National Aeronautics and Space Administration

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Editor's Corner

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We reported in our last issue on the preparations for the launch of the Global Precipitation Measurement (GPM) Core Observatory. The launch window has now been officially scheduled from 1:07 PM to 3:07 PM EST Thursday, February 27 (3:07 AM to 5:07 AM JST Friday, February 28). The spacecraft will launch aboard a Japanese H-IIA rocket from the Japan Aerospace and Exploration Agency's Tanegashima Space Center.

While looking forward to the GPM launch, as a community we are greatly saddened by the passing of **Arthur Hou** in November 2013. Arthur had served as the GPM Project Scientist since 2005. (For more on Arthur's career and accomplishments, please see the *In Memoriam* on page 4 of this issue.) Subsequently, **Gail Skrofronick-Jackson** [NASA's Goddard Space Flight Center (GSFC)] has been appointed as the new GPM Project Scientist. She is eminently qualified for the position having been the GPM Deputy Project Scientist since 2006 and recently appointed as the chief of GSFC's Mesoscale Atmospheric Processes Laboratory. Our best to Gail in her new position, as well as the entire international GPM team on the upcoming launch.

In this issue we have two items related to the GPM mission. The first is a report on the Iowa Flood Studies (IFloodS) that took place in northeastern Iowa from May 1 to June 15, 2013—see page 12 of this issue. Ground, radar, and satellite data collected during IFloodS will be used to quantify the size and shape of raindrops,

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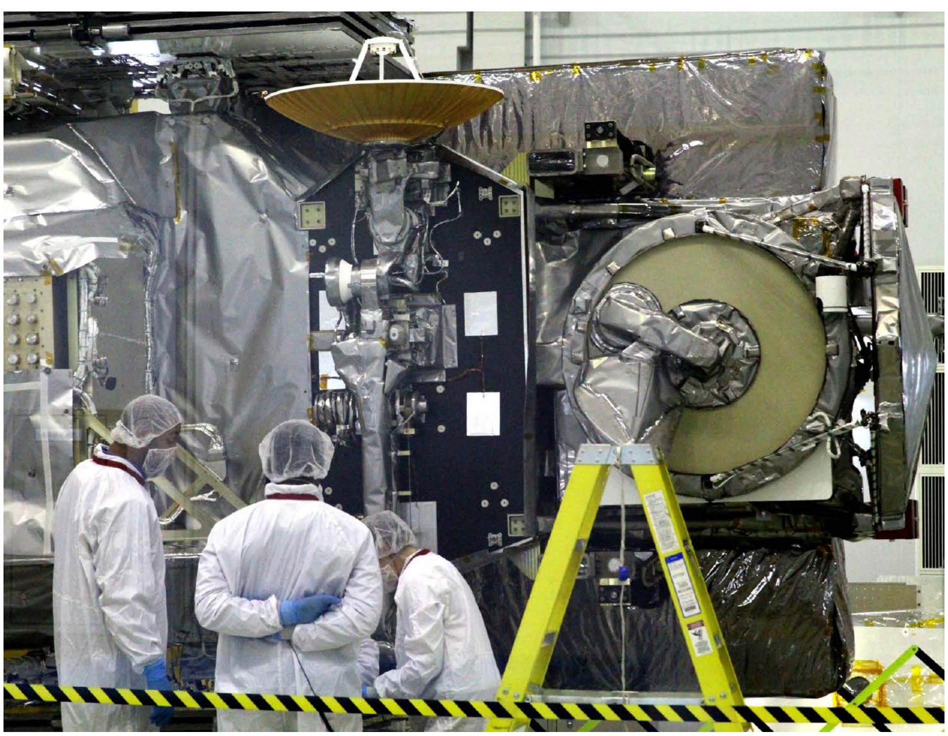

Engineers perform precision tests on the completed GPM spacecraft prior to launch, scheduled for February 27. **Image credit:** NASA, Michael Starobin

the earth observer

In This Issue

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the physics of ice and liquid particles throughout the cloud and below as they fall, temperature, air moisture, and distribution of different size droplets. The ultimate objective is to improve rainfall estimates from satellites, and in particular the algorithms that will interpret raw data from GPM Core and constellation satellites to help in predicting the development of floods.

