound we hear as thunder. Since light travels a million times faster than sound, we see lightning bolts before we hear their thunderclaps. By counting the seconds between a flash of lightning and the thunderclap and dividing by five, we can determine the approximate number of miles to the lightning stroke. See *thunderstorm*.

limb viewing (occultation)

The process of viewing the atmosphere at a tangent to the Earth's surface. The viewing signal, from a star or another satellite, is occulted or obscured by the intervening atmosphere. The absorption of light from the sun or star provides information on the properties of the atmosphere at different heights. Limb viewing instruments can also sense infrared or microwave-emitted radiation from the atmosphere.

line-of-apsides (aka major-axis of the ellipse)

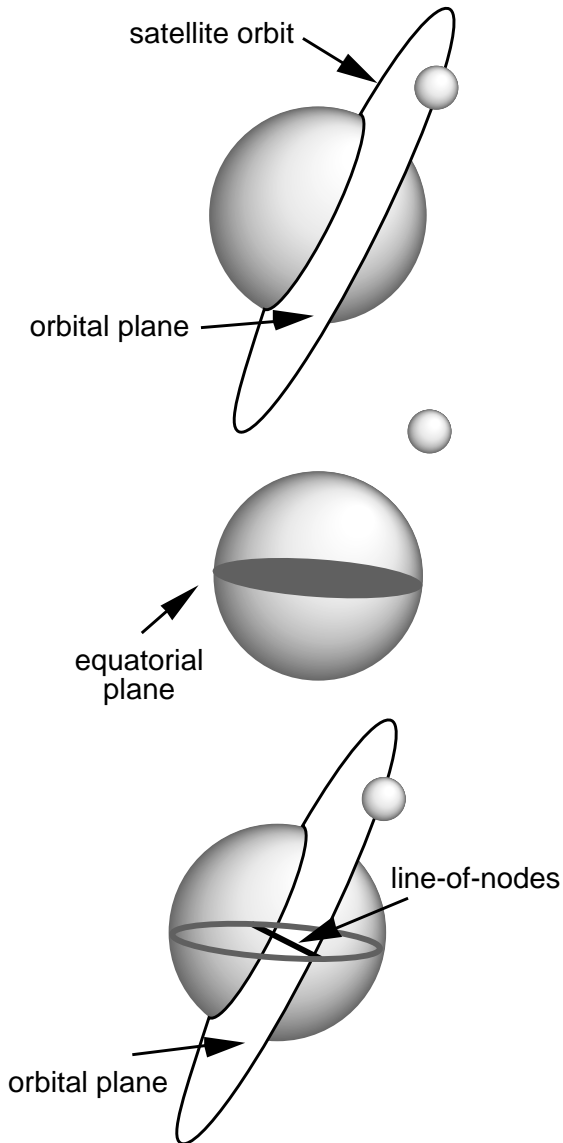
The straight line drawn from the *perigee* (point of orbit closest to Earth) to the *apogee* (point of orbit farthest from Earth) is the line-of-apsides.



CONCEPTS AND TERMS

line-of-nodes

The line created by the intersection of the equatorial plane and the *orbital plane*.



line-of-sight

Area within which visible contact can be made. For example, NOAA polar-orbiting satellites continuously transmit the *APT* signal. Radio reception of the *APT* signal is possible only when the satellite is above the horizon of a particular location (not obstructed by the Earth's surface), with a line-of-sight contact with the satellite.

logarithm

Exponent of the power to which it is necessary to raise a fixed number (the base) to produce the given number. For example, the logarithm of 100 (base 10) is 2 because $10^2 = 100$.

longitude

The angular distance from the Greenwich meridian (0°), along the equator. This can be measured either east or west to the 180th meridian (180°) or 0° to 360° W.

loss of signal (LOS)

The inability to receive a satellite signal because the satellite's orbital path has taken it below the antenna's horizon. This term is relevant to all satellites except *geostationary*.

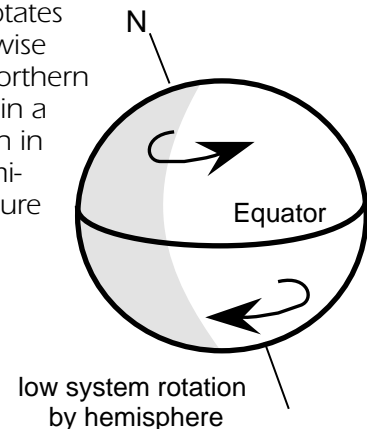
low

A logic state corresponding to a *binary* "0". Satellite imagery is displayed on a computer monitor by a combination of highs and lows. See *high*.

low or low-pressure system

A horizontal area where the *atmospheric pressure* is less than it is in adjacent areas. Since air always moves from areas of high pressure to areas of low pressure, air from these adjacent areas of higher pressure will move toward the low pressure area to equalize the pressure. This inflow of air toward the low will be affected by the Earth's rotation (see *Coriolis force*) and will cause the air to spiral inward in a counterclockwise direction in the northern hemisphere. The air eventually rises near the center of the low, causing cloudiness and precipitation.

The air in a low rotates in a counterclockwise direction in the Northern Hemisphere, and in a clockwise direction in the Southern Hemisphere. Low-pressure cells are called *cyclones*.



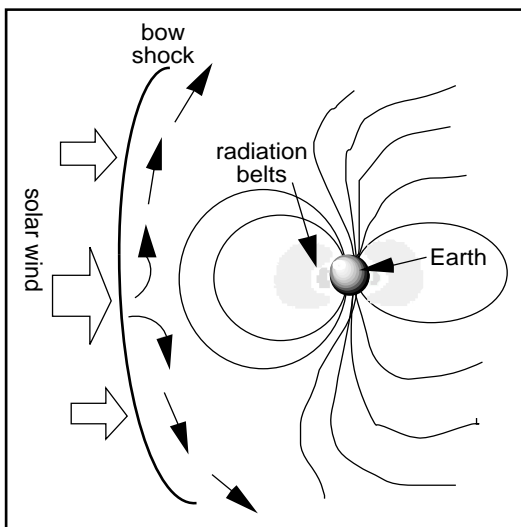
CONCEPTS AND TERMS

M

magnetosphere

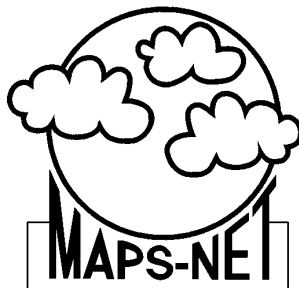
Region surrounding a celestial body where its magnetic field controls the motions of charged particles. The Earth's magnetic field is dipolar in nature. That is, it behaves as if produced by a giant bar magnet located near the center of the planet with its north pole tilted several degrees from Earth's geographic north pole.

The Earth's magnetic field presents an obstacle to the solar wind, as a rock in a running stream of water. This obstacle is called a bow shock. The bow shock slows down, heats, and compresses the *solar wind*, which then flows around the rest of Earth's magnetic field. See *Van Allen belts*.



MAPS-NET

MAryland **P**ilot Earth **S**cience and Technology **E**ducation **N**ETwork. NASA-sponsored education project designed to complement NASA's *Mission to Planet Earth*. MAPS-NET has been developed to enrich math and science curricula and enhance teacher preparation in Earth system science.



Middle and high school teachers learn about Earth sciences and satellite direct readout at graduate-level summer workshops; academia, federal agencies, and the private sector form the support network.

MSFC (Marshall Space Flight Center)

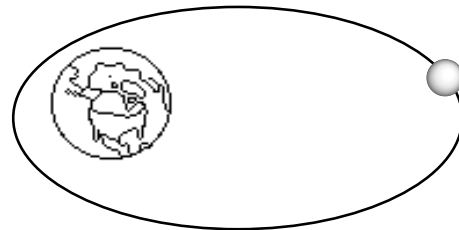
See *NASA Centers*.

mean anomaly (aka M0 or MA or phase)

Specifies the mean location (true anomaly specifies the exact location) of a satellite on an orbit ellipse at a particular time, assuming a constant mean motion throughout the orbit. Epoch specifies the particular time at which the satellite's position is defined, while mean anomaly specifies the location of the satellite at epoch. Mean anomaly is measured from 0° to 360° during one revolution. It is defined as 0° at *perigee*, and hence is 180° at *apogee*. See *Keplerian elements*.

mean motion (aka N0)

Averaged speed of a satellite in a non-circular orbit (i.e., eccentricity > 0). Diagram, page 19.



mean motion, averaged speed in elliptical orbit

Satellites in circular orbits travel at a constant speed. Satellites in non-circular orbits move faster when closer to the Earth, and slower when farther away. Common practice is to compute the mean motion (average the speed), which is measured in revolutions per day.

measurement system integrity

The tracking and documentation over the long term of all causes of error or uncertainty in a final data-analysis product. These include instrument calibration, adequacy of measurement validation, data coverage and sampling density, availability and quality of ancillary data, procedures for data analysis and reduction, the results of checks against independent measurement, and quantitative error analysis.

CONCEPTS AND TERMS

measurement validation

The establishment of confidence in the numerical relationship between the calibrated sensor output and the actual variable being measured.

Mercator projection

A method of making maps in which the Earth's surface is shown as a rectangle with the meridians as parallel straight lines spaced at equal intervals and the parallels of latitude as parallel straight lines intersecting the meridians at right angles. Areas away from the equator appear larger than they are, with the greatest distortion near the poles.

mesopause

The upper boundary of the mesosphere where the temperature of the atmosphere reaches its lowest point.

mesosphere

The atmospheric layer above the stratosphere, extending from about 50 to 85 kilometers altitude. The temperature generally decreases with altitude.

metadata

Information describing the content or utility of a data set. For example, the dates on which data were procured are metadata.

Meteor

The former Soviet Union's series of polar-orbiting weather satellites. The Meteor satellites transmit images in a system compatible with the NOAA polar-orbiting satellites.

meteorology

Study of the *atmosphere* and its phenomena.

METEOSAT

METEOrological SATellite. Europe's geostationary weather satellite, launched by the European Space Agency and now operated by an organization called Eumetsat. METEOSAT transmits at 1691 and 1694.5 MHz.

Metsat

Generic term for meteorological (weather) satellites.

MHz (megahertz)

10^6 hertz.

micrometer (μm , aka micron)

One millionth of a meter, used to measure wavelengths in the electromagnetic spectrum.

microprocessor

Controlling unit of a microcomputer, laid out on a tiny silicon chip and containing the logical elements for handling data, performing calculations, carrying out stored instructions, etc.

microwave

Electromagnetic radiation with wavelengths between about 1000 micrometers and one meter.

middle infrared

Electromagnetic radiation between the near infrared and the thermal infrared, about 2–5 micrometers.

millibar (mb)

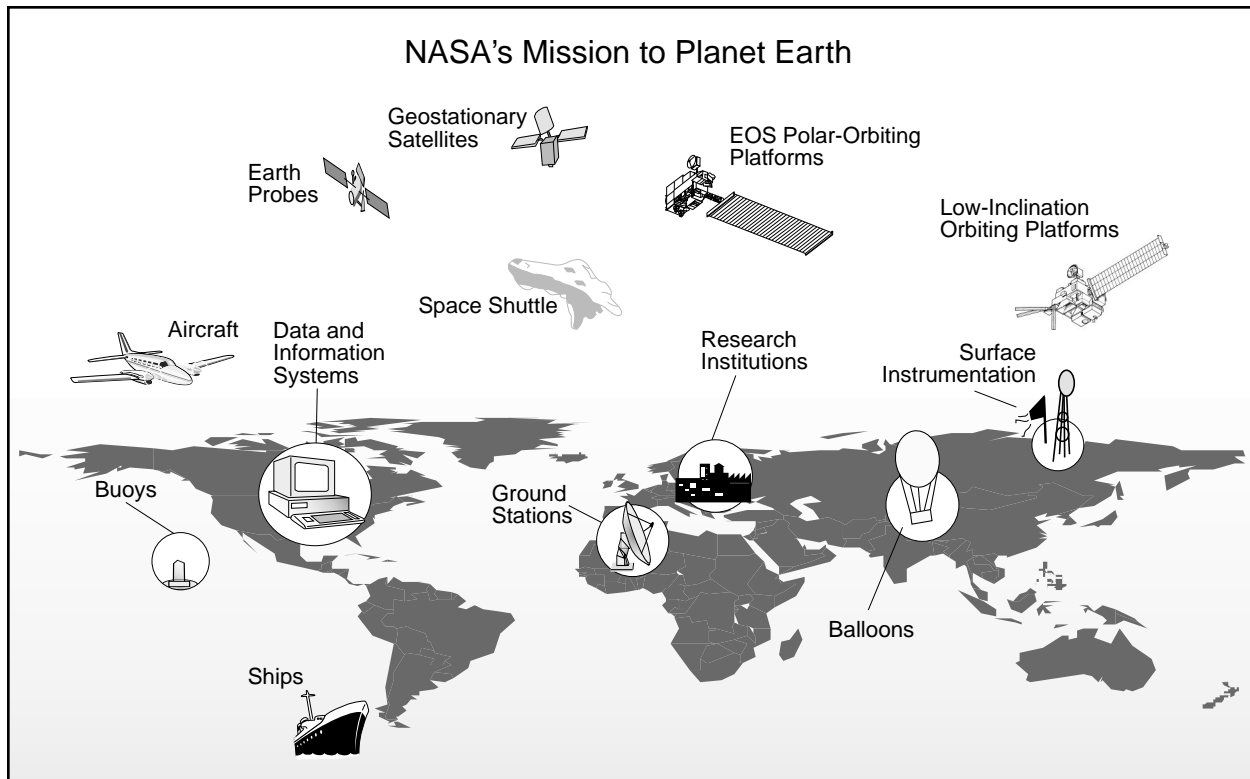
One thousandth of a bar, a unit of *atmospheric pressure*. The average atmospheric pressure at sea level is 1.01325 bars or 1013.25 mb. See *pascal (Pa)*, *atmospheric pressure*.

Mission to Planet Earth (MTPE)

International research program to understand our planet's environment as a system. A major challenge of MTPE is to observe, understand, model, assess, and eventually predict global change. Meeting this challenge will help to evaluate the impact that human activity (e.g., clearing forests and burning fossil fuels) has on our environment, and to distinguish human-induced changes from the effects of natural events (e.g. volcanic eruptions, erosion).

