Standard Tools In Forecasting

Weather Radar

Garry Toth and Don Hillger

Weather observations have traditionally been made by instruments such as thermometers and barometers located at the point where the measurement is made (*in situ*). Unfortunately, it is impossible to place instruments at every point in the atmosphere; it is simply too large. Therefore, measurements can easily miss a thunderstorm or other small scale feature that falls between observing sites. To compensate for this problem, remote sensing techniques have been developed that provide frequent observations of a significant volume of the atmosphere. Earth-orbiting weather satellites provide such data, but ground-based remote sensing is also common. In this article, we will take a philatelic look at ground-based weather radar, sodar, and lidar.

Weather Radar

Weather radar (the word "radar" entered the language as an acronym for **RA**dio **D**etection **A**nd **R**anging) is much more well-known than sodar and lidar. A radar system, consisting of a transmitter, an antenna, and a receiver transmits pulses of radio energy which are reflected back to the antenna, and is measured by the receiver. Certain characteristics of the target, such as its position, can then be identified. The theoretical basis of radar dates from the 1880s when Heinrich Hertz (1857-1894) found that radio waves would pass through some materials but would be reflected or refracted by others (Germany, 1957/*Scott* 762).

Hertz Identified Radar
Germany (*Scott* 762)

Watson-Watt Perfected Radar
Great Britain (*Scott* 1362)

In 1917, Sir Robert Watson-Watt (1892-1973) began work at the British Meteorological Office on the radio detection of thunderstorms. His radio pulse technique eventually became the British radar system that was used to detect enemy aircraft during World War II (Great Britain, 1991/*Scott* 1362). Researchers in other countries also developed radar systems at about the same time. Early in WWII, radar operators found to their surprise that areas of rain could block returns from aircraft. This led to experiments with radar observation of precipitation.

The science of radar meteorology developed quickly after World War II. It was found that for certain radar wave lengths, the microscopic water droplets or ice crystals of which clouds are composed do not return enough power to the receiver to be detected. However, precipitation particles such as raindrops, hailstones, and snowflakes are large enough to be detected. In other words, common weather radars do not "see" clouds; they "see" precipitation. This fact is emphasized in a stamp of Guinea-Bissau (1990/*Scott* 889) in which we find the phrase "echoes of precipitation detected by radar" (in Portuguese). Shorter wavelength radars used for research purposes can detect clouds, but are impractical for operational weather forecasting.

A Radar Reflectivity Scale
Guinea-Bissau (*Scott* 889)

The power returned to the receiver varies over several orders of magnitude, so a logarithmic scale in decibels (**dB**) is used. The returned power measured in decibels is called the radar reflectivity and is symbolized **dBz**. This is the basic unit in radar meteorology. Lower or higher reflectivity values correspond to lighter or heavier precipitation, or to different types of precipitation. Snow gives low reflectivity values while hail gives high values, with rain in between. Reflectivities do not provide direct information about temperature, pressure, humidity, and wind, though the patterns seen in reflectivity data may allow some inferences about those variables.

The most striking part of weather radar is the antenna, a large parabolic bowl with a feedhorn in front of it. The feedhorn, supported by struts, is the part that transmits the radar energy. Various stamps depict weather radar antennas with varying amounts of detail. Bahamas (1973/*Scott* 347) and Senegal (2000/*Scott* 1441) show the antenna, feedhorn, and struts. Barbados (1968/*Scott* 303) and Afghanistan (1989/*Scott* 1358) emphasize a single central feedhorn support, while the antenna on Afghanistan (1989/*Scott* 1360) is drawn incorrectly with neither

Single Central Feedhorn
Barbados (*Scott* 303)

struts nor feedhorn. Other stamps show smaller weather radar antennas in which no details can be discerned. Central African Republic (1964/*Scott* C18) and United Nations New York (1968/*Scott* 188-189) show a nonparabolic antenna design. It is not known if this design was ever used in real weather radars. The Central African Republic stamp is also interesting because it symbolically shows the radar energy moving outward from and then back to the antenna.