The second GPM-related activity that we report in this issue is the recent GPM Applications Workshop that took place at NOAA's Center for Weather and Climate Prediction at the University of Maryland, College Park—see page 26 of this issue. Building on the legacy of its predecessor, the Tropical Rainfall Measuring Mission (TRMM), data from GPM will be used to study hurricanes, extreme rainfall events, provide inputs to climate and land-surface models, and offer new insights into agricultural productivity and world health. The workshop brought together a diverse group of scientists, data users, and end users. NASA's Applied Sciences Program intends for this to be the first in a series of workshops organized to keep the lines of communication open between the science teams and the user community.

Meanwhile, the Aquarius mission continues to perform well, two-and-a-half years after launch. To the delight of oceanographers around the world, Aquarius generates weekly maps of the global salinity field at the ocean surface. An improved salinity product (from a new version of the salinity algorithm) is being evaluated and should be available to the public early this year. In addition, the Aquarius soil moisture product is available at *nsidc.org/data/aquarius*. The Aquarius website has also been updated—*aquarius.umaine.edu/cgi/index.htm*—and contains many examples of Aquarius data including salinity maps, maps of radio frequency interference, and soil moisture maps. Turn to page 5 to learn more about Aquarius' recent achievements and plans for the future.

We reported in the last issue about the successful launch of the Total Solar Irradiance Calibration Transfer Experiment (TCTE) on the U.S. Air Force's STPSat-3 satellite. TCTE is operating nominally and *total solar irradiance* (TSI) cross-calibration activities between TCTE and NASA's SORCE satellite were successfully completed in late December. Obtaining overlap with TSI observations from SORCE (in orbit since January 2003) is crucial for continuing the longterm record of TSI, and a tremendous accomplishment given SORCE's battery-related power management issues described in our last issue[1]. Congratulations to the TCTE and SORCE teams!

With more than four decades of Earth remote sensing observations that can be used to study Earth's changing climate available from NASA and other satellite missions, *data preservation* has become an extremely important topic and a key focus area for NASA's Earth Observing System Data and Information System (EOSDIS) data centers. As an example of this important effort, turn to page 19 to learn about the Goddard Earth Sciences Data and Information Services Center's data preservation efforts for the High Resolution Dynamics Limb Sounder (HIRDLS) on Aura.

Recently, there were two high profile science-conference venues that highlighted NASA Earth Science activities. The most recent meeting of the Conference of the Parties (COP-19) of the United Nations Framework Convention on Climate Change (UNFCCC) was held November 11-22, 2013, at the National Stadium in Warsaw, Poland. The Department of State hosts and coordinates the United States' contribution each year. NASA's contribution to the *U.S. Center* featured hyperwall presentations from several senior NASA scientists and highlighted key climate programs and scientific research. Turn to page 25 to learn more about NASA's COP-19 presence.

The American Geophysical Union's (AGU) Fall Meeting took place December 9-13, 2013 in San Francisco, CA. NASA's exhibit represented the scope of the agency's science activities (including Earth science, planetary science, and heliophysics) while introducing visitors to a variety of science disciplines, research topics, data products, and programs from all of NASA's field centers. Read more about NASA's AGU activities on page 22.

While it is evident from this issue that 2013 ended with a flurry of activity, 2014 promises to be an exciting year for NASA Earth Science. In addition to the imminent launch of GPM, OCO-2 and SMAP are also scheduled for launch in 2014, as well as the deployment of CATS and RapidScat to the International Space Station. We look forward to beginning a new era in precipitation, soil moisture, clouds and aerosols, ocean topography, and related measurements, that in years to come will add to our knowledge of the state of the planet. ■

[1] See the Editorial in the November–December 2013 issue of *The Earth Observer* to learn more [**Volume 25**, **Issue 6**, p. 2].