NASA's MTPE uses space-, aircraft-, and ground-based measurements to provide the scientific basis for understanding global change. The program will produce long-term global maps of clouds, land and ocean vegetation, atmospheric ozone, sea-surface temperature, and other global processes necessary to understand the state of the Earth and to detect any patterns of change. This information will be available to scientists and policy makers through the *Earth Observing System Data and Information System (EOSDIS)*.

CONCEPTS AND TERMS



The centerpiece of NASA's MTPE will be the *Earth Observing System (EOS)*, a series of satellites planned for launch beginning in 1998. Measurements from EOS will be complemented by the *Earth Probes*, a series of discipline-specific satellites and instruments designed to observe Earth processes where smaller platforms and/or different orbits from EOS are required. Planned Earth Probes will measure tropical rainfall, ocean productivity, ozone, and ocean surface winds. In addition, MTPE includes current NASA Earth science missions collecting important data on the global environment, such as the *Upper Atmosphere Research Satellite (UARS)* and the *Ocean Topography Experiment (TOPEX/POSEIDON)*, Space Shuttle experiments such as *ATLAS*, and aircraft campaigns.

model (noun)

A mathematical representation of a process, system, or object developed to understand its behavior or to make predictions. The representation always involves certain simplifications and assumptions.

modem (modulator/demodulator)

Device that allows two computers (which use *binary* data in the form of *bits*) to communicate using a telephone line (which uses tones). When the computer is transmitting data, the modem is needed to modulate binary data into tones. When receiving data, the device is needed to demodulate the tones to obtain the binary data required by the computer. Since the computer must be both a transmitter and receiver of data, the modem must be able to modulate and demodulate data.

modulation

Variation in the frequency of a radio wave in accordance with some other impulse. Modulation is essential to communication systems in which a number of different signals must all share the same medium. One way this sharing can be accomplished is to place each signal in its own band of frequencies in the medium. *Amplitude modulation* and *frequency modulation* are two ways in which signals can be moved within the frequency domain to accomplish placement and sharing.

CONCEPTS AND TERMS

The combining of a number of signals to share a communication medium by dividing it into different frequency bands for each signal is called *frequency-division multiplexing*.

Amplitude modulation (AM) is technologically quite simple, and the bandwidth of the amplitude-modulated carrier is at most twice the bandwidth of the modulating signal. However, an amplitude-modulated carrier is very prone to the effects of additive noise.

Frequency modulation (FM) is more complicated than amplitude modulation, and the *bandwidth* of the frequency-modulated carrier can be many times that of the modulating signal. However, the process of demodulating a frequency-modulated carrier eliminates much of the deleterious effects of additive noise. This trade-off between bandwidth and noise reduction characterizes most communication situations.

monsoon

Heavy winds characterized by a pronounced seasonal change in direction. Winds usually blow from land to sea in the winter, while in the summer, the flow reverses and precipitation is more common. Monsoons are most typical in India and southern Asia.

Montreal Protocol

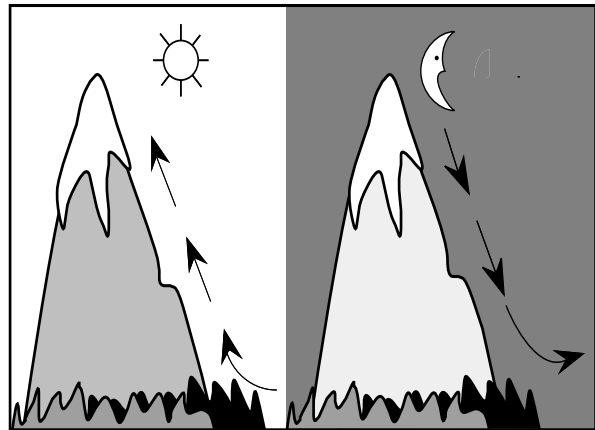
An international agreement to drastically reduce *CFC* production, the Protocol was adopted in Montreal in 1987. It was significantly strengthened at a subsequent meeting in London in 1990 that called for a complete elimination of *CFCs* by the year 2000. The agreement was again amended by a Meeting of the Parties in Copenhagen in November 1992. Consumption of controlled substances—such as *CFCs* and halons—was greatly reduced or eliminated, and many accountability dates were moved forward, often from January 2000 to 1 January 1996.

mosaic

A composite picture built up from a number of image segments. An example of a mosaic is the *WEFAX* transmission, which includes both polar and mercator mosaics derived from *TIROS-N/NOAA* polar orbit image data.

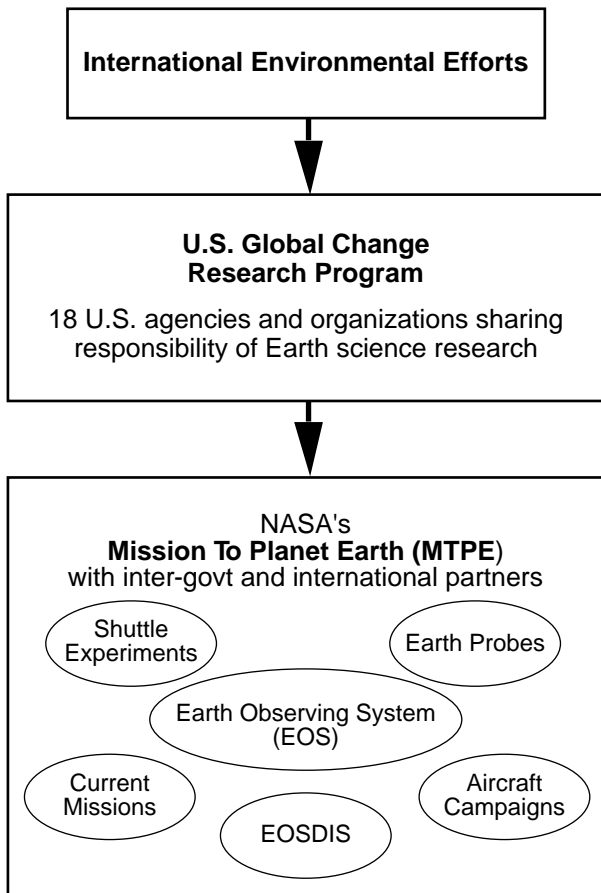
mountain and valley breezes

System of winds that blow downhill during the night (mountain breeze) and uphill during the day (valley breeze).



MTPE

See *Mission to Planet Earth*.



CONCEPTS AND TERMS

multiplexer

A device that combines several separate communications signals into one and outputs them on a single line.

Multispectral Scanner (MSS)

A line-scanning instrument flown on *Landsat* satellites that continually scans the Earth in a 185 km (100 nautical miles) swath. On *Landsats* 1, 2, 4, and 5, the MSS had four *spectral bands* in the visible and near-infrared with an IFOV of 80 meters. *Landsat-3* had a fifth band in the thermal infrared with an IFOV of 240 meters.

N

nadir

Point on Earth directly beneath a satellite, the opposite of zenith. Compare with *subsatellite point*.

nano

See *International System of Units*.

nanometer (nm)

One billionth of a meter. Nanometers are used to measure wavelengths in the *electromagnetic spectrum*.

NASA

See *National Aeronautics and Space Administration*.

NASA Centers

The ten major NASA Centers are:

Ames Research Center (ARC) Located at Moffett Field, California. ARC is active in aeronautical research, life sciences, space science, and technology research. The Center houses the world's largest wind tunnel and the world's most powerful supercomputer system.

The **Dryden Flight Research Center**, Edwards Air Force Base, California, formerly part of ARC, became a separate entity March 1994. Since the 1940s, this Mojave desert site has been a testing ground for high-performance aircraft and is one of two prime landing sites for the Space Shuttle.

Goddard Space Flight Center (GSFC)

Goddard was NASA's first major scientific laboratory devoted entirely to the exploration of space. Located in Greenbelt, Maryland, GSFC's responsibilities include design and construction of new scientific and applications satellites, as well as tracking and communication with existing satellites in orbit. GSFC is the lead center for the *Earth Observing System*, a key element of *Mission to Planet Earth*. GSFC also directs operations at the Wallops Flight Facility on Wallops Island, Virginia, which each year launches some 50 scientific missions to sub-orbital altitudes on small sounding rockets.

Jet Propulsion Laboratory (JPL) Located in Pasadena, California, JPL is operated under contract to NASA by the California Institute of Technology. Its primary focus is the scientific study of the solar system, including exploration of the planets with automated probes. Most of the lunar and planetary spacecraft of the 1960s and 1970s were developed at JPL. JPL also is the control center for the worldwide Deep Space Network, which tracks all planetary spacecraft.

Lyndon B. Johnson Space Center (JSC)

Johnson Space Center, located between Houston and Galveston, Texas, is the lead center for NASA's manned space flight program. JSC has been Mission Control for all piloted space flights since 1965, and now manages the Space Shuttle program. JSC's responsibilities include selecting and training astronauts; designing and testing vehicles and other systems for piloted space flight; and planning and executing space flight missions. The center has a major role in developing the Space Station. In addition, JSC directs operations at the White Sands Test Facility in New Mexico, which conducts Shuttle-related tests. The nearby White Sands Missile Range also serves as a backup landing site for the Space Shuttle.

Kennedy Space Center (KSC) Located near Cape Canaveral, Florida, KSC is NASA's primary launch site. The Center handles the preparation, integration, checkout, and launch of space vehicles and their payloads. All piloted space missions since the Mercury program have been launched from here, including

CONCEPTS AND TERMS

Gemini, Apollo, Skylab, and Space Shuttle flights. KSC is the Shuttle's home port, where orbiters are serviced and outfitted between missions, and then assembled into a complete Shuttle "stack" before launch. The Center also manages the testing and launch of unpiloted space vehicles from an array of launch complexes, and conducts research programs in areas of life sciences related to human spaceflight.

Langley Research Center (LaRC) Oldest of NASA's field centers, LaRC is located in Hampton, Virginia, and focuses primarily on aeronautical research. Established in 1917 by the National Advisory Committee for Aeronautics, the Center currently devotes two-thirds of its programs to aeronautics, and the rest to space. LaRC researchers use more than 40 wind tunnels to study improved aircraft and spacecraft safety, performance, and efficiency.

Lewis Research Center (LeRC) Lewis Research Center, located outside Cleveland, Ohio, conducts a varied program of research in aeronautics and space technology. Aeronautical research includes work on advanced materials and structures for aircraft. Space-related research focuses primarily on power and propulsion. Another significant area of research is in energy and power sources for spacecraft, including the Space Station, for which LeRC is developing the largest space power system ever designed.

George C. Marshall Space Flight Center (MSFC) The MSFC, located in Huntsville, Alabama, is responsible for developing spacecraft hardware and systems, and is perhaps best known for its role in building the Saturn rockets that sent astronauts to the Moon during the Apollo program. It is NASA's primary center for space propulsion systems and plays a key role in the development of payloads to be flown on the shuttle (such as Spacelab). MSFC also manages two other NASA sites: the Michoud Assembly Facility in New Orleans where the Shuttle's external tanks are manufactured, and the Slidell Computer Complex in Slidell, Louisiana, which provides computer support to Michoud and to NASA's John C. Stennis Space Center.

John C. Stennis Space Center (SSC) This Center, located on Mississippi's Gulf Coast, is NASA's prime test facility for large liquid propellant rocket engines and propulsion systems. The main mission of the Center is to support testing, on a regular basis, of the Space Shuttle's main propulsion system. SSC is responsible for a variety of research programs in the environmental sciences and the remote-sensing of Earth resources, weather, and oceans, and is the lead NASA Center for the commercialization of space remote sensing.

NASA Prediction Bulletins

Reports published by NASA's *Goddard Space Flight Center* providing the latest orbit information on satellites. The report gives information in three parts: 1) two line orbital elements, 2) longitude of the south to north equatorial crossings, and 3) longitude and heights of the satellite crossings for other latitudes.

NASDA

See *Japanese National Space Development Agency*.

National Aeronautics and Space Administration (NASA)

U.S. Civilian Space Agency created by Congress. Founded in 1958, NASA belongs to the executive branch of the Federal Government.

NASA's mission to plan, direct, and conduct aeronautical and space activities is implemented by NASA Headquarters in Washington, D.C., and by ten major centers spread throughout the United States. Dozens of smaller facilities, from tracking antennas to Space Shuttle landing strips to telescopes are located around the world. The agency administers and maintains these facilities, builds and operates launch pads, trains astronauts, designs aircraft and spacecraft, and sends satellites into Earth orbit and beyond, and processes, analyzes, and distributes the resulting data and information. See *NASA Centers*.

NASA shares responsibility for aviation and space activities with other federal agencies, including the Departments of Commerce, Transportation, and Defense. Much of the work on major projects such as the Space

CONCEPTS AND TERMS

Shuttle and the Space Station is done in the private sector by aerospace companies under government contract.

From its inception, NASA has been directed to pursue the expansion of human knowledge of phenomena in the atmosphere and space. NASA's programs of basic and applied research extend from microscopic sub-atomic particles to galactic astronomy. In addition to enhancing scientific knowledge, thousands of the technologies developed for aerospace have resulted in commercial applications.

Science offices at NASA Headquarters carry out a wide range of research activities to fulfill NASA's science goals. Science offices within NASA are:

Office of Mission to Planet Earth (MTPE) focuses on the "home planet" as a dynamic system of land, ocean, atmosphere, and life that can be investigated on a global scale from space using remote-sensing tools. See *Mission to Planet Earth*.

Office of Life and Microgravity Sciences and Applications explores the basic physics of how solids, liquids, and gases behave in space; seeks an understanding of the basic mechanisms that underlie space adaptation—developing more effective countermeasures to mitigate the physiological effects of space flight; and studies the role of gravity on life.

Office of Space Science includes the Space Physics and Astrophysics Division which studies the entire universe of stars and galaxies, including the sun. The Solar System Exploration division has launched spacecraft to all the known planets except Pluto in its quest to study the solar system.

National Center for Atmospheric Research (NCAR)

Non-profit organization dedicated to furthering understanding of the Earth's atmosphere. Located in Boulder, Co., NCAR is operated by the University Corporation for Atmospheric Research (UCAR) and sponsored by the National Science Foundation (NSF).