What does a weather radar installation look like? The antennas are usually placed on top of a building, tower, pedestal, or hill so that the radar beam will be as much as possible above the ground. If the beam strikes the ground, it will return an unwanted echo known as ground clutter. Radar antennas are often covered by a protective sphere that may resemble a large golf ball. This sphere is called a radome (a neologism for "radar dome"). Nice philatelic examples of weather radar installations are seen on Belize (1986/*Scott* 813a) and Philippines (1965/*Scott* 922-924) with open antennas on top of a building; Japan (1965/*Scott* 833) with radome on a mountain; Pakistan

Radar Antenna With Feedhorn
Bahamas (*Scott* 347)

Radar Energy Moves To And Fro
Central Africa (*Scott* C18)

Radar Dome With Open Antenna
Philippines (*Scott* 924)

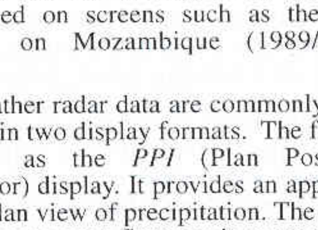
Radome Set On Mountain Top
Japan (*Scott* 833)

(1973/*Scott* 338) with open antenna on a tower; Republic of China (1981/*Scott* 2222) with radome on a pedestal; and Libya (1979/*Scott* 817-819) with radome on a tower. While weather radars are mostly permanent installations, they can be made portable, such as on Iran (1992/*Scott* 2506) in which the radar antenna is mounted on top of a trailer.

Weather radar data must be processed before being displayed on screens in equipment consoles. An older style display console is featured on Belize (1971/*Scott* 971). Modern installations make full use of modern computer work stations and the weather radar data are displayed on screens such as the one shown on Mozambique (1989/*Scott* 1106).

Weather radar data are commonly presented in two display formats. The first is known as the *PPI* (Plan Position Indicator) display. It provides an approximate plan view of precipitation. The radar beam traces out a flat cone in space as the antenna rotates. The radar reflectivities can be presented as colors or shadings on the display screen. For example, Jersey (1988/*Scott* 453) shows two areas of precipitation in the form of lines as they would appear on a *PPI* display.

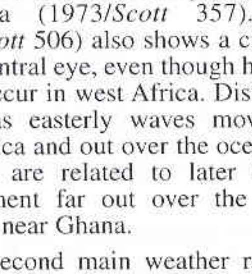
Guinea-Bissau (1990/*Scott* 889) shows a *PPI* display with a large area of precipitation around the station. The scale at the right is the radar reflectivity scale, with lower values in green tones near the bottom, and higher values in various contrasting colors near the top. The meaning of the acronym *SRI* at the top of the scale is uncertain; it may stand for "Storm Reflectivity Index."



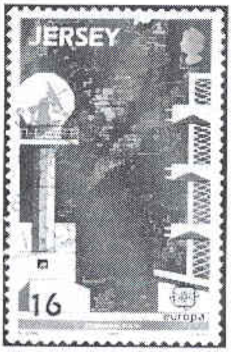
Radome Placed On High Tower
China Republic (*Scott* 2222)

Several stamps show radar views of hurricanes, including the central eye in which skies are clear and no precipitation is found. One nice example is seen on Dominica (1973/*Scott* 357). Ghana (1973/*Scott* 506) also shows a circulation with a central eye, even though hurricanes do not occur in west Africa. Disturbances known as easterly waves move across west Africa and out over the ocean. Some of them are related to later hurricane development far out over the Atlantic, nowhere near Ghana.

The second main weather radar data format is known as the *RHI* (Range Height Indicator) display. To create this display, the radar antenna does not rotate; rather it rocks up and down, and therefore "sees" precipitation returns in a narrow vertical slice of the atmosphere known as a vertical cross section. Only one stamp, Mozambique (1989/*Scott* 1104) is known to feature the *RHI* display. The colors rep-



Radome Mounted On Trailer
Iran (*Scott* 2506)



Radar Scans Precipitation
Jersey (*Scott* 453)

resent various radar reflectivities in what appear to be two or three storm cells through which the beam is passing. No reflectivity scale is included on the stamp.