Acronyms Not Defined in Editorial and Article Titles (in order of occurrence)

Editorial

STPSat-3	Space Test Program Satellite
SORCE	Solar Radiation and Climate Experiment
OCO-2	Orbiting Carbon Observatory - 2
SMAP	Soil Moisture Active Passive
CATS	Cloud-Aerosol Transport System
RapidScat	Rapid Scatterometer

Article Titles

GES DISC	Goddard Earth Sciences Data and Information Services Center
CERES	Clouds and the Earth's Radiant Energy System
USGS	United States Geological Survey
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations

Arthur Y. Hou

(1947–2013)

It is with profound sadness that we report the passing of **Dr. Arthur Hou**, Project Scientist for the upcoming Global Precipitation Measurement (GPM) mission. Arthur passed peacefully at home on November 20, 2013. His passing coincided with the date that GPM was shipped to Japan for its planned launch at the end of February.

Under Arthur's humble and dedicated leadership, GPM has become a truly global team effort. He excelled in providing scientific oversight for achieving GPM's many science objectives and application goals, including delivering high-resolution precipitation data in near-real time for better understanding, monitoring, and prediction of global precipitation systems and high-impact weather events such as hurricanes. Arthur successfully cultivated international partnerships around the globe, and because of his commitment to precipitation measurement science, a new capability will soon be in orbit.

Arthur began his career at NASA's Goddard Space Flight Center (GSFC) in 1990. Early on he worked in the planetary sciences, studying Venus and Uranus. Later he turned to Earth science and did pioneering work on the effect of tropical heating on the Hadley Circulation. He was also highly involved with Earth science data assimilation, and later served as the NASA deputy project scientist for the joint NASA-Japan Aerospace Exploration Agency (JAXA) Tropical Rainfall Measuring Mission (TRMM). His research interests included dynamic meteorology, climate modeling, and data assimilation, focusing on the use of space-based observations of clouds and precipitation in global modeling through data assimilation.

Arthur was not only a superb scientist, he was also a gracious and thoughtful person. He served as a professional mentor to numerous junior- and mid-level scientists. His presence, leadership, generous personality, and the example he set as a true "team-player" will be greatly missed.

Arthur received both an S.M. (1978) and a Ph.D. (1981) in Applied Physics from Harvard University and an S.B. (1970) and S.M. (1972) in Aeronautics and Astronautics respectively from the Massachusetts Institute of Technology. He received numerous awards during his distinguished career, including the *NASA/GSFC Robert H. Goddard Exceptional Achievement Award in Leadership* in 2011. He was elected as a Fellow of the American Meteorological Society in 2014.

Arthur poured so much of his energy into the GPM mission. As the mission is prepared for launch, it is fitting that this issue of *The Earth Observer* be dedicated to his memory. On behalf of the Earth science and precipitation community, we extend our condolences to Arthur's family, friends, and many colleagues.

An Update on the Aquarius Mission: Two-and-a-Half Years and Going Strong

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Introduction

Launched on June 10, 2011, the Aquarius/Satélite de Aplicaciones Cientificas (SAC)-D mission is a partnership between NASA and the Argentine space agency [Comisión Nacional de Actividades Espaciales (CONAE)]. CONAE built the observatory bus, called SAC-D, where "D" represents CONAE's fourth partnership with NASA. Aquarius, which measures sea surface salinity, is the primary instrument onboard the observatory. SAC-D also carries CONAE-sponsored sensors, along with other international instruments—see *Other Instruments Onboard SAC-D* on page 7—that complement data from Aquarius.

Two months after launch, the Aquarius instrument was turned on, producing NASA's first global map of ocean salinity in September 2011. To the delight of oceanographers around the world, Aquarius continues to generate weekly maps of the global salinity field at the ocean surface—see **Figure 1,** for example. This article highlights some of the data products being generated by Aquarius and novel scientific findings, including tips on how to access these resources.

