Seeing which way the wind blows: New doppler radar takes flight on this summer's HS3 mission

August 1 2013

The HIWRAP dual frequency Doppler radar will hang under the Global Hawk. On the left, the golden disc is the antenna and on the right, the two small white discs are the radar beam transmitters, one for each of two frequencies. The whole apparatus spins while flying. Credit: Bill Hrybyk / NASA

(Phys.org) —Most aircraft carrying Doppler radar look like they've grown a tail, developed a dorsal fin, or sprouted a giant pancake on their backs. But when the unmanned Global Hawk carries a radar system this summer, its cargo will be hard to see. The autonomous and compact High-altitude Imaging Wind and Rain Profiler, or HIWRAP, a dual-frequency conical-scanning Doppler radar, will hang under the aircraft's belly as it flies above hurricanes to measure wind and rain and to test a new method for retrieving wind data.

HIWRAP is one of the instruments that will fly in this summer's mission to explore Atlantic Ocean hurricanes. NASA's Hurricane and Severe Storm Sentinel, or HS3, airborne mission will investigate tropical cyclones using a number of instruments and two Global Hawks. The HS3 mission will operate between Aug. 20 and Sept. 23.

"Radar is an important remote sensor for atmospheric research," said Lihua Li, an engineer who helped develop HIWRAP at NASA's Goddard Space Flight Center in Greenbelt, Md. "Radar signals penetrate clouds and precipitation, allowing scientists to detect information on raindrops or ice particles." That information, he said, is one piece of the puzzle toward improving scientists' understanding of weather events.

This past year, Li and his colleagues further improved their radar technology to make it more effective at high altitudes. The ultimate goal is using radar to measure weather events from space.

Building a better radar

Before fully appreciating the team's accomplishments, it's important to understand how radar works. Under these systems, a transmitter sends a microwave pulse into the atmosphere. After it strikes a target, like a cloud particle, the microwave breaks apart into many return microwave frequencies, which then bounce back to the instrument. The returning microwave frequencies are different from the original pulse from the radar. From those differences, scientists can identify cloud particles as rain, ice or a mix. The returning microwave frequencies also reveal water content and the particles' size, shape, and distribution.

Radars send out several thousand of these pulses each second. The result is a three-dimensional image from the cloud top to the ground of what's going on inside storms and hurricanes.

To generate and send a rapid number of microwave pulses, radars generally need a lot of power. To have better sensitivity and accuracy, radars generally need big receiving antennas. But radars flying high above Earth's surface have strict limits on the size, weight, and power consumption of the instruments.

NASA's Global Hawk lifts off the runway at NASA's Wallops Flight Facility, Wallops Island, Va. on Sept. 19, 2012, during the 2012 HS3 mission. The Global Hawk took off to investigate Tropical Storm Nadine near the Azores Islands in the Eastern Atlantic Ocean. Credit: NASA Wallops

Engineers had to balance all these things against the science requirements for HIWRAP, which was designed to fly on the sleek Global Hawk. Since 2005, Li and Gerry Heymsfield, who leads Goddard's High Altitude Radar group, have pushed the design envelope with HIWRAP. They began with using compact transmitters that use less power, a digital receiver that gives them more flexibility to modify the outgoing microwave pulses, and a scanning antenna that widens HIWRAPs area of view below. Looking a bit like an upside-down golden flower, HIWRAP weighs in at about 300 pounds and has a footprint the size of a small washing machine.

But most significant are new advancements that push the boundary of radar capability both on long-endurance flights and at high altitudes. HIWRAP can measure the Doppler effect of moving ice particles and raindrops from 60,000 feet.

Blowing in the wind

It's the setup of a classic physics problem. As a train thunders by a railroad crossing, its roar changes as it moves closer, zooms past and recedes away. At the crossing, the movement of the train running into or away from its own sound waves changes the sound's observed pitch, or frequency, in what's called a Doppler shift.

With a few measurements and equations, the Doppler shift of a frequency can reveal how fast the train is moving. Scientists interested in raindrops or other atmospheric particles use the same principle. Doppler radar sends out pulses of microwaves whose frequency will shift when they bounce off moving raindrops, and scientists can use this to figure out how fast ice or rain is moving in storms.

Detecting movement of rain and other precipitation tells scientists about another piece of the atmospheric puzzle—wind. "[With Doppler] we sense the motion of rain or ice particles in storm clouds," said Heymsfield, who has been working to improve high-altitude radar measurements for 20 years. "From that we can get the horizontal winds and the circulation in hurricanes."

Li noted that Doppler measurements also have been used to estimate the size of the rain or ice particles. Together with the wind data, HIWRAP provides data sets on tropical cyclones critically needed for improved understanding and forecasting these weather events.

Straightforward, yet challenging

While Doppler physics is straightforward, in reality it's very challenging. One difficulty is that the return frequencies from the target rainfall and clouds come back with a clutter of other things that also bounce back a signal, like the ground or ocean surface. To get the Doppler velocity of rain, for instance, you then have to separate all those signals.

An added complication arises when the radar is on an aircraft or a satellite. "The instrument itself is moving, so it also has Doppler information," Li said. "This makes the retrieval of rain or ice particle Doppler velocity extremely difficult." The aircraft has a high ground speed, which causes a wider range of frequencies to be returned from the targets and the magnitude of the Doppler shift to get bigger. This Doppler effect has to be distinguished from the Doppler effect of the cloud and rain target. Imagine trying to measure the velocity of a toy train with an instrument whizzing by on a full-sized train 12 miles away, the height of a high-altitude plane. Or, imagine taking measurements from 250 miles away—the altitude of a satellite in space.

One way to get a better return signal from high-altitude aircraft is to send out more radar pulses, more quickly. HIWRAP sends out 5,000 pulses per second. For a satellite passing over the ground at about 12,000 mph, it's even more important to have a rapid series of pulses. But too many pulses per second can muddy the measurement if the returning Doppler-shifted frequencies overlap. Scientists need a way to distinguish which returning frequency corresponds with which emitted pulse. For HIWRAP's upcoming HS3 mission, Li and his team will test a method of putting an identifier on each outgoing microwave pulse.

He and his colleagues incorporated the necessary modifications to the outgoing radar pulses into HIWRAP's transmitter and receiver. While the technique has the potential to improve measurements on any Doppler radar, especially those on aircraft, its true impact will be on the next generation of precipitation satellite radars that will view rain worldwide every few hours. Currently, only two satellites carry radar in space and neither returns particle motion.

"Doppler implementation will be the next step," Li said. "That's what we are pushing for."

Provided by NASA

Citation: Seeing which way the wind blows: New doppler radar takes flight on this summer's HS3 mission (2013, August 1) retrieved 23 April 2024 from https://phys.org/news/2013-08-doppler-radar-flight-summer-hs3.html