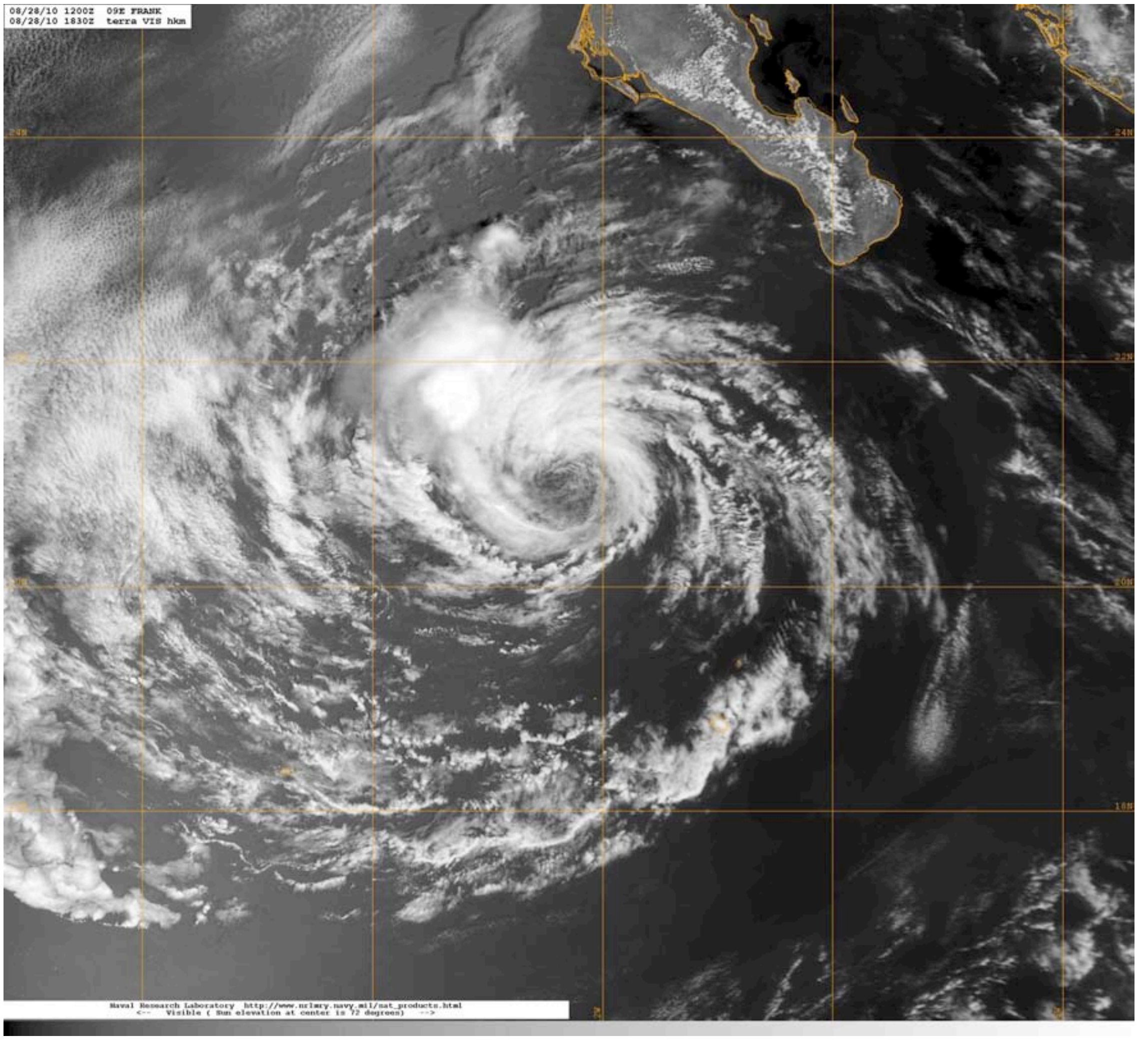
Some observations on the first flight of the Global Hawk into a Tropical Cyclone