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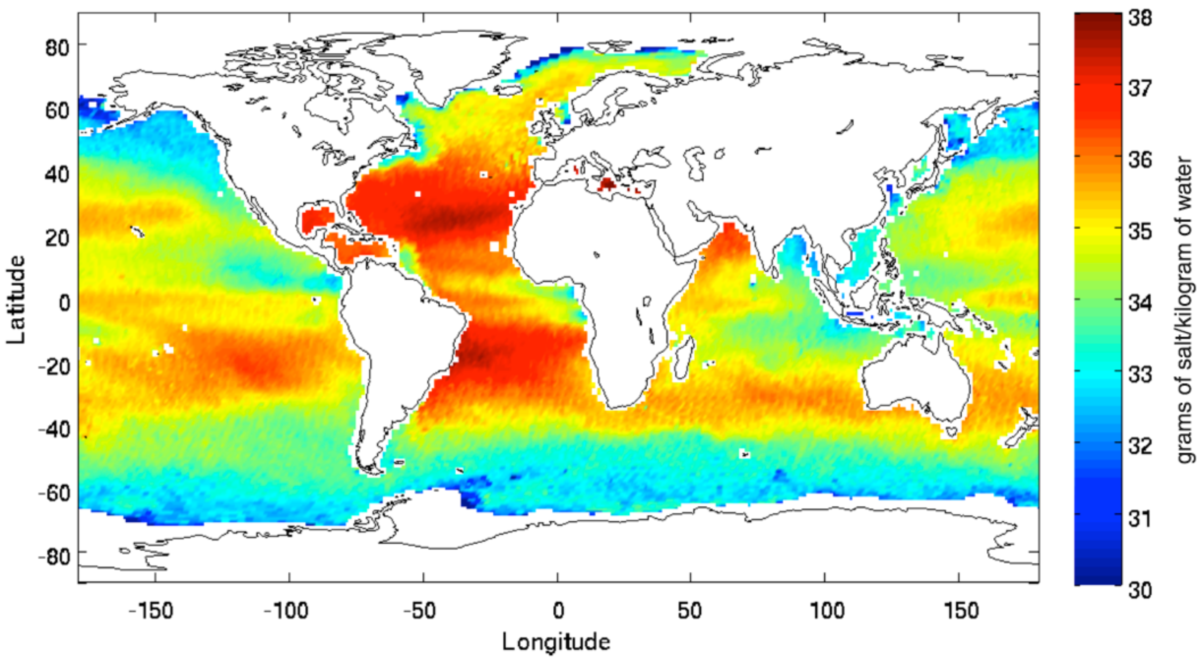

Figure 1. This map shows average, global, ocean surface salinity during spring 2013 as measured by Aquarius. **Image credit:** NASA

Ocean Surface Salinity and Soil Moisture: Data and Products

Salinity has been measured at sea for centuries, first using buckets to collect samples, and later (within the past few decades) with instruments known as "CTDs," which simultaneously measure *conductivity* (as a proxy for salinity), *temperature,* and ocean *depth* (based on pressure). This technology is used to provide *single-point samples* throughout the ocean. For example, the Argo program (*www.argo.ucsd.edu*) has over 3500 profiling floats with CTDs currently deployed in all ocean basins, used as a resource for validating Aquarius data.

Over time scales pertinent to climate, the amount of salt in our ocean basins is relatively stable; however, the amount of freshwater entering and leaving the ocean is constantly changing. Monitoring global ocean surface salinity each week is key to understanding freshwater flux and its relationship to Earth's water cycle.

The scientific objective for Aquarius is to monitor the seasonal and year-to-year variation of large-scale surface salinity features by providing monthly salinity maps with a spatial resolution of 150 km (~93 mi) and an accuracy of about 0.2 grams of dissolved salt per kilogram of seawater. Figure 1 shows that, over the open ocean, salinity ranges only from about 32 to 37 grams of salt per kilogram of seawater. Aquarius is making this very challenging measurement with a combination of passive and active L-band instruments: three radiometers at 1.4 GHz and a scatterometer at 1.26 GHz. See *Making the Measurement Possible* on page 7 for an overview of how this is done.

