AQUA'S FIRST 10 YEARS: AN OVERVIEW

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NASA's Aqua spacecraft was launched at 2:55 a.m. on May 4, 2002, from Vandenberg Air Force Base in California, into a near-polar, sun-synchronous orbit at an altitude of 705 km. Aqua carries six Earth-observing instruments to collect data on water in all its forms (liquid, vapor, and solid) and on a wide variety of additional Earth system variables (Parkinson 2003). The design lifetime for Aqua's prime mission was 6 years, and Aqua is now well into its extended mission, approaching 10 years of successful operations. The Aqua data have been used for hundreds of scientific studies and continue to be used for scientific discovery and numerous practical applications.

Aqua's six Earth-observing instruments include three sounders, these being the Atmospheric Infrared Sounder (AIRS), the Advanced Microwave Sounding Unit (AMSU), and the Humidity Sounder for Brazil (HSB). AIRS is unique to Aqua and has 2378 infrared channels and 4 visible/near-infrared channels, far exceeding the number of channels of previous satellite sounders. AMSU and HSB, in contrast, are both near-copies of sounders that have flown previously. Aqua's other three instruments are the Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E), provided by the Japan Aerospace Exploration Agency (JAXA), the Moderate Resolution Imaging Spectroradiometer (MODIS), and the Clouds and the Earth's Radiant Energy System (CERES). MODIS and CERES are also on the Terra satellite, launched in December 1999, and both Aqua and Terra have two CERES sensors and one MODIS. The AMSR-E was the first AMSR in orbit; a second AMSR, AMSR2, is expected to be launched on Japan's Global Change Observation Mission – Water (GCOM-W) in 2012.

Despite being several years beyond its design lifetime, the Aqua spacecraft and four of its Earth-observing instruments (AIRS, AMSU, MODIS, and CERES) continue to operate well. The HSB failed on February 5, 2003, and the AMSR-E ceased operation, at least temporarily, on October 4, 2011, after over nine highly successful years. There is enough fuel on board Aqua for at least several more years of operation and perhaps operation well into the 2020s.

Approximately 100 core data products concerning the Earth's atmosphere, hydrosphere, cryosphere, and biosphere are routinely derived from the Aqua data. These data have been used in well over 2,000 scientific publications, which in turn have been cited over 25,000 times. The following illustrate the many important ways the Aqua data have been and are being used in scientific studies:

-- AIRS/AMSU data provided the first global maps of carbon dioxide (CO_2) in the mid troposphere and revealed the CO_2 distributions to be strongly influenced by the mid-latitude jet streams, synoptic weather systems, and the strength of the Northern Hemisphere annular mode (Chahine et al. 2008; Jiang et al. 2010).

-- AIRS/AMSU data have led to improved understanding of the impact of the Saharan Air Layer on hurricane formation and intensification (Shu and Wu 2009).

-- AIRS/AMSU data have yielded improved understanding of gravity waves in the middle atmosphere (Alexander and Barnet 2007) and possible effects of gravity waves on the formation of polar stratospheric clouds (Eckermann et al. 2009).

-- AMSR-E all-weather measurements have provided unprecedented global monitoring of sea surface temperatures (Chelton and Wentz 2005), which, for one example, have been used with AMSR-E ocean surface wind and integrated water vapor measurements to estimate ocean-atmosphere latent heat flux (Konda et al. 2009).

-- AMSR-E data have provided all-weather measurements with sufficient resolution to resolve leads in sea ice and have been used to study the large-scale processes governing the seasonal variability of sea ice in the Southern Ocean (Kimura and Wakatsuchi 2011).

-- AMSR-E data have extended to high latitudes the high-quality precipitation retrievals of the Tropical Rainfall Measuring Mission (TRMM).

-- MODIS fluorescence data provide the first synoptic view of phytoplankton physiological stress due to iron limitation (Behrenfeld et al. 2009).

-- MODIS data have been used to identify oceanic blooms of trichodesmium, a species of cyanobacteria linked to toxic red tides (Hu et al. 2010).

-- The enhanced, 'deep-blue' MODIS aerosol algorithm allows derivation of aerosol properties over bright reflecting surfaces, such as deserts, overcoming a limitation of earlier algorithms that were appropriate only for aerosols above dense vegetation and oceans (Hsu et al. 2004, Levy et al. 2007).

-- CERES top-of-the-atmosphere radiation data from the Aqua and Terra satellites and in-situ measurements of ocean heat content have been used to calculate that in recent years the Earth has been accumulating energy at a rate of approximately 0.5 ± 0.43 Wm^{-2} (Loeb et al. 2012).

-- CERES-derived outgoing longwave radiation (OLR) and AIRS-derived surface temperature, atmospheric temperature, and water vapor have been analyzed to determine regional differences in the sensitivity of OLR to the other three variables, finding a 'super greenhouse effect' in the tropical convective region (Dessler et al. 2008).

-- CERES radiative flux data have been used with aerosol data from the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) to suggest that aerosols have a pronounced direct radiative effect, reducing outgoing shortwave radiation at the top of the atmosphere (Yorks et al. 2009). Similarly, CERES and other Aqua data are being used in conjunction with data from numerous other satellites in a variety of additional collaborative studies of the Earth system.

-- Aqua data are being used to extend many earlier data sets, with the important goal of generating long-term climate data records (CDRs).

Although the Aqua mission was developed largely for its anticipated scientific contributions, Aqua data also have numerous practical applications. As anticipated well before launch, the high accuracy of the AIRS temperature and water vapor measurements have led to their incorporation in weather forecast models, with resulting measurable improvements in forecast skill (Cardinali 2009). Additionally, the AMSR-E sea surface temperature, water vapor, and precipitation data have been used by hurricane prediction centers; and incorporation of MODIS polar wind data in weather forecast models has resulted in improved forecasts for the polar regions and beyond (Le Marshall et al. 2008).

Other practical applications of the Aqua data, many greatly facilitated by Aqua's direct broadcast capability, include: the use of MODIS data by the U.S. Forest Service and other forest services around the world to monitor forest fires; the use of AIRS and MODIS data by airplane pilots and aviation administrations to monitor volcanic emissions and help steer planes clear of volcanic ash; the use of the AIRS data by the Environmental Protection Agency for air-quality analyses; the use of CERES data by utility companies for energy management; the use of MODIS data by the U.S. Department of Agriculture for monitoring crop yields and drought; the use of CERES data by the Department of Agriculture in analyses of the factors affecting crop yields; the use of AMSR-E sea surface temperature data by the Japanese fishing industry in their analyses of local and regional fishing conditions; the use of AMSR-E and MODIS data for the monitoring of floods and their aftermath; the use of MODIS data for monitoring oil spills and dust storms; the use of MODIS data for monitoring phytoplankton blooms and hence identifying regions abounding with marine life; and the use of AMSR-E and MODIS data for sea ice monitoring by ships maneuvering in polar oceans.

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