National Oceanic and Atmospheric Administration (NOAA)

NOAA was established in 1970 within the U.S. Department of Commerce to ensure the safety of the general public from atmospheric phenomena and to provide the public with an understanding of the Earth's environment and resources. NOAA includes: the National Ocean Service which charts the oceans and waters of the U.S. and manages 265,000 acres of estuarine reserves; the National Marine Fisheries Service which maintains the world's largest and most complex marine fisheries management system; the NOAA Corps which operates 18 NOAA research and survey ships and flies 15 NOAA aircraft; and the Office of Oceanic and Atmospheric Research which supports experiments, laboratories, and the National Sea Grant College Program, among other efforts. NOAA has two main components: the National Weather Service (NWS), and the National Environmental Satellite, Data, and Information Service (NESDIS).

The National Weather Service provides weather watch and warning services to the public through 57 Weather Service Forecast Offices (WSFO) and over 100 smaller local Weather Service Offices (WSOs) nationwide. Three national forecasting centers provide general and specialized guidance to WSFOs using computer forecast models, satellite data, and conventional surface and upper air observations from around the world. The centers are:

- National Meteorological Center, Camp Springs, Maryland;
- National Severe Storms Forecast Center, Kansas City, Missouri;
- National Hurricane Center, Coral Gables, Florida.

NWS River Forecast Centers (RFCs) provide river stage and flood forecasts.

NESDIS provides support to the Weather Service forecast mission by operating a series of environmental satellites and disseminating satellite imagery and derived products to the National Centers and WSFOs. NESDIS operates

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three national data and information centers: the National Geophysical Data Center, the National Climatic Data Center (NCDC), and the National Oceanographic Data Center (NODC). See *SOCC*

NOAA organizations perform numerous services in addition to monitoring weather conditions. They assess crop growth and other agricultural conditions, sense shifting ocean currents, and measure surface temperatures of oceans and land. They relay data from surface instruments that sense tide conditions, Earth tremors, river levels, and precipitation.

National Space Science Data Center (NSSDC)

The NSSDC provides on-line and off-line access to a wide variety of astrophysics, space plasma and solar physics, lunar and planetary, and Earth science data from NASA space flight missions, in addition to selected other data, models, and software. Located at Goddard Space Flight Center (GSFC) in Greenbelt, Maryland, the NSSDC is sponsored by the Information Systems Office of NASA's Office of Space Sciences. NSSDC on-line data and services are currently free of charge, off-line support (e.g., replications and mailing of magnetic tapes) are available for the cost of fulfilling the request.

The NSSDC Master Catalog (NMC) provides an on-line listing of available data sets and the forms that the data are available in (such as CD-ROM), and provides information about the spacecraft and experiments (including past, present, and future NASA and non-NASA) from which these data were obtained. The on-line NASA Master Directory (NMD) identifies and briefly describes data of potential interest to the NASA research community, and where possible, provides electronic links to publicly-accessible data at sites world-wide. On-line information services are made available through the menu-based NSSDC Online Data Information Service (NODIS).

For more information contact: CRUSO (Coordinated Request & User Support Office) National Space Science Data Center

c/o World Data Center-A-R&S
(only if corresponding from outside the USA)
NASA Goddard Space Flight Center, Code 633.4
Greenbelt, Maryland 20771
phone: (301) 286-6695, FAX: (301) 286-1771
Internet: REQUEST@NSSDCA.GSFC.NASA.GOV
DECnet: NSSDCA::REQUEST

National Weather Service (NWS)

See *National Oceanic and Atmospheric Administration*.

nautical mile

A unit of distance (U.S.) equal to exactly 1.852 kilometers or about 6076.1 feet. A nautical mile is approximately equal to 1/60 of a degree or 1 minute of arc of a great circle of the Earth (i.e., 1 minute of arc of latitude or of longitude at the equator).

NCAR

See *National Center for Atmospheric Research*.

NCDC

National Climatic Data Center, located in Asheville, North Carolina. See *National Oceanic and Atmospheric Administration*.

near infrared

Electromagnetic radiation with wavelengths from just longer than the visible (about 0.7 micrometers) to about two micrometers. See *electromagnetic spectrum*.

nephanalysis

A type of analysis using satellite cloud pictures to study the relationship between cloud forms and storm systems. In classical mythology, Nephele was a woman Zeus formed from a cloud.

nepheloccygia

Clouds that resemble recognizable shapes.

NESDIS

National Environmental Satellite Data and Information Service. See *National Oceanic and Atmospheric Administration*.

Newton's law of universal gravitation

All bodies attract each other with what is called gravitational attraction. This applies to the largest stars as well as the smallest particles of matter.

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The force of attraction between two small bodies (or between two spherical bodies of any size) is proportional to the product of their masses and inversely proportional to the square of the distance between their centers. In other words, the closer two bodies are to each other, the greater their mutual attraction. As a result, to stay in orbit, a satellite needs more speed in a low than a high orbit.

Kepler's three laws of planetary motion, which had been derived empirically by Johannes Kepler, were obtained with mathematical rigor as a consequence of Newton's law of universal gravitation in conjunction with his three laws of motion. See *Kepler's three laws of motion*.

Newton's laws of motion

Newton's three laws of motion are:

- 1) Every body continues in a state of uniform motion in a straight line unless acted upon by some external force.
- 2) The time rate of change of momentum (mass x velocity) is proportional to the impressed force. In the usual case where the mass does not change, this law can be expressed in the familiar form:
$$\text{force} = \text{mass} \times \text{acceleration} \text{ or } F = ma.$$
- 3) To every force or action, there is always an equal and opposite reaction.

Kepler's three laws of planetary motion, which had been derived empirically by Johannes Kepler, were obtained with mathematical rigor as a consequence of Newton's law of universal gravitation in conjunction with his three laws of motion. See *Kepler's three laws of motion*.

NGDC

National Geophysical Data Center, located in Boulder, Colorado. See *National Oceanic and Atmospheric Administration*.

nibble

Four *bits* of data.

Nimbus Satellite Program

A NASA program to develop observation systems meeting the research and development requirements of atmospheric and Earth scientists. The Nimbus satellites, first launched in

1964, carried a number of instruments: microwave radiometers, atmospheric sounders, ozone mappers, the Coastal Zone Color Scanner (CZCS), infrared radiometers, etc. Nimbus-7, the last in the series, provided significant global data on sea-ice coverage, atmospheric temperature, atmospheric chemistry (i.e. ozone distribution), the Earth's radiation budget, and sea-surface temperature. See *Total Ozone Mapping Spectrometer (TOMS)*.

NOAA

See *National Oceanic and Atmospheric Administration*. Operational designation for the U.S. polar-orbiting meteorological satellites. Current NOAA spacecraft are variations of the *TIROS-N* bus.

NODC

National Oceanographic Data Center, located in Washington, D.C. See *National Oceanic and Atmospheric Administration*.

NRA

NASA Research Announcement.

NREN

National Research and Education Network.

NSF

National Science Foundation.

NSFNET

National Science Foundation NETWORK.

NSSDC

See *National Space Science Data Center*.



oasis

A spot in a desert made fertile by water, which normally originates as groundwater.

occluded front (occlusion)

A composite of two fronts formed as a cold front overtakes a warm front. A cold occlusion results when the coldest air is behind the cold front. The cold front undercuts the warm front and, at the Earth's surface, coldest air replaces less-cold air.

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A warm occlusion occurs when the coldest air lies ahead of the warm front. Because the cold front can not lift the colder air mass, it rides piggyback up on the warm front over the coldest air.

ocean

The salt water surrounding the great land masses. The land masses divide the ocean into several distinct portions, each of which also is called an ocean. The oceans include the Pacific Ocean, the Atlantic Ocean, the Indian Ocean, and the Arctic Ocean.

ohm

The unit of electrical resistance, equal to the resistance of a circuit in which an *electromotive force* of one volt maintains a current of one *ampere*. Named for German physicist Georg S. Ohm (1787–1854).

orbit

The path described by a heavenly body in its periodic *revolution*. Earth satellite orbits with inclinations near 0° are called equatorial orbits because the satellite stays nearly over the equator. Orbits with inclinations near 90° are called polar orbits because the satellite crosses over (or nearly over) the north and south poles. See *inclination*.

orbital decay

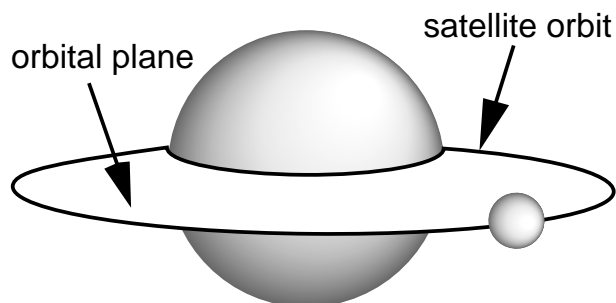
See *period decay*.

orbital inclination

See *inclination*.

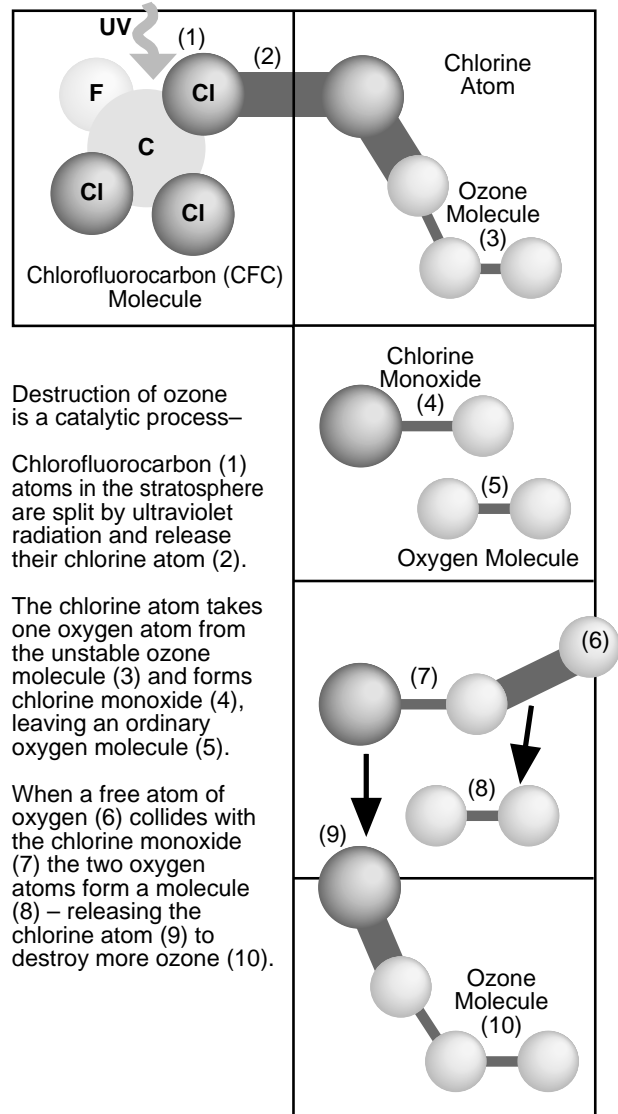
orbital plane

An imaginary gigantic flat plate containing an Earth satellite's orbit. The orbital plane passes through the center of the Earth.



ozone

An almost colorless, gaseous form of oxygen with an odor similar to weak chlorine. A relatively unstable compound of three atoms of oxygen, ozone constitutes—on the average—less than one part per million (ppm) of the gases in the atmosphere (peak ozone concentration in the *stratosphere* can get as high as 10 ppm). Yet ozone in the stratosphere absorbs nearly all of the biologically damaging solar ultraviolet radiation before it reaches the Earth's surface where it can cause skin cancer, cataracts, and immune deficiencies, and can harm crops and aquatic ecosystems. See *ozone layer*.



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Ozone is produced naturally in the middle and upper *stratosphere* through dissociation of molecular oxygen by sunlight. In the absence of chemical species produced by human activity, a number of competing chemical reactions among naturally-occurring species—primarily atomic oxygen, molecular oxygen, and oxides of hydrogen and nitrogen—maintains the proper ozone balance.

In the present-day stratosphere, this natural balance has been altered, particularly by the introduction of man-made *chlorofluorocarbons*. If the ozone decreases, the ultraviolet radiation at the Earth's surface will increase. See *greenhouse gas*.

Tropospheric ozone is a by-product of the photochemical (light-induced) processes associated with air pollution. See *photochemical smog*. Ozone in the troposphere can damage plants and humans.

ozone hole

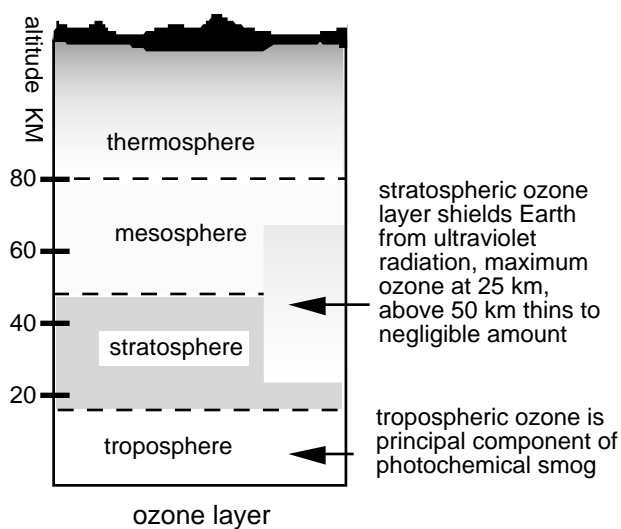
A large area of intense stratospheric ozone depletion over the Antarctic continent that typically occurs annually between late August and early October, and generally ends in mid-November. This severe ozone thinning has increased conspicuously since the late seventies and early eighties. This phenomenon is the result of chemical mechanisms initiated by man-made chlorofluorocarbons (see *CFCs*). Continued buildup of CFCs is expected to lead to additional ozone loss worldwide.

