A Complete Picture: Weather Satellites and Contemporary Meteorology

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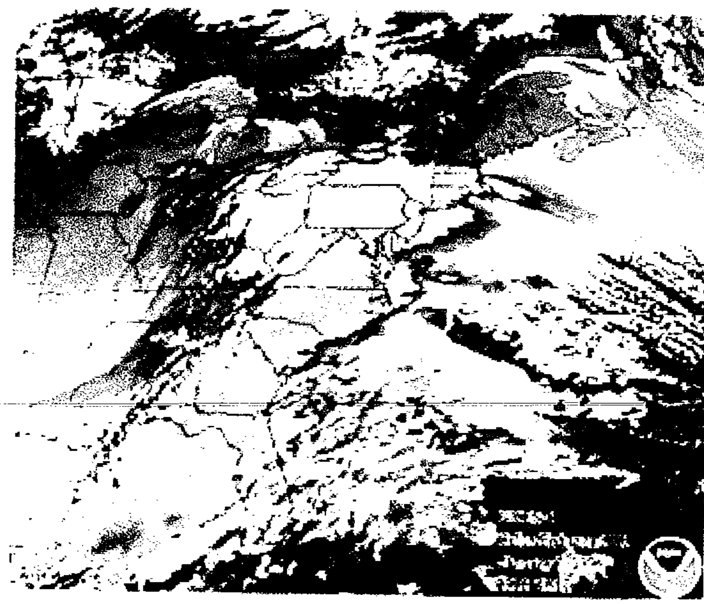

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Weather satellites and remote sensing have formed the backbone of contemporary meteorology, providing detailed analysis for countless meteorological fields over the past 30 years. During the course of an average television weather report, at least one satellite image is shown to demonstrate to a viewer a basic meteorological overview. Although modern meteorology has been heavily impacted by the rapid technological development of weather satellites, the growing ability of meteorologists to correctly interpret and apply information from satellites has revolutionized an industry that hinges on accuracy. Meteorological satellites are depended on to provide pinpoint forecasts, including key fields of extreme weather such as tropical cyclones, snowstorms, and thunderstorm predictions. Now, more than ever, weather satellites are transforming the way we look, predict, and monitor meteorology, and the role of satellites in determining accurate forecasts will only continue to grow in the coming years.

History of Weather Satellites

Certainly, the growth of weather satellites from meteorological obscurity to dependable prominence was not an overnight process. Ever since the United States launched the first weather satellite, Vanguard 2, in 1959, scientists have determinedly pursued the advancement of weather satellites for the purpose of improving day-to-day forecasting. Rapid technological advances in the 1960's fostered the unprecedented growth and surprising versatility of satellites in determining forecasts. Now, meteorologists depend on the unique vantage point and in-depth detail that modern satellites offer forecasters.

Weather satellite technology began rather modestly on February 17th, 1959, when the Naval Department launched Vanguard 2 into orbit. Vanguard 2 was the first attempt by any organization to apply emerging satellite technology with meteorology, although it was unsuccessful, as the mission failed to bring home any satellite photographs.

However, the weather world would not have to wait much longer for a successful satellite mission, for in April 1960, NASA successfully launched TIROS I, which would become the first satellite to provide images of earth from space. TIROS, or Television and Infrared Observation Satellite, measured the infrared radiation given off by the earth and its atmosphere, giving meteorologists an indication of cloud temperatures (based on emitted wavelengths). The success of TIROS I led NASA to launch a total of nine different versions of TIROS between 1960 and 1965. By the end of the TIROS experiment, cameras allowed for more than simple visible photography, gaining the ability to measure cloud height and temperature during day and nighttime hours.