On 28 August 2010, NASA and NOAA scientists collaborated in the effort to conduct a first ever high-altitude flyover of a tropical cyclone with a UAS, the NASA Global Hawk. At the pre-dawn hour of 6:00 AM PDT, the Global Hawk took off autonomously from the runway in the desert at Edwards AFB, California and spiraled over the Air Base to gain high altitude before heading west to the Pacific Ocean. An hour before the takeoff and after a pre-flight briefing, a group of about 20 scientists, engineers, pilots, and technical and aircraft support personnel were at their assigned stations in a specially designed operations room at the NASA Dryden Flight Research Center at Edwards already monitoring all aspects of the jet's mechanical, electrical, communications, and scientific instrument status. They were prepared to staff, conduct, and monitor this flight for up to 18 hours.



The purpose of the flight was to test the Global Hawk's capability to overfly the weather conditions that could be expected within a tropical cyclone and, to test and evaluate the retrieval and transmission back to the ground station, data collected from several sophisticated remote-sensing instruments, including a radar and profilers. The target was a low-pressure system in the Eastern Pacific basin, just south of the Baja Peninsula in Mexico, and that was Hurricane Frank a couple of days before.

After an hour or so of conducting spiral maneuvers over the desert to gain altitude and perform detailed checks of the scientific instruments, the Global Hawk reached an altitude of about 50,000 feet and headed west towards the mountainous coastline of California. Watching with keen interest and awe, we saw real-time imagery from a specially designed high-definition and wide-angle camera mounted on the belly of the Global Hawk. It soon became apparent that this imagery was not only invaluable to help guide the scientists towards atmospheric targets and to assist the pilots to avoid weather hazards, but could be used to provide detailed structures of cloud patterns and types to aid in evaluating data from the scientific instruments onboard.