The thinning is focused in the Antarctic because of particular meteorological conditions there. During Austral spring (September and October in the Southern Hemisphere) a belt of stratospheric winds encircles Antarctica essentially isolating the cold stratospheric air there from the warmer air of the middle latitudes. The frigid air permits the formation of ice clouds that facilitate chemical interactions among nitrogen, hydrogen, and chlorine (elevated from CFCs) atoms, the end product of which is the destruction of ozone.

ozone layer

The layer of ozone that begins approximately 15 km above Earth and thins to an almost negligible amount at about 50 km, shields the

Earth from harmful ultraviolet radiation from the sun. The highest natural concentration of ozone (approximately 10 parts per million by volume) occurs in the stratosphere at approximately 25 km above Earth. The stratospheric ozone concentration changes throughout the year as stratospheric circulation changes with the seasons. Natural events such as volcanoes and solar flares can produce changes in ozone concentration, but man-made changes are of the greatest concern.



ozone-measuring satellite instruments

Satellite-based ozone-measuring instruments can measure ozone by looking at the amount of ultraviolet absorption reflected from the Earth's surface and clouds. Some instruments provide data within the different levels of the atmosphere. The *Total Ozone Mapping Spectrometer (TOMS)* maps the total amount of ozone between ground and the top of the atmosphere.

The amount and distribution of ozone molecules in the stratosphere varies greatly over the globe, changing in response to natural cycles such as seasons, sun cycles, and winds. Utilizing satellites has enabled scientists to assess ozone levels simultaneously over the entire Earth, and has led them to conclude that global ozone levels are being depleted.

ozone mini-hole(s)

Rapid, transient, polar-ozone depletion. These depletions, which take place over a 50-kilometer

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squared area, are caused by weather patterns in the upper troposphere. The decrease in ozone during a mini-hole event is caused by transport, with no chemical depletion of ozone. However, the cold stratospheric temperatures associated with weather systems can cause clouds to form that can lead to the conversion of chlorine compound from inert to reactive forms. These chlorine compounds can then produce longer-term ozone reductions after the mini-hole has passed.

P

paleogeography

The study of ancient or prehistoric geography.

paleoclimate

Climate as it existed in the distant past, particularly before historical records.

panchromatic

Sensitive to all or most of the visible spectrum.

parasitic element

See *antenna*.

parity

The addition of one or more redundant bits to information to verify its accuracy.

pascal (Pa)

Unit of *atmospheric pressure* named in honor of Blaise Pascal (1632–1662), whose experiments greatly increased knowledge of the atmosphere. A pascal is the force of one newton acting on a surface area of one square meter. It is the unit of pressure designated by the International System.

$$100,000 \text{ Pa} = 1000 \text{ mb} = 1 \text{ bar.}$$

See *atmospheric pressure*, millibar.

passive system

A system sensing only radiation emitted by the object being viewed or reflected by the object from a source other than the system. See *active system*.

payload

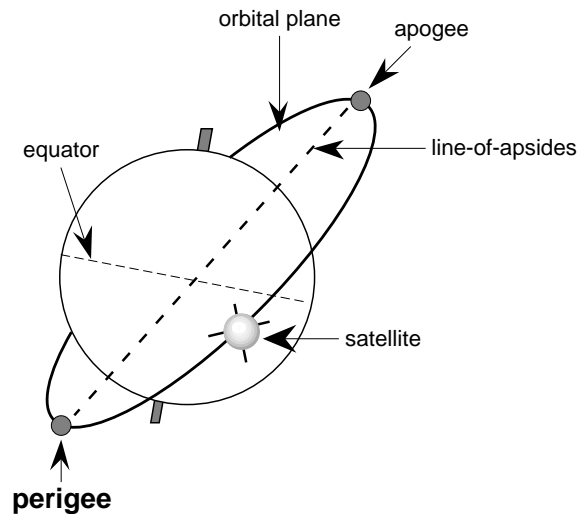
The instruments that are accommodated on a spacecraft.

PC

Personal computer.

perigee (aka periapsis or perifocus)

On an elliptical orbit path, the point where a satellite is closest to the Earth. See *Keplerian*



elements.

perihelion

The point in the orbit of a planet or comet which is nearest the Sun (as opposed to the aphelion, which is the point in the orbit farthest from the Sun).

period

Time required for a satellite to make one complete orbit.

period decay (aka decay)

The tendency of a satellite to lose orbital velocity due to the influence of atmospheric *drag* and gravitational forces. A decaying object eventually impacts the surface of the Earth or burns up in the atmosphere. This parameter directly affects the satellite's *mean motion*.

permafrost

See *cryosphere*.

perturbations

Minor corrections to the Keplerian model of a satellite orbit as an ellipse of constant shape and orientation. Since satellite orbits are affected by Earth's gravity and drag caused by the Earth's atmosphere (causing satellites to

CONCEPTS AND TERMS

spiral downward), minor adjustments must be made to the orbit.

pH

A symbol for the degree of acidity or alkalinity of a solution. Expressed as a negative logarithm of the hydrogen ion concentration in a solution, $\text{pH} = -\log_{10}[\text{H}^+]$. If the hydrogen ion concentration of a solution increases, the pH will decrease, and vice versa. The value for pure distilled water is regarded as neutral, pH values from 0 to 7 indicate acidity, and from 7 to 14 indicate alkalinity.

phase interval

In *direct readout*, the time between the end of a satellite image start tone and the start of the actual frame data. The phase interval represents white level video, interrupted by a black level pulse marking the start of each line and is used to set up phasing prior to image display.

phenology

Subdiscipline of agriculture, a science that treats relations between climate and periodic biological phenomena that are related to or caused by climatic conditions, such as the budding of trees and the migration of birds.

photochemical smog

A type of smog that forms in large cities when chemical reactions take place in the presence of sunlight, its principal component is *ozone*. Ozone and other oxidants are not emitted into the air directly but form from reactions involving nitrogen oxides and hydrocarbons. Because of its smog-making ability, ozone in the lower atmosphere (troposphere) is often referred to as "bad" ozone.

photon

A quantum (smallest unit in which waves may be emitted or absorbed) of light.

photosynthetically active radiation

Electromagnetic radiation in the part of the spectrum used by plants for photosynthesis.

physical climate system

The system of processes that regulate climate, including atmospheric and ocean circulation, evaporation, and precipitation.

pixel

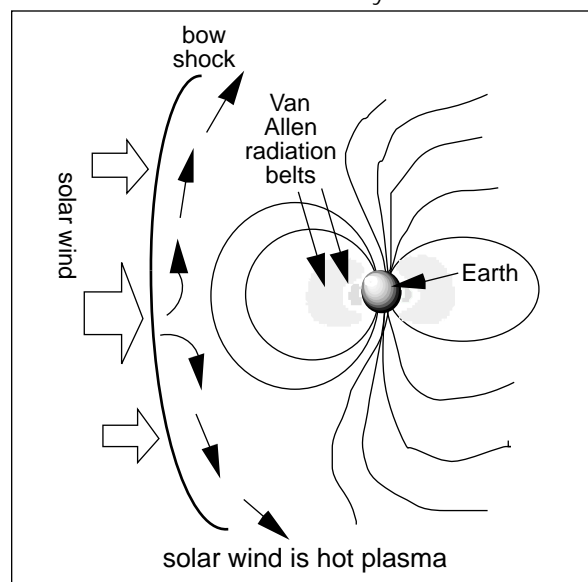
Smallest part (addressable element) of an electronically-coded image, such as a computer display. Pixel is a contraction of "picture element."

planetary albedo

The fraction of incident solar radiation that is reflected by a planet and returned to space. The planetary albedo of the Earth-atmosphere system is approximately 30 percent, most of which is due to backscatter from clouds in the atmosphere.

plasma

A fourth state of matter (in addition to solid, liquid, and gas) that exists in space. In this state, atoms are positively charged and share space with free negatively-charged electrons. Plasma can conduct electricity and interact



strongly with electric and magnetic fields. The solar wind is actually hot plasma blowing from the sun. See *magnetosphere*.

plate tectonics

Concept that the Earth's crust is composed of rigid plates that move over a less rigid interior.

platforms

A satellite that can carry instruments. See *bus*. The same term is applied to automatic weather data transmitters installed on buoys, balloons, ships, and planes, and mounted in remote areas.

POES (Polar-orbiting Operational

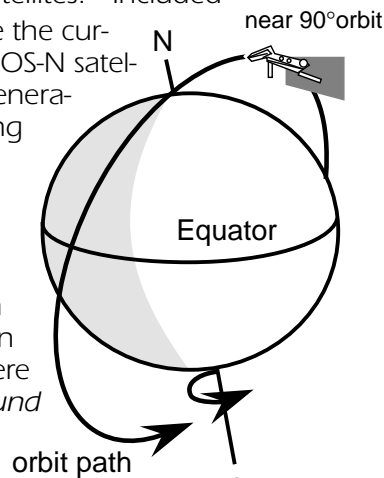
CONCEPTS AND TERMS

Environmental Satellite)

Operated by the National Oceanic and Atmospheric Administration, they are designated "NOAA satellites." Included in this group are the current series of TIROS-N satellites, the third-generation polar-orbiting environmental spacecraft operated by NOAA.

polar orbit

An orbit with an orbital inclination of near 90° where the satellite *ground track* will cross both polar regions once during each orbit. The term is used to describe the near-polar orbits of spacecraft such as the USA's *NOAA/TIROS* and *Landsat* satellites.



precession

The comparatively slow torquing of the orbital planes of all satellites with respect to the Earth's axis, due to the bulge of the Earth at the equator which distorts the Earth's gravitational field. Precession is manifest by the slow rotation of the line of nodes of the orbit (westward for inclinations less than 90° and eastward for inclinations greater than 90°).

precipitation

Moisture that falls from clouds. Although clouds appear to float in the sky, they are always falling, their water droplets slowly being pulled down by gravity. Because their water droplets are so small and light, it can take 21 days to fall 1,000 feet and wind currents can easily interrupt their descent. Liquid water falls as rain or drizzle. All raindrops form around particles of salt or dust. (Some of this dust comes from tiny meteorites and even the tails of comets.) Water or ice droplets stick to these particles, then the drops attract more water and continue getting bigger until they are large enough to fall out of the cloud. Drizzle drops are smaller than raindrops. In many clouds, raindrops actually begin as tiny

ice crystals that form when part or all of a cloud is below freezing. As the ice crystals fall inside the cloud, they may collide with water droplets that freeze onto them. The ice crystals continue to grow larger, until large enough to fall from the cloud. They pass through warm air, melt, and fall as raindrops.

When ice crystals move within a very cold cloud (10 °F and -40 °F) and enough water droplets freeze onto the ice crystals, snow will fall from the cloud. If the surface temperature is colder than 32 °F, the flakes will land as snow.

Precipitation Weights:

- one raindrop .000008 lbs
- one snowflake .0000003 lbs
- one cumulus cloud 10,000,000 lbs
- one thunderstorm 10,000,000,000 lbs
- one hurricane 10,000,000,000,000 lbs

prevailing westerlies

Winds in the middle latitudes (approximately 30° to 60°) that generally blow from west to east. The subtropical high pressure regions at the *horse latitudes* (30°) forces surface air poleward, and the rotation of the Earth causes these winds to bear to the right (east) in the Northern Hemisphere and to the left (east) in the Southern Hemisphere (see *Coriolis force*). This is, to some extent, an idealized picture of the atmospheric circulation. The actual circulation on individual days includes modifications and variations due to the migratory cyclones and anticyclones of middle latitudes, causing rapid and often violent weather changes, as warm semi-tropical air from the horse latitudes meets cold polar air from the high latitudes. See *wind*.

prime meridian

An imaginary line running from north to south through Greenwich, England, used as the reference point for longitude.

printed circuit

A fiber card on which integrated circuits and other electronic components can be mounted. Connections between the components are etched in the correct circuit patterns.

process

An association of phenomena governed by

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physical, chemical, or biological laws. An example of a process is the vertical mixing of ocean waters in the so-called surface-mixed layer; the state variables for this process include temperature, salinity in the water on a vertical scale of tens of meters, and heat flow and wind stress at the sea surface. Other examples include the volcanic deposition of dust and gases into the atmosphere, eddy formation in the atmosphere and oceans, and soil development.

process study

An organized, systematic investigation of a particular process designed to identify all of the state variables involved and to establish the relationships among them. Process studies yield numerical *algorithms* that connect the state variables and determine their rates of change; such *algorithms* are essential ingredients of Earth system *models*.

prograde orbit

Orbits of the Earth in the same direction as the rotation of the Earth (west-to-east).

psychrometer

An instrument designed to measure *dew point* and relative *humidity*, consisting of two thermometers (one dry bulb and one wet bulb). The dew point and humidity levels are determined by drying the wet bulb (either by fanning or whirling the instrument) and com-

R

paring the difference between the wet and dry bulbs with preexisting calculations. See *hygrometer*.

R&D

Research and Development.

radiant

1. In optics, the point or object from which light proceeds. 2. In geometry, a straight line proceeding from a given point, or fixed pole, about which it is conceived to revolve. 3. In astronomy, the point in the heavens from which a shower of meteors seems to proceed.

radiation

Energy transfer in the form of *electromagnetic waves* or particles that release energy when absorbed by an object.

radiation budget

A measure of all the inputs and outputs of radiative energy relative to a system, such as Earth. See *Earth Radiation Budget Experiment*.

radiative cooling

Cooling process of the Earth's surface and adjacent air, which occurs when infrared (heat) energy radiates from the surface of the Earth upward through the atmosphere into space. Air near the surface transfers its thermal energy to the nearby ground through *conduction*, so that radiative cooling lowers the temperature of both the surface and the lowest part of the atmosphere.

radiative transfer

Theory dealing with the propagation of electromagnetic radiation through a medium.

radioactive

Giving off or capable of giving off radiant energy in the form of particles or rays, as in alpha, beta, and gamma rays.

radiometer

An instrument that quantitatively measures electromagnetic radiation. Weather satellites carry radiometers to measure radiation from snow, ice, clouds, bodies of water, the Earth's surface, and the sun.

radio frequency (RF)

A frequency that is useful for radio transmission, usually between 10 kHz and 300,000 MHz.

radiosonde

A balloon-borne instrument that measures meteorological parameters from the Earth's surface up to 20 miles in the atmosphere. The radiosonde measures temperature, pressure, and humidity, and transmits or "radios" these data back to Earth. Upper air winds also are determined through tracking of the balloon ascent.