A newer type of weather radar is based on principles originated by the physicist Christian Doppler (1803-1853). He showed that the frequency of waves striking a detector depends on the motion toward or away from the detector of the object emitting them. Doppler radars make use of this Doppler effect to measure the radial velocity of the wind: the velocity directly toward or away from the radar. The information thus obtained is complicated to interpret, but can be very useful in the hands of a skilled meteorologist. Commercial weather services often advertise Doppler weather radar information, but the images provided to the public are always those of traditional radar reflectivities. No stamps are known to refer to Doppler weather radar, but Doppler is commemorated on a stamp of Austria (1992/*Scott* 1563).

A Hurricane Seen By Radar
Dominica (*Scott* 357)

Weather Radar Data Displayed
Mozambique (*Scott* 1106)

Sodar

Sodar (**SO**nic **D**etection **A**nd **R**anging) systems are similar in principle to radar, but use sound waves instead of radio waves. They are also known as acoustic sounders. Their operation is based on the scattering of sound waves caused by certain patterns of wind, humidity, or turbulence in the atmosphere. The first experiments with acoustic scattering were carried out in the late 1950s in Australia and Russia. Sodar development continued in the 1960s and later in the U.S. and other countries.

The sodar emits an acoustic pulse, and then measures the properties of the returned signal, including the Doppler shift, to calculate the wind speed and direction in the lowest several hundred meters of the atmosphere. Information about the turbulence in that layer is also obtained. The transmit and receive antennas of a sodar system may be collocated, or may in fact be the same antenna.

Sodar systems appear on a few stamps such as (Peoples Republic of China (2000/*Scott* 3067), French Southern and

Doppler Investigated Radar
Austria (*Scott* 1563)

Sodar System Also Used
Hong Kong (*Scott* 420)

Antarctic Territories (1995/*Scott* 206), and Hong Kong (1983/*Scott* 420). While not nearly as common as radar systems, they are important in some meteorological research and data collection projects.

Lidar

Lidar (**LI**ght **D**etection **A**nd **R**anging) systems are also similar in principle to radar, but they use light as the basic element. Lidar systems were developed in the 1960s after the first lasers became available. The original systems were large and complex, with lasers potentially dangerous to human eyes. Modern systems are smaller and use micropulses of light that are safe to the eye.

Lidar systems emit a beam or pulse of laser light which is scattered and absorbed by the atmosphere. The part that returns to the system passes through a telescope to be measured by a photodetector. The processed signals can provide information on a variety of atmospheric variables including wind, temperature, water vapor, ozone, cloud properties, aerosols, particulates, and optical characteristics.

Two stamps are known to refer to ground-based lidar systems. French Southern and Antarctic Territories (1994/*Scott* C131) depicts a lidar station in Antarctica. Australian Antarctic Territory (2002/*Scott* L119a) shows the lidar station at Davis base in Antarctica. Lidar is also mentioned in the text of the margins of Niger (1997/*Michel* 82), but these references are apparently to a space-based rather than a ground-based lidar. Ground-based lidar systems, like sodars, are important in meteorological research.

Conclusion

The development of ground-based remote sensing systems has been of great benefit to meteorology. Radar systems are now a standard tool in weather forecasting, and in the dissemination of weather information. This is especially true in the developed countries possessing the necessary infrastructure to support radar networks. Sodar and lidar are less familiar to the public, but are valuable tools for the research community. All three systems can complement existing networks of meteorological observations, but could never replace them.

A complete list of stamps and other philatelic items that relate to ground-based remote sensing in meteorology can be found at *<http://www.cira.colostate.edu/ramm/hillger/groundbased.htm>*. The authors would be pleased to correspond with readers interested in meteor philately in general, and in ground-based remote sensing in particular.•

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