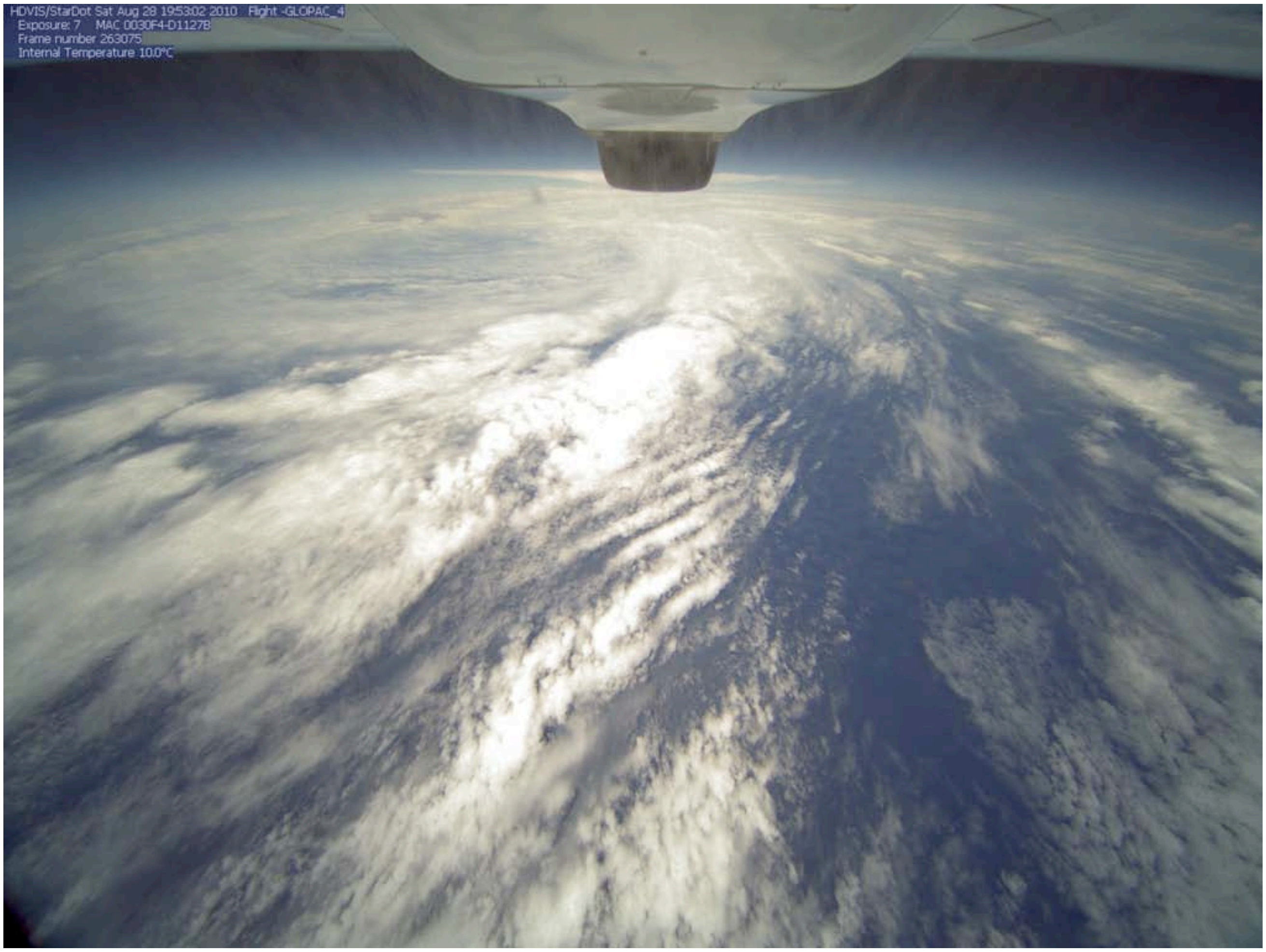
This type of imagery is not only very valuable and useful scientifically, but it is also almost unprecedented. It provides a look from above the clouds like a satellite might give you but with much better horizontal resolution and at a much higher time rate. As the Global Hawk was approaching the California coastline, spectacular imagery of the mountains and fog banks that frequently inundate the coast and inland valleys was relayed to us on the ground. We knew also that soon we would be seeing the huge expanse of shallow stratocumulus clouds that almost always occur in this region because of the cool water temperatures and stable atmosphere just above the sea surface. It is the combination of cool water and dry, stable air that partially led to the demise of Hurricane Frank and that resulted in the tropical low that the Global Hawk was now headed to.

Some three hours into the flight, it was now time for the mission scientists to evaluate the conditions of our targeted storm and make any necessary changes to our pre-planned flight track. NASA and NOAA shared the mission scientist's role to coordinate with and advise the Global Hawk pilots of real-time aircraft track changes and conditions that could be expected at an altitude of about 60,000 feet. We knew that the storm had very little active thunderstorm activity left in it but it was still a large and vigorous circulation and some bursts of convection could be expected. We had planned to conduct a square-spiral pattern around the storm with box patterns getting successively closer to the storm's center. After flying the western and southern, periphery of the cyclone, a small area of convection, just to the north of the storm center was beginning to blossom. This was our target! Not only could this convection help to evaluate the ability of the Global Hawk to overfly such weather, it would gives us data over a deeper layer of the atmosphere to validate the scientific instruments on board. We decided to stop flying the box pattern and instead ask the pilots if they could head north, close to the storm center and above the cloud tops to the northwest, These clouds now had temperatures at their tops of near -50°C, about the limit that the Global Hawk was prepared to do on this day.