Radiosonde observations generally are taken twice a day (0000 and 1200 *UTC*) around the globe. NOAA's National Weather

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Service (NWS) operates a network of about 90 radiosonde observing sites in the U.S. and its territories. When the balloons burst, radiosondes return to Earth on a parachute. Approximately 25 percent are recovered and returned to NWS for reconditioning and reuse.

radio spectrum

The complete range of frequencies or wave lengths of electromagnetic waves, specifically those used in radio and television.

radio wave

An electrical impulse sent through the atmosphere at radio frequency.

rain forest

An evergreen woodland of the tropics distinguished by a continuous leaf canopy and an average rainfall of about 100 inches per year. Rain forests play an important role in the global environment. The Earth sustains life because of critical balances and interactions among many factors. Were there not processes at work that limit the effects of other essential processes, Earth would become uninhabitable. Destruction of tropical rain forests reduces the amount of leaf area in the tropics, and consequently the amount of carbon dioxide absorbed, causing increases in levels of carbon dioxide and other atmospheric gases. It is estimated that cutting and burning of tropical forests contributes about 20 percent of the carbon dioxide added to the atmosphere each year. The World Resources Institute and the International Institute for Environment and Development have reported that the world's tropical forests are being destroyed at the rate of fifty-four acres per minute, or twenty-eight million acres lost annually. Rain forest destruction also means the loss of a wide spectrum of biological life, erosion of soil, and possible *desertification*.

rain gauge

Calibrated container that measures the amount of rainfall during a specific period of time.

RAM

Random Access Memory. Computers use two types of memory, RAM and ROM. RAM is the computer's working area, the primary location

where the microprocessor stores the information it needs. The designation "random access" stems from the microprocessor's ability to access information in memory randomly by knowing its location, or address, rather than hunting through memory sequentially from beginning to end. Because information in RAM is stored electronically, accessing data stored in RAM is much faster than getting that data from a mechanical storage device such as a disk drive. But because it is stored electronically, all information in RAM is temporary (which is why you must store it on a more permanent storage capability, such as a disk). Compare with *ROM*.

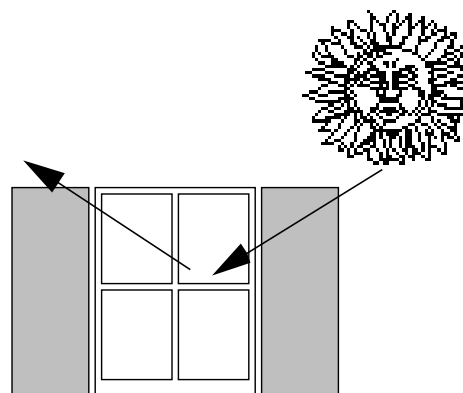
real time

As it happens.

receiver sensitivity

The ability of a receiver to detect weak signals through the noise level of the receiving system, which includes the antenna and internal thermal noise of the receiver. See *signal-to-noise ratio*.

reflection



The return of light or sound waves from a surface. If a reflecting surface is plane, the angle of reflection of a light ray is the same as the angle of incidence.

remapping

Flattening the Earth into a standard map projection. When the spherical Earth is photographed by satellites, areas lying near the outer edge of the picture are distorted. Remapping rectifies the distortion.

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remote sensing

The technology of acquiring data and information about an object or phenomena by a device that is not in physical contact with it. In other words, remote sensing refers to gathering information about the Earth and its environment from a distance, a critical capability of the *Earth Observing System*.

For example, spacecraft in low-Earth orbit pass through the outer thermosphere, enabling direct sampling of chemical species there. These samples have been used extensively to develop an understanding of thermospheric properties. Explorer-17, launched in 1963, was the first satellite to return quantitative measurements of gaseous stratification in the thermosphere. However, the *mesosphere* and lower layers cannot be probed directly in this way—global observations from space require remote sensing from a spacecraft at an altitude well above the *mesopause*. The formidable technological challenges of atmospheric remote sensing, many of which are now being overcome, have delayed detailed study of the *stratosphere* and mesosphere by comparison with thermospheric research advances.

Some remote-sensing systems encountered in everyday life include the human eye and brain, and photographic and video cameras.

resolution

A measure of the ability to separate observable quantities. In the case of imagery, it describes the area represented by each *pixel* of an image. The smaller the area represented by a pixel, the more accurate and detailed the image. *APT* has a resolution of 4 km, i.e., each pixel represents a square, 4 km on each side. *HRPT* has a resolution of 1.1 km at nadir (4 km at edge of scan), and *WEFAX* of 8 km. See *resolution cell*.

resolution cell

The smallest unit of area in an image of discrete elements. The area represented by a *pixel*.

retrograde orbit

An east-to-west orbit of Earth (Earth spins west to east). See *prograde orbit*.

revolution

Process of the Earth circling the sun in its orbit. Revolution determines the seasons, and the length of the year. In addition, differences in seasons occur because of Earth's inclination (tilt on its axis) of about 23.5 degrees as it revolves around the sun. Compare with *rotation*.

RF

See *radio frequency*.

right ascension of ascending node (aka Ω , RAAN or RA of Node)

One of six *Keplerian elements*, it indicates the rotation of the *orbit plane* from some reference point. Two numbers orient an *orbital plane* in space; *inclination* is the first, this is the second. After specifying inclination, an infinite number of orbital planes are possible. The intersection of the equatorial plane and the orbital plane (see diagram, *line of nodes*) must be specified by a location on the equator that fully defines the orbital plane. The line of nodes occurs in two places. However, by convention, only the ascending node (where the satellite crosses the equator going from south to north) is specified. The descending node (where the satellite crosses the equator going from north to south) is not.

Because the Earth spins, conventional latitude and longitude points are not used to separate where the lines of node occur. Instead, an astronomical coordinate system is used, known as the right-ascension/declination coordinate system, which does not spin with the Earth. Right ascension of ascending node is an angle, measured at the center of the Earth, from the vernal equinox to the ascending node. For example, draw a line from the center of the Earth to the point where the satellite crossed the equator (going from south to north). If this line points directly at the vernal equinox, then RAAN = 0°.

ROM

Read Only Memory. Refers to the computer memory chips that contain information the computer uses (along with system files) throughout the system, including the information it needs to get itself started. Information in ROM is permanent; it doesn't vanish when the power is turned off. Compare with *RAM*.

CONCEPTS AND TERMS

S

sampling

The process of obtaining a sequence of discrete digital values from a continuous sequence of analog data.

SAR

See *synthetic aperture radar*.

SARSAT

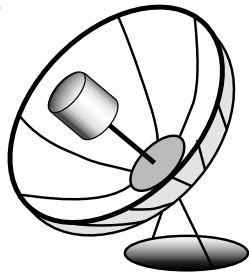
Search and Rescue Tracking System carried on NOAA polar-orbiting satellites that receives emergency signals from persons in distress. The satellites transmit these signals to ground receiving stations in the U.S. and overseas. Signals are forwarded to the nearest rescue coordination center which computes the location from which the emergency signals came and provides the coordinates of the emergency site to a rescue team. See *Search and Rescue*.

satellite

A free-flying object that orbits the Earth, another planet, or the sun.

satellite dish (aka parabolic reflector)

Bowl shaped antennas that collect and focus the signals that a satellite beams down to Earth. The dish reflects the incoming radio frequency energy to a focal point where it can be picked up by a feedhorn antenna to transfer the RF energy to a transmission line. The bigger the dish, the greater will be the intercepted RF energy and hence, the gain. For example, a satellite dish is used to receive *GOES WEFAX* imagery.



Satellite Operations Control Center (SOCC)

NOAA National Environmental Satellite Data and Information Service (NESDIS) Satellite Operations Control Center located in Suitland, Maryland. A principal operating feature of the NOAA system is the centralized remote control of the satellite through command and data

acquisition (CDA) stations. The CDA stations transmit command programs to the satellite, and acquire and record meteorological and engineering data from the satellite. Data is transmitted from CDA to Suitland NESDIS Data Processing Services Subsystem (DPSS). DPSS is responsible for data processing and timely generation of meteorological products and distribution of these products.

satellite orbital elements

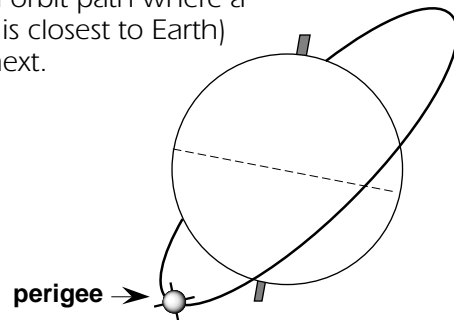
See *Keplerian elements*.

satellite positioning

A procedure by which satellites are used to locate precise objects or particular points on Earth.

satellite revolution

The time from one *perigee* (the point of an elliptical orbit path where a satellite is closest to Earth) to the next.



S-Band

One of the segments or bands into which the radio frequency spectrum above 1000 MHz is divided, designated by letters. Signals from *GOES* and other geostationary spacecraft transmitting on or near 1691 MHz are transmitting on S-Band.

scanner

A system that optically scans its detector(s) across a scene and records or stores the data in a two-dimensional format to form an image.

scanning radiometer

An imaging system consisting of lenses, moving mirrors, and solid-state image sensors used to obtain observations of the Earth and its atmosphere. Scanning radiometers, which are the sole imaging systems on all current operational weather satellites, have far better long-term performance than the vidicon TV camera tubes used with earlier spacecraft.

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scattering

The process by which electromagnetic radiation interacts with and is redirected by the molecules of the atmosphere, ocean, or land surface. The term is frequently applied to the interaction of the atmosphere on sunlight, which causes the sky to appear blue (since light near the blue end of the spectrum is scattered much more than light near the red end).

screaming eagles

Cloud pattern so named because some observers maintain they can see the head of an eagle facing west in these cloud patterns. The pattern is similar to a *comma*, only the pattern is disorganized and not solid. Weather associated with screaming eagles consists of rain showers and gusty surface winds up to about 25 knots. The eagles can intensify and enlarge when moving into areas east of *troughs*; in that case, intense thunderstorms can develop. Screaming eagles are common in the Pacific Ocean between Hawaii and the equator, and are uncommon in the western Atlantic.

sea breeze

Local coastal wind that blows from the ocean to land. Sea breezes usually occur during the day, because the heating differences of land and sea cause pressure differences. Cooler, heavier air from the sea moves in to replace rising warm air on the coastline. See *land breeze*.

sea level

The datum against which land elevation and sea depth are measured. Mean sea level is the average of high and low tides.

Search and Rescue

International satellite-aided search and rescue project. COSPAS/ SARSAT satellites monitor the entire surface of the Earth, and transmit distress signals to special ground receiving stations.

The receiving stations compute the location of the signal, and notify the nearest rescue coordination center. Satellite search has cut recovery time from days to hours, and has aided downed airplanes, capsized boats, and persons in other emergencies.

SEM

See *Space Environment Monitor*, *TIROS*.

semi-major axis (aka a)

One of the six Keplerian elements, it indicates the size of an orbit. The semi-major axis is one-half of the longest diameter of an orbital ellipse, e.g., one-half of the distance between the *apogee* and *perigee* of an Earth orbit. (The semi-major axis is related to the orbital period and mean motion by Kepler's third law. See Kepler's three laws of motion.) See *Keplerian elements* for diagram.

sensor

Device that produces an output (usually electrical) in response to stimulus such as incident radiation. Sensors aboard satellites obtain information about features and objects on Earth by detecting radiation reflected or emitted in different bands of the *electromagnetic spectrum*. Analyzing the transmitted data provides valuable scientific information about Earth.

Weather satellites commonly carry *radiometers*, which measure radiation from snow, ice, clouds, and bodies of water. Spaceborne radars are used for Earth observations, bouncing radar waves off land and ocean surfaces to study sea-surface conditions, ice thickness, and land surface features. A wind scatterometer is a special type of radar designed to measure ocean surface winds indirectly by bouncing signals off the water and measuring them from various angles. Infrared (IR) detectors measure heat generated by Earth features in the IR band of the spectrum.

Photographic reconnaissance sensors in their simplest form are large telescope-camera systems used to view objects on Earth's surface. The bigger the lens, the smaller the object that can be detected. Camera-telescope systems now incorporate all sorts of sophisticated electronics to produce better images, but even these systems need cloudless skies, excel-

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lent lighting, and good color contrast between objects and their surroundings to detect objects the size of a basketball. Some of the satellites produce film images that must be returned to Earth, but a more convenient method is to record the image as a series of digital code numbers, then reconstruct the image from the electronic code using a computer at a ground station.

sensor calibration

The relationship between input and output for a given measurement.

signal

Electrical impulses, sound or picture elements, etc., received or transmitted. Signals can exist in many different forms and media (electrical/wires, acoustic/air, light/transparent fibers, etc.), but all signals will vary with time.

The signal shape plotted as a function of time is called the waveshape or waveform. Some waveforms are repetitive or periodic, that is, a small segment of the waveform repeats itself regularly. Other waveforms, such as noise, are nonperiodic or aperiodic. All waveforms can be distilled into the combination of pure waves called sine waves. The frequency of a sine wave is the rate at which the fundamental shape repeats itself.

Most signals occupy a limited range of frequencies between a lower limit and an upper limit. This range or band of frequencies occupied by a signal is called the *bandwidth* of the signal.

Communication medium or channel can pass only a specific range or band of frequencies, which is called the bandwidth of the channel. The bandwidths of the channel and the signal determine the number and types of signals that can be transmitted by a particular communication channel. Signals often are too small and need to be made larger through a process called amplification. The amount of amplification is measured in decibels. However, amplification is an imperfect process, and inadvertently introduces various distortions, noise, and bandwidth limitations. Often, multiple signals must share the same medium. One way the sharing can be accom-

plished is to place each signal in its own band of frequencies within the total band of the medium. The combining of a number of signals to share a medium by dividing it into different frequency bands for each signal is called *frequency-division multiplexing*.

Frequency-division multiplexing requires the ability to move signals around so that each multiplexed signal occupies its own band.

This is accomplished through a process called *modulation*, in which a high-frequency *sine* wave carries the signal into the specified band. Either the amplitude or the frequency of the carrier wave can be varied, or modulated, in synchrony with the information-bearing signal. These methods are called amplitude modulation (AM) and frequency modulation (FM). FM is the more complex process of the two, and the bandwidth of the FM carrier can be many times that of the modulating signal. The process of demodulating a frequency-modulated signal eliminates much of the deleterious effects of additional noise. (The trade-off between bandwidth and noise immunity characterizes most communication systems. Both are analog modulation schemes for multiplexing signals in the frequency spectrum.)