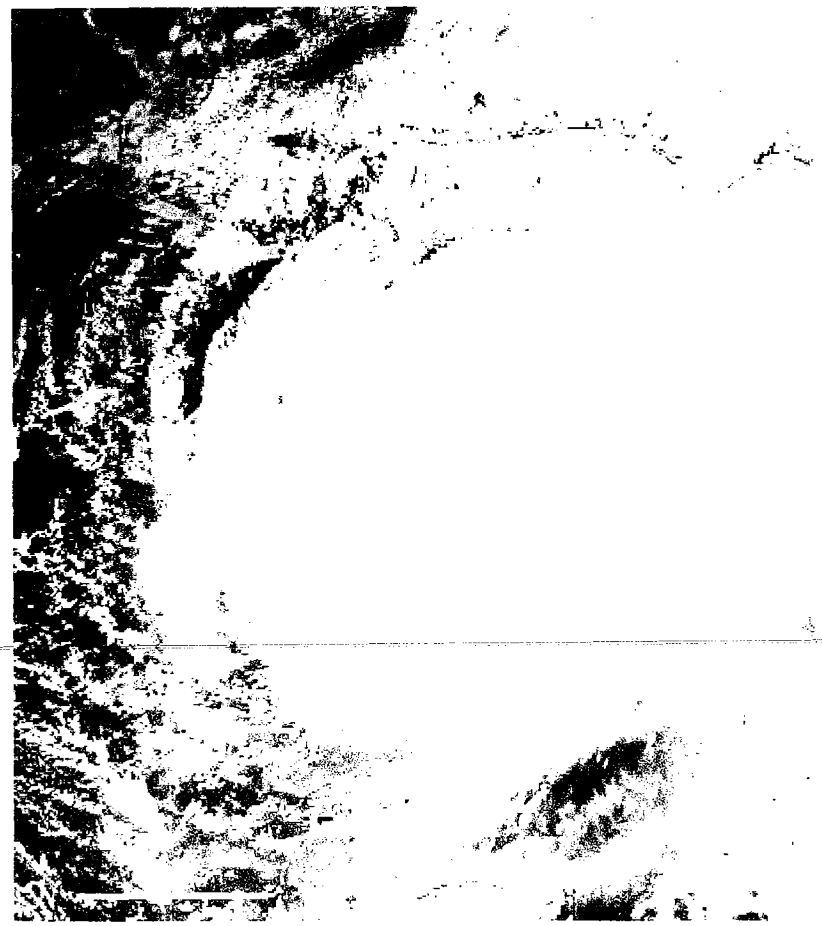
TIROS' success led to the subsequent initiation of another meteorology-oriented space mission in 1964, the Nimbus program. The primary contribution that the Nimbus program gave was the satellites' ability to detect electromagnetic waves, which allowed scientists to differentiate between water vapor and liquid vapor. The seven Nimbus satellites were also able to measure air pressure, ocean and air temperatures, and cloudiness from space, a revolutionary concept that greatly enhanced forecasters' ability to accurately predict the weather. Also, one of the major contributions from the Nimbus program became the satellites' ability to measure temperature through clouds, allowing scientists to detect warm and cold cores in a hurricane, thus allowing meteorologists to determine the strength and prognosis of a tropical cyclone.

Following the Nimbus program's substantial contributions, a new generation of satellites established the foundation for modern meteorological satellite technology. A new realization occurred to NASA scientists; if they could get a satellite to orbit the earth at the same speed as the planet's rotation, a particular point on the earth's surface could be covered by a satellite at all hours. Thus, geostationary satellites, known as GOES, became the first weather satellites to offer continuous coverage of a fixed point on the earth's surface. However, the GOES project initially carried some image-quality concerns, due to the high altitude required for the geostationary satellites to orbit at the same speed as the earth's axis. But, over the course of twenty years, scientists have largely ironed out the resolution problems that initially plagued the GOES project. The GOES project also uniquely featured the instant transmission of images and photographs back to earth, allowing meteorologists to have up-to-the-second access to satellite imagery for the first time. Over forty years after the first launch of a GOES satellite, two GOES satellites (GOES-11 and GOES-12) remain in orbit, providing photographs that critically influence a weather forecast on a day-to-day basis. The GOES satellites are credited as being the basic backdrop for contemporary weather forecasting.

With the actual satellite technology seemingly uncovered, meteorologists shifted their attention to efficiently sorting through the information provided by the satellites. Satellites, beginning in the early 1990's, had the capability to interact with remote ground-based observational platforms (ocean buoys, mountain peaks) and transmit the information to land-based stations. With such a high influx of raw data coming into the National Weather Service (NWS), federal agencies teamed up with the NWS to form more than 800 Automated Surface Observing Stations (ASOS) across the United States to better coordinate remote sensed information. Following the installation of the ASOS network, meteorologists were better able to send and receive surface observations, effectively intertwining satellite and surface observations to form one large and efficient weather observation network.

In order to further maximize data and consolidate time, the NWS devised the Advanced Weather Interactive Processing System (AWIPS) to assemble every tool necessary to provide an accurate forecast at a meteorologist's fingertips. Combining NEXRAD (Doppler radar), ASOS, and computer model forecasts, AWIPS is essentially a giant computer that collects satellite, radar, and computer information and renders a total picture of the atmosphere. AWIPS machines, located in over a hundred locations nationwide, are amongst some of the more modern contributions to a new era of meteorology, where satellites and surface observations are teaming up to provide a comprehensive, detailed and easily discernable forecast for meteorologists.