The pilots, relying on our expertise and their own extensive training, agreed and they remotely changed the course of the aircraft. The mission scientists used a combination of NOAA and NASA real-time satellite products, superimposed with current, past, and future positions of the aircraft, to decide where the aircraft should head to so as to obtain the best possible data without placing the plane at risk of turbulence or other adverse conditions. These real-time satellite products and the use of the belly camera were indispensible for evaluating these conditions.

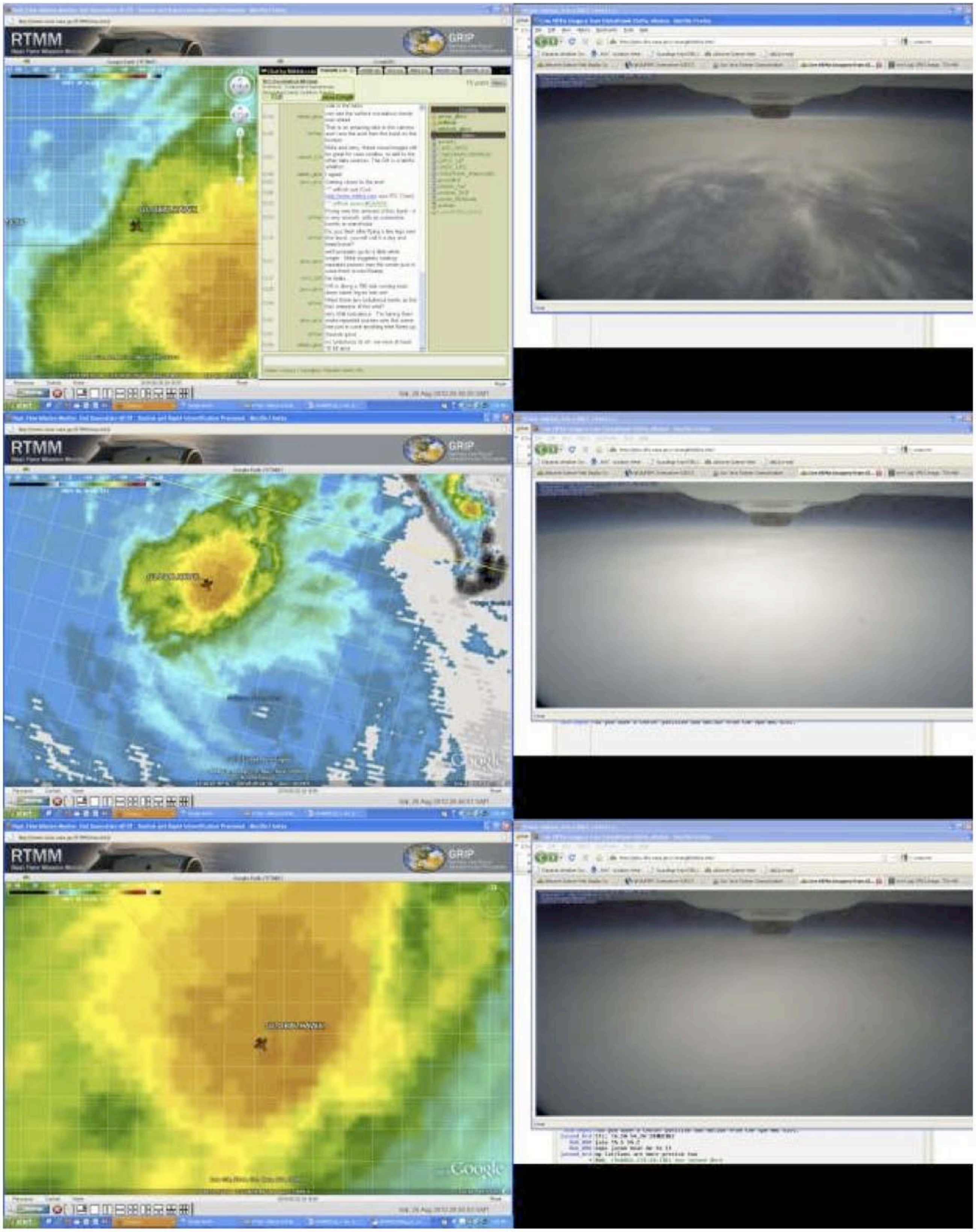
As we headed north toward the center of the tropical cyclone, we witnessed more spectacular and valuable imagery. Not only could we see the spiral bands that were encircling the storm, but also we could see the tightly-wrapped bands of shallow convection that made up the very center of the storm.