Digitizing a signal requires a number of steps and results in a binary digital signal that takes on one of two discrete values. This process results in considerable immunity to additive noise, but requires a considerable increase in bandwidth.

signal-to-noise ratio (SNR)

In *decibels* (dB), the difference between the amplitude of a desired *radio frequency (RF)* signal and the internal or external RF noise level in a system. A negative SNR indicates the signal is below the system noise level and unusable. The greater the positive SNR, the less effect noise will have on the final quality. SNR of at least +12dB is necessary to produce imagery with minimal noise effects.

sine wave

A smoothly varying wave that repeats itself; its frequency is the rate at which the fundamental shape repeats itself. Any waveform can be

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distilled into a combination of pure sine waves of varying frequencies and amplitudes.

sink

The process of providing storage for a substance. For example, plants—through photosynthesis—transform *carbon dioxide* in the air into organic matter, which either stays in the plants or is stored in the soils. The plants are a sink for carbon dioxide.

Skylab

The first U.S. space station, launched unmanned in May 1973 and soon after occupied in succession by three crews through November 1973.

SNR

See *signal-to-noise ratio*.

SOCC

See *Satellite Operations Control Center*.

software

The programs, data, or routines used by a computer, distinguished from the physical components (e.g., hardware).

solar backscatter ultraviolet radiometer (SBUV)

Instrument that measures the vertical distribution and total *ozone* in the Earth's *atmosphere*. Data is used for the continuous monitoring of ozone distribution to estimate long-term trends. SBUV instruments are flown on *NOAA polar-orbiting satellites*.

solar constant

Aka total solar irradiance. The constant expressing the amount of solar radiation reaching the Earth from the sun, approximately 1370 watts per square meter. It is not, in fact, truly constant and variations are detectable.

solar cycle

Eleven-year cycle of sunspots and solar flares that affects other solar indexes such as the solar output of ultraviolet radiation and the solar wind. The Earth's magnetic field, temperature, and *ozone* levels are affected by this cycle.

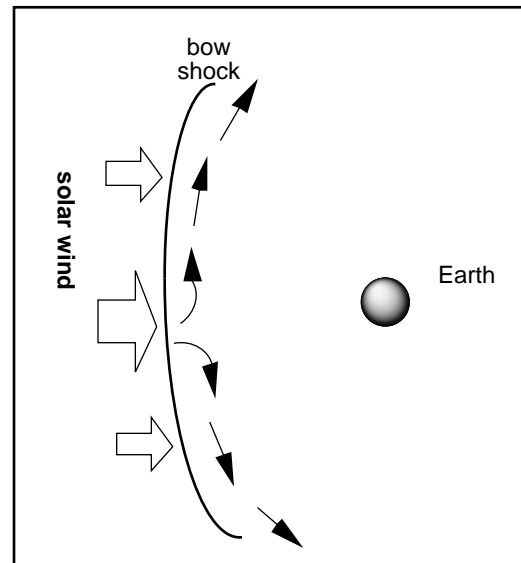
solar radiation

Energy received from the sun is solar radiation. The energy comes in many forms, such

as visible light (that which we can see with our eyes). Other forms of radiation include radio waves, heat (infrared), ultraviolet waves, and x-rays. These forms are categorized within the *electromagnetic spectrum*.

solar wind

A continuous *plasma* stream expanding into interplanetary space from the sun's corona. The solar wind is present continuously in interplanetary space. After escaping from the gravitational field of the sun, this gas flows outward at a typical speed of 400 km per second to distances known to be beyond the orbit of Pluto. Besides affecting Earth's weather, solar activity gives rise to a dramatic visual phenomena in



our atmosphere. The streams of charged particles from the Sun interact the Earth's magnetic field like a generator to create current systems with electric potentials of as much as 100,000 volts. Charged electrons are energized by this process, sent along the magnetic field lines towards Earth's upper atmosphere, excite the gases present in the upper atmosphere and cause them to emit light which we call the auroras. The auroras are the northern (aurora borealis) and southern (aurora Australis) lights.

sounder

A special kind of *radiometer* that measures changes in atmospheric temperature with height, as well as the content of various chemi-

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cal species in the atmosphere at various levels. The High Resolution Infrared Radiation Sounder (HIRS), found on NOAA polar-orbiting satellites, is a passive instrument. See *passive system*.

Space Environment Monitor (SEM)

Instrument that measures the condition of the Earth's magnetic field and the solar activity and radiation around the spacecraft, and transmits these data to a central processing facility. NOAA polar-orbiting and geostationary satellites both carry SEMs. See *TIROS*.

Spacelab

A manned laboratory module built by the European Space Agency (ESA) that accommodates dozens of experiments on each flight, mainly in the categories of materials science and life science.

Spacelink

NASA electronic database for educators, with information stored on a computer at the Marshall Space Flight Center. Via computer, educators communicate with NASA education specialists and access the following menus: current NASA news, aeronautics research, U.S. Space Program historical information, aerospace research in the 1980s and beyond, overviews of NASA and its Centers, NASA educational services, classroom materials, and space program spin-offs. The computer access number is 205-895-0028, the data word format is 8 data bits, no parity, and 1 stop bit—300, 1200, or 2400 baud modem required. Callers with Internet access may reach NASA Spacelink at: spacelink.msfc.nasa.gov.

space physics

Scientific study of magnetic and electric phenomena that occur in outer space, in the upper atmosphere of the planets, and on the sun.

Space Shuttle

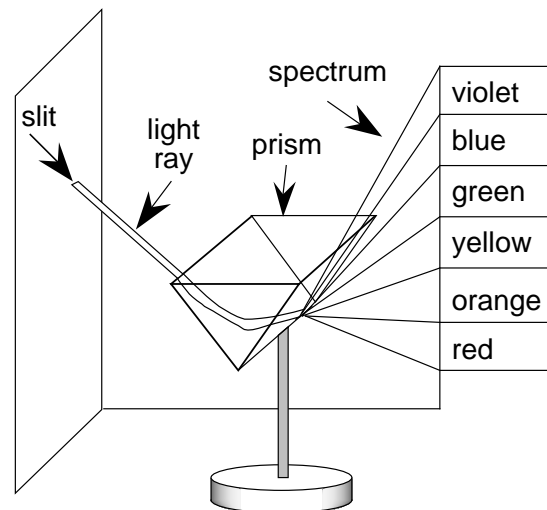
NASA's manned, recoverable spacecraft designed to be used as a launch vehicle for Earth-orbiting experiments and as a short-term research platform.

spectral band

A finite segment of wavelengths in the *electromagnetic spectrum*.

spectrum

1. The series of colored bands diffracted and arranged in the order of their respective wave lengths by the passage of white light through a prism or other diffracting medium and shading continuously from red (produced by the longest visible wave) to violet (produced by the shortest visible wave).
2. Any of various arrangements of colored



bands or lines, together with invisible components at both ends of the spectrum, similarly formed by light from incandescent gases or other sources of radiant energy, which can be studied by a spectrograph.

3. In radio, the range of wave lengths of radio waves, from 3 centimeters to 30,000 meters, or of frequencies of radio waves, from 10 to 10,000,000 kilocycles. Also radio spectrum.
4. The entire range of radiant energies. See *electromagnetic spectrum*.

SPOT

Systeme Pour l'Observation de la Terre. French, polar-orbiting Earth observation satellite(s) with ground resolution of 10 meters. SPOT images are available commercially and are intended for such purposes as environmental research and monitoring, ecology management, and for use by the media, environmentalists, legislators, etc.

SPOT Image

Company that markets data gathered by the

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SPOT satellite worldwide.

start tone

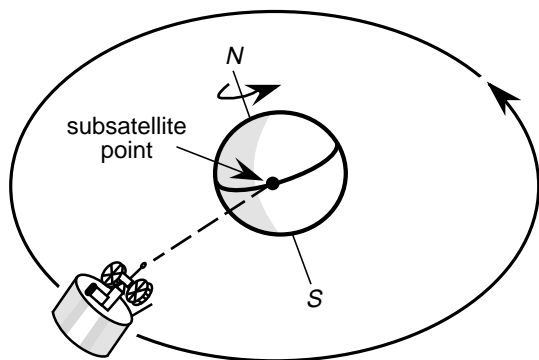
Five seconds of 300 Hz black to white square wave modulation of the WEFAX subcarrier signaling the start of a frame transmission (the beginning of a *direct readout* image).

stop tone

Five seconds of 450 Hz black to white square wave modulation of the WEFAX subcarrier, signaling the stop of a frame transmission (end of a *direct readout* image).

stratosphere

Region of the atmosphere between the troposphere and mesosphere, having a lower boundary of approximately 8 km at the poles to 15 km at the equator and an upper boundary of approximately 50 km. Depending upon latitude and season, the temperature in the lower stratosphere can increase, be isother-



mal, or even decrease with altitude, but the temperature in the upper stratosphere generally increases with height due to absorption of solar radiation by *ozone*.

subcarrier

The 2400 Hz audio tone transmitted by *APT* and *WEFAX* spacecraft. Amplitude modulation of this tone is used to convey video information.

subsatellite point

Point where a straight line drawn from a satellite to the center of the Earth intersects the Earth's surface.

subsatellite track

See *ground track*.

subsystem

1. A subunit of either the physical climate system (e.g., ocean dynamics) or the biogeochemical cycles (e.g., terrestrial ecosystems).
2. A subunit of a spacecraft, e.g., the telemetry subsystem, the power subsystem, the sensor subsystem, etc.

sun

The closest star to Earth (149,599,000 km away on average). The sun dwarfs the other bodies in the solar system, representing approximately 99.86 percent of all the mass in the solar system. One hundred and nine Earths would be required to fit across the Sun's disk, its interior could hold over 1.3 million Earths.

The source of the Sun's energy is the nuclear reactions that occur in its core. There, at temperatures of 15 million degrees Celsius (27 million degrees Fahrenheit) hydrogen atom nuclei, called protons, are fused and become helium atom nuclei. The energy produced through fusion at the core moves outward, first in the form of electromagnetic radiation called photons. Next, energy moves upward in photon heated solar gas—this type of energy transport is called convection. Convective motions within the solar interior generate magnetic fields that emerge at the surface as sunspots and loops of hot gas called prominences. Most solar energy finally escapes from a thin layer of the Sun's atmosphere called the photosphere—the part of the Sun observable to the naked eye.

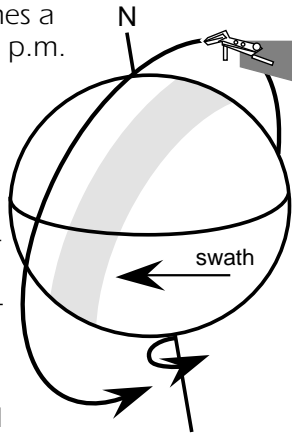
The sun appears to have been active for 4.6 billion years and has enough fuel for another 5 billion years or so. At the end of its life, the Sun will start to fuse helium into heavier elements and begin to swell up, ultimately growing so large that it will swallow Earth. After a billion years as a "red giant," it will suddenly collapse into a "white dwarf." It may take a trillion years to cool off completely.

sun-synchronous

Describes the orbit of a satellite that provides consistent lighting of the Earth-scan view. The satellite passes the equator and each latitude at the same time each day. For example, a satellite's sun-synchronous orbit might cross

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the equator twelve times a day, each time at 3:00 p.m. local time. The orbital plane of a sun-synchronous orbit must also precess (rotate) approximately one degree each day, eastward, to keep pace with the Earth's revolution around the sun.



survey mode

Refers to observational emphasis upon frequent global coverage, usually with restricted spatial and spectral resolution, aimed at developing a consistent, long-term data product for later interpretation.

swath

The area observed by a satellite as it orbits the Earth.

synoptic chart

Chart showing meteorological conditions over a region at a given time; weather map.

synoptic view



The ability to see large areas at the same time.

synthetic aperture radar (SAR)

A high-resolution ground-mapping technique that effectively synthesizes a large receiving antenna by processing the phase of the reflected radar return. The along-track resolution is obtained by timing the radar return (time-gating) as for ordinary radar. The cross-track (azimuthal) resolution is obtained by processing the Doppler phase of the radar return. The cross-track "dimension" of the antenna is a function of the length of time over which the Doppler phase is collected. See *Doppler effect*.

TDRSS

See *Tracking and Data Relay Satellite System*.

telemetry

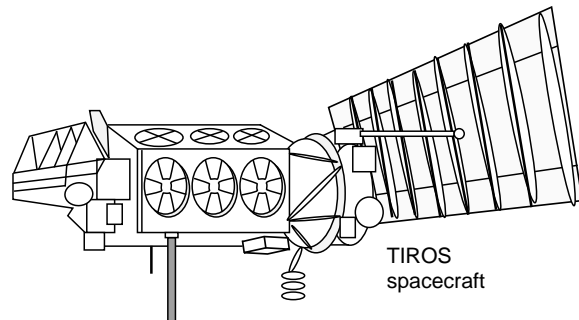
1. Telecommunications transmission to a distance of measured magnitude by radio or telephony with suitably coded modulation, e.g., amplitude, frequency, phase, pulse.
2. Transmission of data collected at a remote location over communications channels to a central station.
3. Surveying measurement of linear distances by use of tellurometer—a device that uses microwaves to measure distance.

telephony

Used to transmit sounds between widely removed points with or without connecting wires.

Television and Infrared Observation Satellite (TIROS)

A series of NASA and NOAA satellites launched to monitor Earth's weather from outer space. The era of the meteorological satellites began with the launch of TIROS-1 on April 1, 1960. For the first time, it was possible to monitor weather conditions over most of the world regularly from space. A series of these satellites were launched throughout the 1960s, those



funded by NASA for research and development were called TIROS, and those funded by the Environmental Science Services Administration (ESSA, the predecessor of NOAA) for the operational system were called ESSA.

A second generation of *ITOS/NOAA** environmental satellites was initiated by the launch of ITOS-1 in 1970, followed by a number of NOAA satellites. The third generation of TIROS-N/NOAA environmental satellites was initiated by the launch of TIROS-N in 1978.

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* Pairs of acronyms such as ITOS/NOAA arise because NASA funds and names its prototype satellites and then the operating agency funds and names the rest of the series.