Currently, the United States operates four different weather satellites continuously: GOES-11, GOES-12 and NOAA-17 and NOAA-18. The two GOES satellites are, as discussed, geostationary and are capable of monitoring a fixed location at any time by traveling at the same speed as the earth. However, the two NOAA satellites are polar-orbiting satellites, or satellites that travel over the earth from north to south, intersecting at the earth's poles. Since geostationary satellites often have rather poor resolution on their photographs, NOAA maintains the two polar-orbiting satellites for picture-clarity purposes. Polar-orbiting satellites, unlike geostationary satellites, can travel closer to the earth's surface and take higher-resolution weather images. Of course, the major drawback to a polar-orbiting satellite is that it cannot cover a fixed location at all times (since it is traveling perpendicular to the earth's rotation) and thus can only take pictures in six to twelve hour intervals.



<u>Uses and Applications of Satellites in Modern Forecasting</u>

Since their inception into mainstream meteorology in the 1960's, satellites have become increasingly reliable and depended on by weather forecasters. With all the technology in place to create an accurate forecast, the only task left for meteorologists to ponder is how to apply the satellite technology into their forecasts. Hurricanes, thunderstorms and simple low pressure centers can be easily monitored and tracked by weather satellites, but the controversial question of deserting human observation and intuition in favor of satellite technology remains. The answer, according to WABC-TV meteorologist Bill Evans, is to combine both human observation and satellite technology to create one effective forecast.

"You do what's called 'now-casting'," Evans said. "You look at the weather as it is happening, since weather is a fluid motion and it's always moving, and you try and apply both satellite and personal thought into creating a good forecast."

Although every aspect of weather forecasting has undergone considerable change due to satellites, the study of hurricanes has undoubtedly been the most significantly impacted by satellite technology. For most fields satellites are a key part of a forecast, but for tropical cyclones, satellites form the basic foundation for a cyclone's prognosis.

"Now that we have the Dvorak Method for hurricanes, we can determine the wind speed in a hurricane from a satellite picture," Evans said. "Before satellites it was almost impossible to monitor the inter-tropical convergence zone, but now it's simple."

The Dvorak Method, first put into full meteorological practice in the 1990's, takes a satellite photograph of a tropical cyclone and determines its wind speed, trajectory, and growth potential. The method, according to Evans, saves the government money by limiting dependency on costly Air Force reconnaissance aircraft and allows a meteorologist to "forecast a hurricane from a desk".

Aside from the Dvorak Method, whose full credibility is not etched into stone yet, satellites provide essential images to a meteorologist that provide a clear picture of a tropical cyclone's status. Satellite loops detail the track and likely trajectory (although tropical cyclones are notorious for rapidly shifting course) of a tropical cyclone through simple optical observation. Cold fronts, wind shear and low pressure systems are easily detected on satellite imagery and are crucial elements to determining the track and strength of a hurricane. Satellites are not just a useful tool in the study of tropical cyclones; they are the start and end of any credible forecast for the tropics.

Certainly, tropical studies are not the only meteorological aspect to feel the revolutionary impact from weather satellites. The study of thunderstorms and tornadoes has received a significant boost from the advancement in weather satellite technology, especially with the development of water vapor imagery. Although the advancement of radar has certainly made a greater impact on thunderstorm predictability, satellites have nonetheless contributed significantly to predicting thunderstorms. The aforementioned water vapor imagery pinpoints with great accuracy areas of instability in the atmosphere and also precisely detects cloud temperatures, allowing meteorologists the ability to confidently predict thunderstorm "hot spots" days in advance.

"We use infrared to look at cloud tops and how high they are," Evans said. "Satellites are a basic building block to determining a good thunderstorm forecast."

Day-to-day meteorology has undergone a rapid transformation courtesy of satellite technology, but the study of climatology has also reaped the benefits of having an eye above the sky. Global warming and major climate shifts (such as El Niño) are easier to identify through satellite monitoring.

"There's a lot of satellites that do studies around the earth with drought and El Niño and black holes at different poles," Evans said. "We know a lot more about what's happening on earth thanks to the satellites."

But ultimately, for a regional meteorologist such as Evans, weather satellites provide a solid starting point for any forecast.

"These days, we show a satellite image right after we show the temperatures," Evans said. "You can create a whole forecast off a satellite loop."

Conclusion

The increase in advanced warning of extreme weather events can be directly tied to the improvements and adjustments made to weather satellites in the past 40 years. But concerning the next 40 years and beyond, certainly, the outlook for the role of satellites in weather forecasting is auspicious. Constant changes and adjustments are being made to satellites as we speak, and the weather world will continue to lean an even bigger shoulder on weather satellites. Within the past ten years, AWIPS and the Dvorak Method have taken the weather world by storm, basing their revolutionary forecasting methods on weather satellites. And with a world possibly undergoing a weather revolution of its own, satellites may be the tip of the key to unlock a feasible remedy to global warming.

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Picture Credits:

Page 1: Google Image: GOES-8 Satellite photo of USA east coast.

Page 6: NOAA picture: Hurricane Rita in the Gulf of Mexico