One might be able to see this from satellite imagery but not with the kind of detail time resolution. We were getting a new image every half-minute compared to about 30 minutes apart with typical satellite data.



The Global hawk passed just to the east of the storm center as it approached the convective burst to the north. From the aircraft camera system, we could see both the clouds below the aircraft and the cirrus cloud shield ahead and near our flight altitude of 58,000 feet. We estimated that with cloud-top temperatures of -45° C to -50 ° C, as measured by the satellite date we were monitoring, that the Global Hawk should fly a safe distance of about 10,000 feet above the cirrus cloud deck. Air temperatures measured by instrumentation on the Global Hawk was a frigid -72°C. Our estimates proved correct and we had the opportunity to compare satellite imagery at the precise time and location of the aircraft with the view from the Global Hawk camera looking down at the cirrus cloud shield.

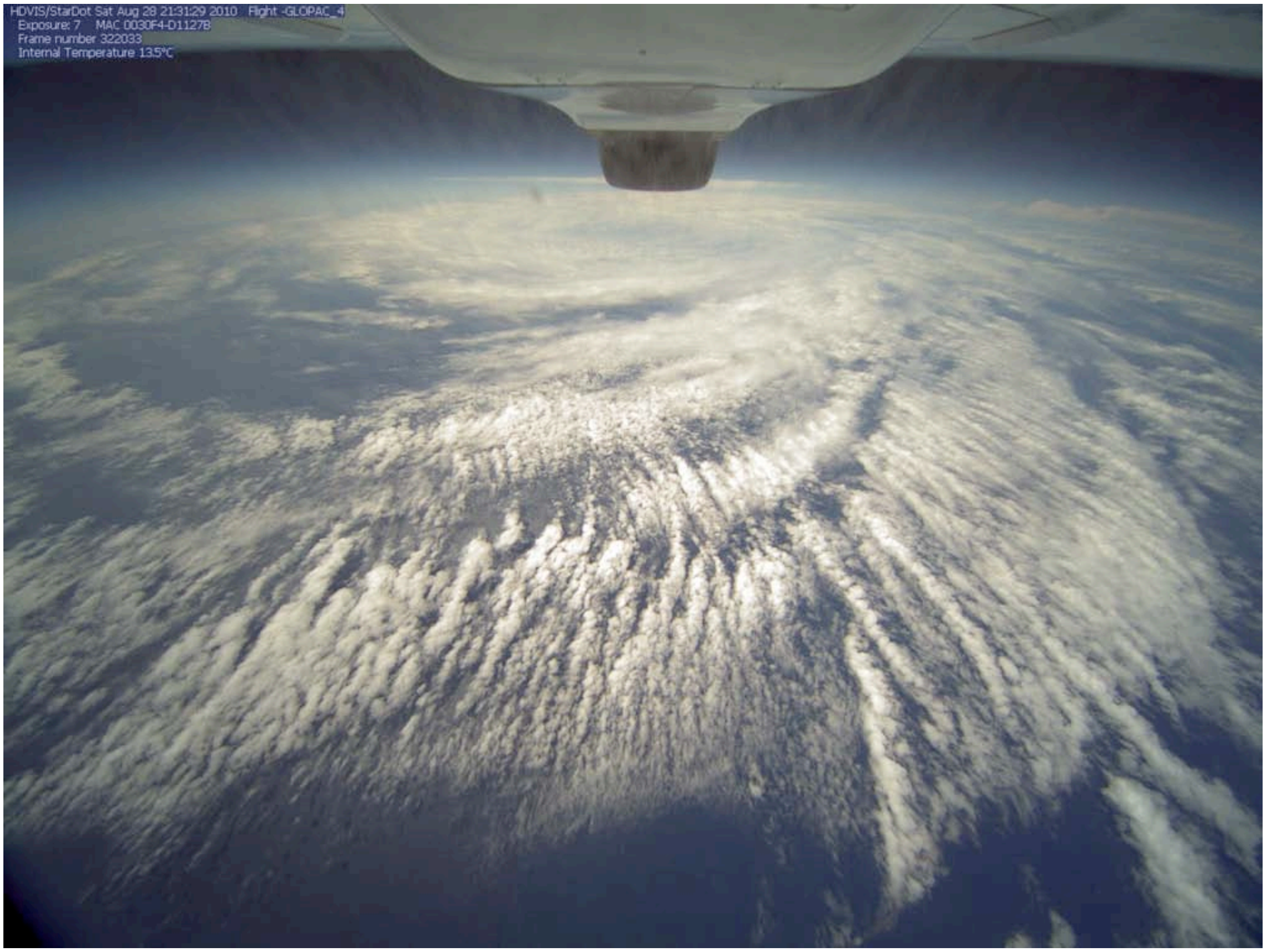
The aircraft passed safely over the cirrus canopy, collecting data from the radar and profilers that were pointing downward and penetrating through the clouds. We then asked the pilots to turn the aircraft around and back though the same area for a second look. As the plane performed this maneuver, we saw that the convection was decaying and that the cirrus shield was now the remnants of what had been a vigorous burst of convection an hour or so earlier. This was obvious from the vantage point of being 60,000 feet in the air but not as obvious from satellite imagery alone.