TIROS-N/NOAA satellites

NOAA satellites that continuously orbit the Earth from North to South Pole (hence, polar orbiting) at an altitude of approximately 470 nautical miles (870.44 km or 540.86 statute miles). These environmental satellites collect visible and infrared imagery and provide atmospheric-sounding data and meteorological data relay and collection. A primary mission of TIROS-N/NOAA is to monitor the 70 percent of the globe covered by water—where weather data is sparse and provide continuous data to the *National Weather Service* for use in numerical forecast modeling. Each TIROS-N/NOAA carries six primary systems:

1. The *Advanced Very High Resolution Scanning Radiometer (AVHRR)* senses clouds over both ocean and land, using the visible and infrared parts of the spectrum. It stores measurements on tape, and later plays them back to NOAA's command and data acquisition stations. The satellites also broadcast in real time, and the broadcasts can be received around the world by anyone equipped with a direct readout receiving station.

2. The *TIROS Operational Vertical Sounder (TOVS)* is a 3-part TIROS system to measure:

- Temperature profile of the Earth's atmosphere from the surface to 10 *millibars*;
- Water content of the Earth's atmosphere;
- Total ozone content of the Earth's atmosphere;

3. The ARGOS Data Collection and Platform Location System (**DCS**) collects data from sensors placed on fixed and moving platforms, including ships, buoys, and weather balloons, and transmits data to a ground station antenna. Because ARGOS also determines the precise location of these moving sensors, it can serve wildlife managers by monitoring and tracking the transmitters placed on birds and animals.

4. The Space Environment Monitor (**SEM**) measures energetic particles emitted by the sun over essentially the full range of energies and magnetic field variations in the Earth's near-space environment. Readings made by these instruments are invaluable in measuring the sun's radiation activity.

5. Search and Rescue Tracking (**COSPAS/SARSAT**) equipment receives emergency signals from persons in distress. The satellites transmit the signals to ground receiving stations. The signals then are forwarded to rescue coordination centers. The rescue centers compute the location of the signals and provide the coordinates of the emergency site (usually within a few miles).

6. Earth Radiation Budget Experiment (ERBE) is a radiometer, flown on NOAA 9 and 10, designed to measure all radiation striking and leaving the Earth. This enables scientists to measure the loss or gain of terrestrial energy to space. Shifts in this energy "budget" affect the Earth's average temperatures. Even slight changes can affect climatic patterns.

temperature

Measure of the energy in a substance. The more heat energy in the substance, the higher the temperature. The Earth receives only one two-billionth of the energy the sun produces. Much of the energy that hits the Earth is reflected back into space. Most of the energy that isn't reflected is absorbed by the Earth's surface. As the surface warms, it also warms the air above it.

terabit

A trillion (10^{12}) *bits*.

thematic mapper (TM)

A *Landsat* multispectral scanner designed to acquire data to categorize the Earth's surface. Particular emphasis was placed on agricultural applications and identification of land use. The scanner continuously scans the surface of the Earth, simultaneously acquiring data in seven spectral channels. Overlaying two or more bands produces a *false color* image. The ground *resolution* of the six visible and short-wave bands of the Thematic Mapper is 30 meters, and the resolution of the thermal infrared band is 120 meters. Thematic map-

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pers have been flown on Landsats-4 and -5.

thermal infrared

Electromagnetic radiation with wavelengths between about 3 and 25 micrometers.

thunder

The sound that results from *lightning*. Lightning bolts (static electricity) produce intense heat. This burst of heat makes the air around the bolt expand explosively, producing the sound we hear as thunder. Since light travels faster than sound, we see the lightning before we hear the thunder.

thunderstorm

Local storm resulting from warm humid air rising in an unstable environment. Air may start moving upward because of unequal surface heating, the lifting of warm air along a frontal zone, or diverging upper-level winds (these diverging winds draw air up beneath them). The scattered thunderstorms that develop in the summer are called air-mass thunderstorms because they form in warm, maritime tropical air masses away from other weather fronts. More violent severe thunderstorms form in areas with a strong vertical wind shear that forces the updraft into the mature stage, the most intense stage of the thunderstorm. Severe thunderstorms can produce large hail, forceful winds, flash floods, and tornadoes.

TIROS

See *Television and Infrared Observation Satellite*.

TM

See *thematic mapper*.

TNL

Thermal Noise Level.

TOGA

See *Tropical Ocean Global Atmosphere Program*.

TOMS

See *Total Ozone Mapping Spectrometer*.

TOPEX/POSEIDON

Ocean Topography Experiment, United States (NASA)/France (CNES). Launched in 1992, the mission carries a radar sensor—called an altimeter—to measure the ocean's surface topography with unprecedented precision.

TOPEX/POSEIDON is a core element of the international *World Ocean Circulation Experiment (WOCE)* and the *Tropical Ocean Global Atmosphere (TOGA)* seagoing measurements program. Mission objectives are to:

- Study ocean circulation and its interaction with the atmosphere to understand climate change better;
- Improve our knowledge of heat transport in the ocean;
- Model global ocean tides;
- Study the marine gravity field;
- Calculate sea-level variations on both global and local scales.

tornado

A twisting, spinning funnel of low pressure air. The most unpredictable weather event, tornadoes are created during powerful thunderstorms. As a column of warm air rises, air rushes in at ground level and begins to spin. If the storm gathers energy, a twisting, spinning funnel develops. Because of the funnel's cloud and rain composition and the dust, soil, and debris it draws up, the funnel appears blackish in color. The most energetic storms result in the funnel touching the ground. In these tornadoes, the roaring winds in the funnel can reach 300 mph, the strongest winds on Earth. Funnel usually travel at 20 to 40 mph, moving toward the northeast. When tornadoes form over lakes or oceans they suck water into the funnel cloud and are called *waterspouts*.

Total Ozone Mapping Spectrometer (TOMS)

Flown on NASA's Nimbus-7 satellite, its primary goal is to continue the high-resolution global mapping of total ozone on a daily basis. The Nimbus-7 launch in 1978 enabled TOMS to begin delivering data in 1979 and continue providing information until 1993. TOMS has mapped the total amount of ozone between the ground and the top of the atmosphere, provided the first maps of the ozone hole, and continues to monitor this phenomenon.

Because of its longevity, TOMS also has

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obtained information on the more subtle trends in ozone outside the ozone hole region. This results from development of a powerful new calibration technique that removes the instrument measurement drift that developed over the years. With this technique applied to the TOMS 14.5-year data record, a global ozone decrease of 2.69 percent per decade was detected.

To ensure that ozone data will be available through the next decade, NASA will continue the TOMS program using U.S. and foreign launches. In 1991, the former Soviet Union launched a Meteor-3 satellite carrying a TOMS instrument provided by NASA. A third TOMS will be launched onboard a NASA Earth probe satellite in 1994, and the Japanese *Advanced Earth Observations Satellite (ADEOS)* will carry a fourth TOMS when it launches in 1996.

TOVS

TIROS Operational Vertical Sounder. See *Television Infrared Operational Satellite (TIROS)*.

Tracking and Data Relay Satellite System (TDRSS)

An orbiting communications satellite, developed by NASA, used to relay data from satellite sensors to ground stations and to track the satellites in orbit.

trade winds

Surface air from the *horse latitudes* that moves back toward the equator and is deflected by the *Coriolis Force*, causing the winds to blow from the Northeast in the Northern Hemisphere and from the Southeast in the Southern Hemisphere. These steady winds are called trade winds because they provided trade ships with an ocean route to the New World. See *wind*.

TRMM

See *Tropical Rainfall Measuring Mission*.

Tropical Ocean-Global Atmosphere (TOGA)

TOGA is a program jointly sponsored by the United Nations World Meteorological Organization (WMO); the International Council of Scientific Unions (ICSU); the United Nations Educational, Scientific, and Cultural Organization

(UNESCO) Intergovernmental Oceanographic Commission (IOC); and the ICSU Scientific Committee on Oceanic Research (SCOR).

TOGA has four major objectives:

- To collect and catalog observations of the tropical atmosphere and ocean;
- To assess the evolution of the tropical atmosphere/ocean system in real time;
- To promote the development of short-term climate-prediction computer models for the tropics;
- To study the influence of the tropical atmosphere/ocean system on the climate at higher latitudes.

Tropical Rainfall Measuring Mission (TRMM)

A joint NASA/NASDA mission planned for launch in 1997. The goal of TRMM is to obtain a minimum of 3 years of climatologically significant observations of rainfall in the tropics. Because rainfall is such a variable phenomenon, adequate sampling is a difficult problem. By averaging the instantaneous rainfall rates for 30 days over a 5° by 5° grid, TRMM will obtain observations that meet climatological requirements. TRMM measurements, used together with cloud models, also will provide accurate estimates of vertical distributions of latent heating in the atmosphere.

The present uncertainty about the quantity and distribution of precipitation, especially in the tropics, prohibits definition of the mass and energy exchange between the tropical ocean and atmosphere. Since the tropical atmosphere and oceans are closely coupled, cloud radiation and rainfall are likely to have significant effects on ocean circulation and marine biomass.

TRMM data will play a significant role in global change studies, especially in developing an interdisciplinary understanding of atmospheric circulation, ocean-atmospheric coupling, and tropical biology. TRMM data on tropical clouds, evaporation, and heat transfer will be used to understand the larger scale coupling of the atmosphere to oceans. See *Earth Probes*.

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tropical storm formation

Tropical storms generally form in the eastern portion of tropical oceans and track westward. *Hurricanes*, typhoons, and *willy-willies* all start out as weak low pressure areas that form over warm tropical waters (e.g., surface water temperature of at least 80 °F). Initially, winds and cloud formations over the warm tropical waters are minimal. Both intensify with time. Formation of tropical storms also requires a significant *Coriolis* effect to induce proper spin in the wind formation. As the storm begins to organize itself into a coherent pattern, it will experience increased activity and intensity.

When a storm develops a clearly recognizable pattern, it is referred to as a tropical depression. When wind speeds reach 35 knots (40.3 mph), it is called a tropical storm and is given a name. When wind speed equals or exceeds 74 mph, the storm is called a hurricane. In the western Pacific, a hurricane is referred to as a typhoon. In waters around Australia it is called a cyclone or willy-willy.

Hurricanes intensify when moving over areas of increased water temperatures, and weaken over colder water surfaces. Upper atmosphere wind shear (different wind direction and speeds at different elevations) will frequently prevent or slow intensification of tropical storms by “spreading out” the storm horizontally and preventing the formation of strong updrafts of warm, humid air. Movement over a land-mass will weaken hurricane winds but will result in large-scale rain that can result in large-scale flooding. When encountering a strong frontal system (such as a polar front) the hurricane will curve and track along the leading edge of the front or become implanted in it.

Satellite infrared imagery can identify surface water temperatures that will foster tropical storm development.

tropics

The area between 23.5 degrees north and south of the equator. This region has small daily and seasonal changes in temperature, but great seasonal changes in precipitation.

troposphere

The lower atmosphere, to a height of 8-15 km above Earth, where temperature generally decreases with altitude, clouds form, precipitation occurs, and convection currents are active. See *atmosphere*.

tropospheric emission spectrometer



A high-resolution infrared spectrometer for monitoring the minor components of the lower atmosphere.

trough

Elongated area of low atmospheric pressure, either at the surface or in the upper atmosphere.

true anomaly (aka J)

One of six Keplerian elements, it locates a satellite on an orbit. True anomaly is the true perigee (perihelion) as seen from the center of the Earth (sun). See *Keplerian elements*.

typhoon

Hurricanes in the Western Pacific Ocean.

ultraviolet radiation

The energy range just beyond the violet end of the visible spectrum. Although ultraviolet radiation constitutes only about 5 percent of the total energy emitted from the sun, it is the major energy source for the stratosphere and mesosphere, playing a dominant role in both energy balance and chemical composition.

Most ultraviolet radiation is blocked by Earth's atmosphere, but some solar ultraviolet penetrates and aids in plant photosynthesis and helps produce vitamin D in humans. Too much ultraviolet radiation can burn the skin, cause skin cancer and cataracts, and damage vegetation.

UARS

See *Upper Atmosphere Research Satellite*

United States Geological Survey (USGS)

A bureau of the Department of the Interior. USGS was established in 1879 following sev-

CONCEPTS AND TERMS

eral Federally-sponsored independent natural resource surveys of the West and Midwest. The Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. The USGS monitors resources such as energy, minerals, water, land, agriculture, and irrigation. The resulting scientific information contributes to environmental-policy decision making and public safety. For example, USGS identifies flood- and landslide-prone areas and maintains maps of the United States.

United States Global Change Research Program (USGCRP)

The USGCRP addresses significant uncertainties concerning the natural and human-induced changes to Earth's environment. The USGCRP has a comprehensive and multidisciplinary scientific research agenda. See *Global Change Research Program*.

Upper Atmosphere Research Satellite (UARS)

UARS is part of a long-term, international program of space research into global atmospheric change. Beginning in 1991, NASA's UARS program began to carry out the first systematic, detailed satellite study of the Earth's stratosphere, mesosphere, and lower thermosphere; establish the comprehensive data base



needed for an understanding of stratospheric ozone depletion; and bring together scientists and governments around the world to assess the role of human activities in atmospheric change. Launched on September 12, 1991, UARS became the first official space component of *Mission to Planet Earth*.

USGCRP

See *United States Global Change Research Program*.

UTC

See *Coordinated Universal Time*.

UV

Ultraviolet. See *ultraviolet radiation*.

Van Allen belts or Van Allen Radiation belts

Doughnut-shaped regions encircling Earth and containing high energy electrons and ions trapped in the Earth's magnetic field (the magnetic field has definite boundaries, and is distorted into a tear-drop shape by the solar wind). Explorer I, launched by NASA in 1958, discovered this intense radiation zone. These regions are called the inner and outer Van Allen radiation belts, named after the scientist who first observed them. See *magnetosphere*.

vernal equinox

The beginning of spring in the Northern Hemisphere. The time/day that the sun crosses the equatorial plane going from south to north.

Very High Frequency (VHF)

Referring to the 50–400 MHz portion of the radio frequency spectrum. Polar-orbiting satellite transmissions (APT) are made in the 136–138 MHz range using FM *modulation*.

video

A signal containing information on the brightness levels of different portions of an image along with information on line and frame synchronization. In the case of satellite signals, the video information is transmitted in the form of an AM modulated *subcarrier*.

visible

That part of the electromagnetic spectrum to which the human eye is sensitive, between about 0.4 and 0.7 micrometers. See *spectrum*.

Visible/Infrared Spin Scan Radiometer (VISSR)

High-resolution, multi-spectral imaging system flown on the pre-GOES-8 geostationary GOES spacecraft. Similar systems are flown on the METEOSAT and GMS spacecraft.

volcano

A naturally occurring vent or fissure at the Earth's surface through which erupt molten, solid, and gaseous materials. Volcanic eruptions inject large quantities of dust, gas, and aerosols into the atmosphere. A major

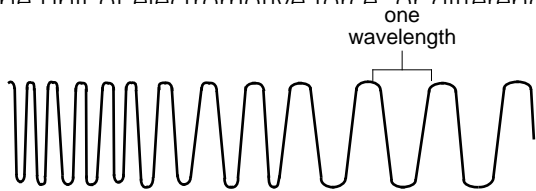
CONCEPTS AND TERMS

W

component of volcanic clouds is sulfur dioxide, a strong absorber of ultraviolet radiation. Chemical interactions between sulfur dioxide and water cause sulfuric acid aerosols which can scatter some of the incident solar radiation back to space, thus causing a global cooling effect. For example, Mt. Pinatubo in the Philippines erupted in June 1991, and in the following year the global surface temperature was observed to decrease by about 0.3° C.

volt

The unit of electromotive force, or difference



of potential, which will cause a current of one ampere to flow through a resistance of one ohm. Named for Italian physicist Alessandro Volta (1745–1827).

Degrees west longitude, referenced to the Greenwich (prime) meridian.

water vapor (aka moisture)

Water in a gaseous form.

wave

1. In electricity, a periodic variation of an electric current or voltage.

2. In physics, any of the series of advancing impulses set up by a vibration, pulsation, or disturbance in air or some other medium, as in the transmission of heat, light, sound, etc.

wavelength

Physical distance of one period (wave repeat).

weather

Atmospheric condition at any given time or place. Compare with *climate*.

Weather Facsimile (WEFAX)

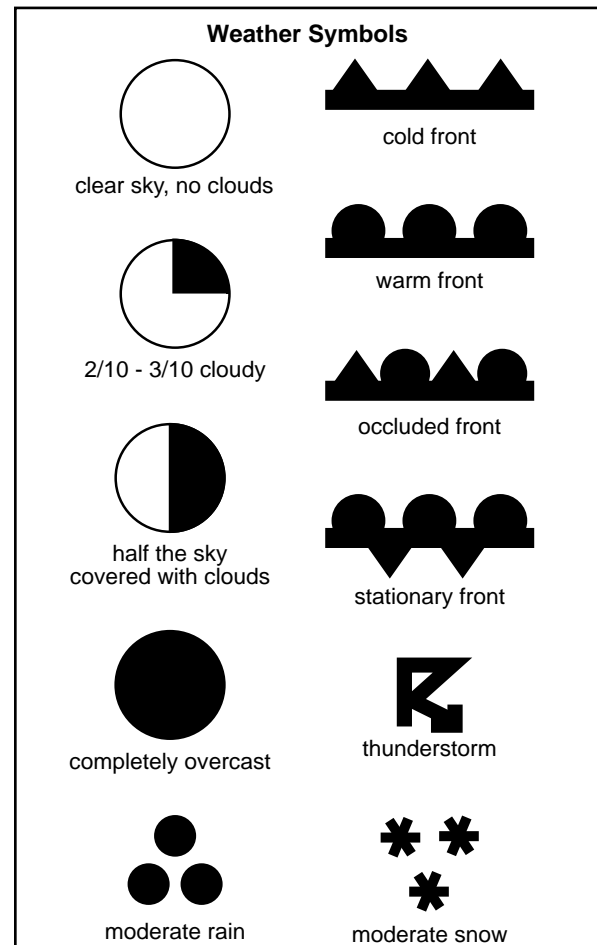
A system for transmitting visual reproductions of weather forecast maps, temperature summaries, cloud analyses, etc. via radio waves. WEFAX transmissions are relayed by NOAA's geostationary GOES spacecraft.

weather symbols

Some commonly used symbols are illustrated in the chart on the right.

weather terms

- **Clear:** Sky cloud-free to 30 percent covered.
- **Sunny:** Sunshine 70-100 percent of the day.
- **Partly sunny** and **partly cloudy:** Both terms refer to 40 to 70 percent cloud cover. Partly sunny is used in the day; partly cloudy is used at night.
- **Fog:** A cloud on the ground. Fog is com-



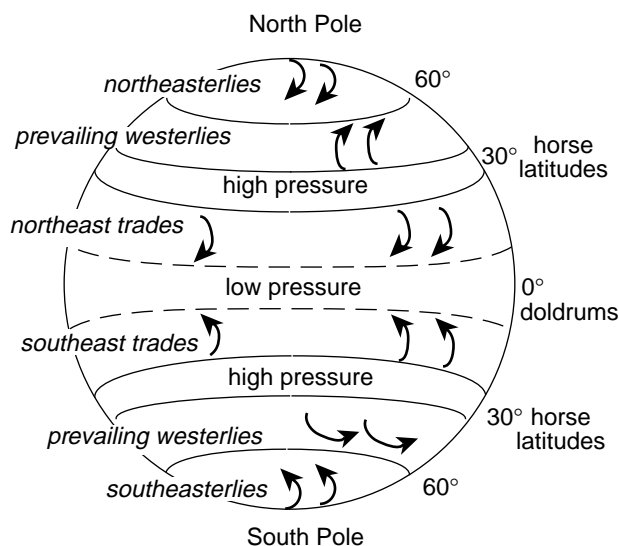
CONCEPTS AND TERMS

posed of billions of tiny water droplets floating in the air.

- **Snow:** Precipitation of ice crystals.
- **Snow flurries:** Intermittent snowfall that may result in little accumulation.
- **Sleet:** Pellets of ice that form when rain or melting snowflakes freeze while falling. (Occurs in cold weather; hail usually occurs in summer.)
- **Freezing rain:** Rain that turns to ice on impact with the surface.
- **Rain:** Extended period of precipitation. Associated with large storm systems rather than single clouds or thunder storms.
- **Showers:** Brief interval of rain that does not affect a large area.
- **Squall:** Fast-moving thunderstorm or line of thunderstorms that often can produce damaging winds, hail, and tornadoes.
- **Hail:** Pieces of ice that fall from thunderstorms. Hail often is composed of concentric rings of ice that form as the particle moves through “wet” and “dry” areas of

MPH	*	Description	Effects
0-1	0	calm	smoke rises straight up; water like mirror
1-3	1	light air	smoke drifts slowly; ripples on the water
4-7	2	slight breeze	leaves rustle; small wavelets
8-12	3	gentle breeze	leaves & twigs in motion; large wavelets
13-18	4	moderate breeze	small branches move; small waves 2-4 feet tall
19-24	5	fresh breeze	small trees sway; whitecaps 4-8 feet tall
25-31	6	strong breeze	large branches sway; whitecaps 8-13 feet tall
32-38	7	near gale	whole trees in motion; waves 13 feet tall
39-46	8	gale	twigs break off trees; waves up to 16 feet tall
47-54	9	strong gale	branches break; waves up to 21 feet
55-63	10	whole gale	trees blown over; waves up to 26 feet
64-73	11	storm	widespread damage; waves up to 35 feet tall
74-up	12	hurricane	widespread damage; large ships sink

* Beaufort Number



Earth's large-scale wind belts

the thunderstorm.

Weather watch

Statement about a particularly dangerous weather system that may occur at some specified time in the future.

Weather warning

Statement that dangerous weather is likely or is occurring. Take action.

WEFAX

See *weather facsimile*.

willy-willy

Australian term for tropical cyclone, *hurricane*.

wind

A natural motion of the air, especially a noticeable current of air moving in the atmosphere parallel to the Earth's surface. Winds are

CONCEPTS AND TERMS

wind speed (mph)	temperature					
	35	30	25	20	15	10
5	32	27	22	16	11	6
10	22	16	10	3	-3	-9
15	16	9	2	-5	-11	-18
20	12	4	-3	-10	-17	-24
25	8	1	-7	-15	-22	-29
30	6	-2	-10	-18	-25	-33
35	4	-4	-12	-20	-27	-35
40	3	-5	-13	-21	-29	-37
45	2	-6	-14	-22	-30	-38

WIND CHILL (degrees F)

caused by unequal heating and cooling of the Earth and atmosphere due to absorbed, incoming solar radiation and infrared radiation lost to space—as modified by such effects as the Coriolis force, the condensation of water vapor, the formation of clouds, the interaction of air masses and frontal systems, friction over land and water, etc.

The chart above is an abbreviated version of the Beaufort Wind Scale, named for the British admiral who invented it in 1805.

wind chill

The wind can reduce significantly the amount of heat your body retains. The following wind chill chart does not take into account such variables as type of clothing worn, amount of exposed flesh, and physical condition, all of which would alter body heat.

simple wind-chill equation

$$T_w = T_A - 1.5 \times V_A$$

$$T_w = \text{wind chill}$$

$$T_A = \text{air temperature}$$

$$V_A = \text{wind speed}$$

For example, if the temperature is 20° and the wind 20 mph:

$$T_w = 20 - 1.5 \times 20$$

$$T_w = 20 - 30$$

$$T_w = -10^\circ \text{ F}$$

wind vane

An instrument used to indicate wind direction.

wind vector

Arrow representing wind velocity. The arrow points in the direction of the wind. The length of the arrow is proportional to wind speed.

wind velocity

Vector term that includes both wind speed and wind direction.

window

Term used to denote a region of the electromagnetic spectrum where the atmosphere does not absorb radiation strongly.

WOCE

See *World Ocean Circulation Experiment*.



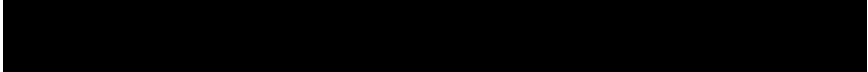
workstation

A “smart” computer terminal that serves as a primary scientific research tool, offering direct access to experimental apparatus, information files, internal computers, and output devices, usually connected to an external communications network.

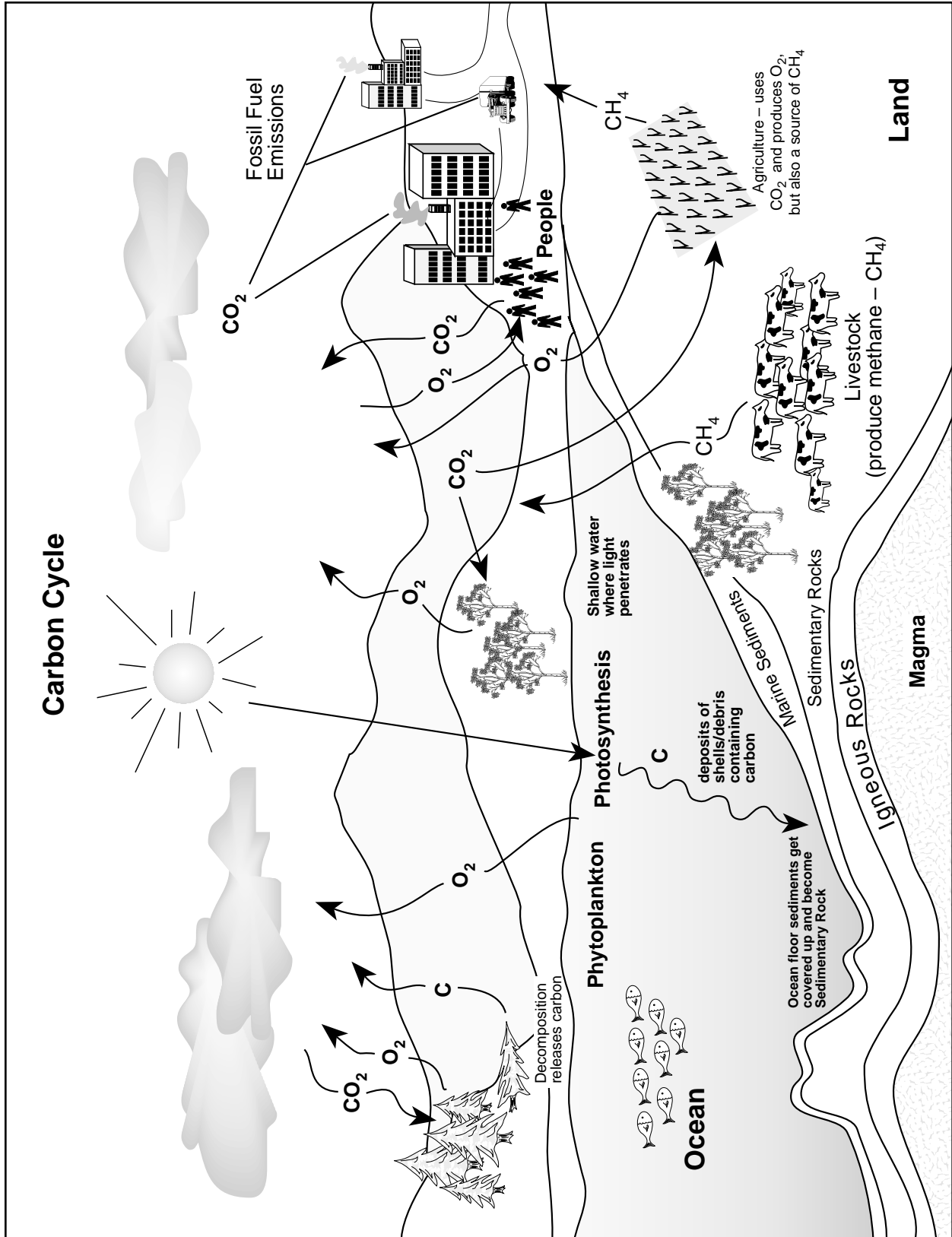


World Ocean Circulation Experiment (WOCE)

A study of the general global circulation of the oceans. It emphasizes the measurements and understanding needed to describe and understand the circulation, to simulate it, and to predict its changes in response to climatic changes.



APPENDIX



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