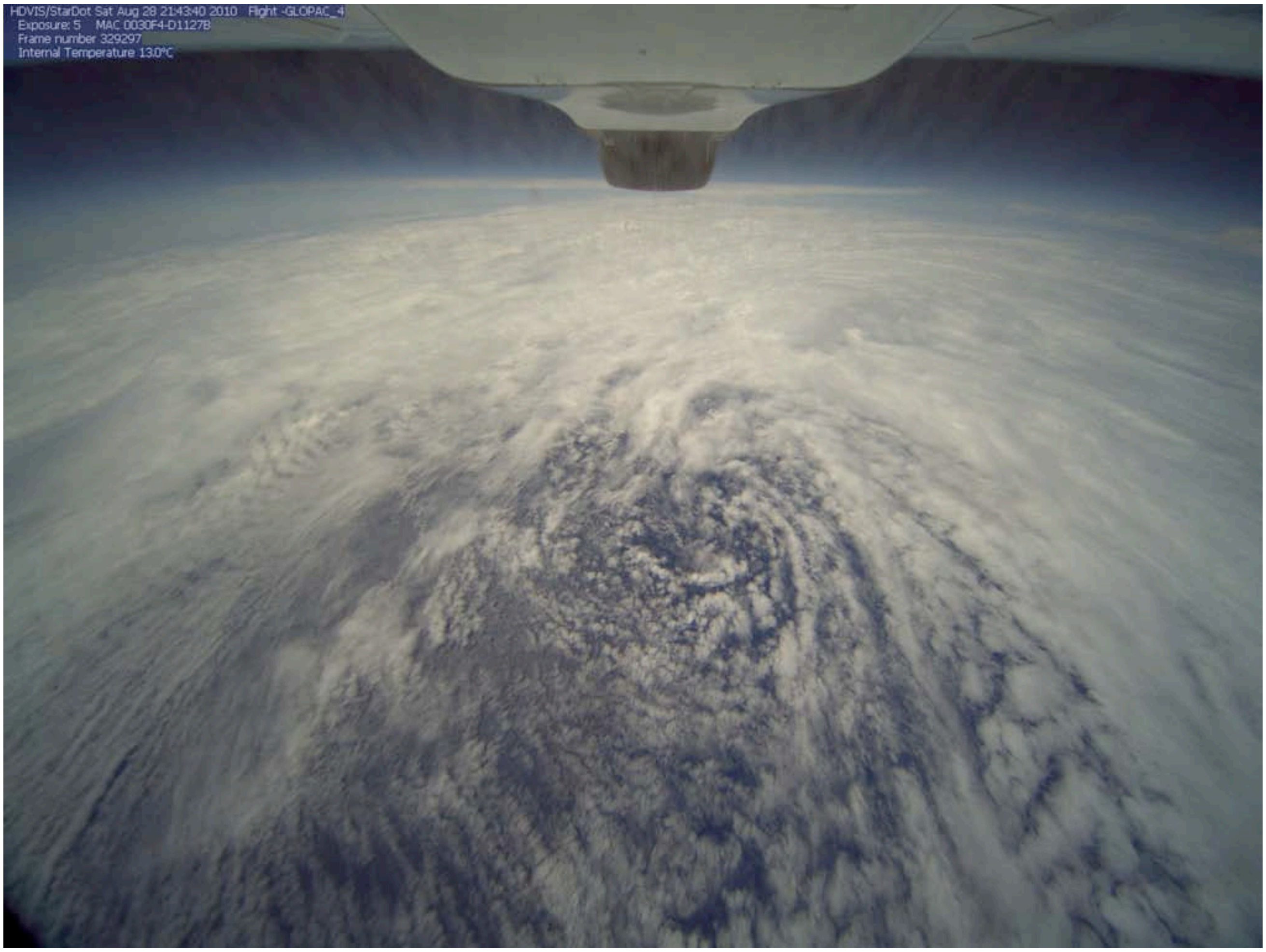


The mission scientists then decided to ask the pilots to direct the Global Hawk to head back to the south of the storm center in the hope that a new convective burst might occur and that the plane could sample. We knew, though, that the thermodynamic conditions in this area were not conducive for supporting thunderstorm initiation and growth. The remnants of Frank were now almost completely one big, spinning array of shallow rainbands.

After going about 60 miles south of the storm center we realized that is was highly unlikely that any new thunderstorms would form, given the environmental conditions and time of day. We would direct the Global hawk north, directly over the center this time and head back to Edwards early unless some signs of convective initiation were evident.

We had one more surprise from the Global Hawk after the plane turned around and headed north, toward the storm center. Imagery from the camera underneath the aircraft showed remarkable structure in the rainbands near the periphery of the circulation of the cyclone. These appeared to be boundary-layer rolls, small but very organized, parallel lines of shallow convection oriented perpendicular to the wind field. These types and other, similar roll clouds, are an active area of research within the tropical cyclone community and the Global Hawk could provide valuable information about their structure and distribution within the tropical cyclone environment. The remote sensing instruments could provide further information about the structure of these remarkable clouds.





After overflying the storm center, which was comprised of very tightly-spaced spiral or sharply-curved bands of stratocumulus clouds, we saw no evidence of new convection and decided to have the Global Hawk return to California. We had already accomplished what we wanted to: that the Global Hawk could safely and effectively over fly clouds and convection in a tropical system; that imagery and data could be transmitted and viewed from our ground operations center and; that we could easily and effectively make real-time changes to our pre-planned flight pattern. After months of preparation and hard work from the NASA and NOAA scientific and technical staff involved with the Global Hawk all working as one team, we were all glad to tell the Global Hawk to fly home. The next bigger and more challenging test for the Global Hawk and the NASA and NOAA team would come soon enough in a Hurricane named Earl, gaining strength and marching west in the Atlantic.

Michael Black

Hurricane Research Division, NOAA/AOML