Aquarius' global maps provide the temporal and spatial coverage needed to discern key patterns of ocean change. Two-and-a-half years into the Aquarius mission, Argo and other conventional *in situ* sensing (e.g., from ships and buoys) continue to play an important role in complementing satellite measurements and helping ocean scientists to understand salinity, from local-to-global scales. This close relationship between satellite and conventional measurements was evident at the November 2013 Aquarius/SAC-D Science Team Meeting in Buenos Aires, Argentina, where 70% of the salinity-science oral presentations included Argo data or reports from the Salinity in the Upper Ocean Regional Study (SPURS) field experiment (*spurs.jpl.nasa.gov*).

Over time scales pertinent to climate, the amount of salt in our ocean basins is relatively stable; however, the amount of freshwater entering and leaving the ocean is constantly changing. Monitoring global ocean surface salinity each month is key to understanding *freshwater flux* and its relationship to Earth's water cycle. For example, Aquarius maps of ocean surface salinity show seasonal variation in the waters surrounding the Indian subcontinent, which is due to geography and climate. **Figure 2** shows that to the west, an arid climate and lack of freshwater input results in a salty Arabian Sea, while to the east,

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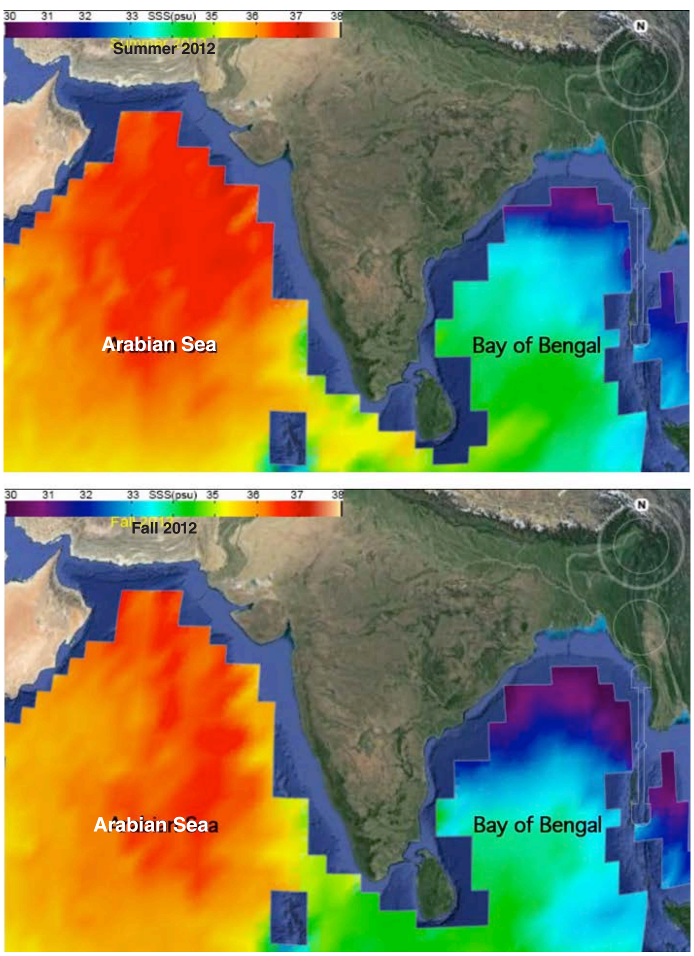


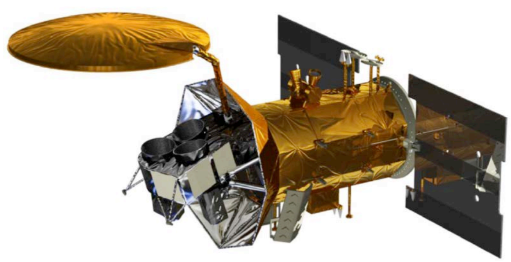
Figure 2. These maps show seasonal differences in ocean surface salinity near the Indian subcontinent measured by Aquarius. Data from June through August 2012 [*top*] and September through November 2012 [*bottom*] are shown. High salinity (dark shades) in the Arabian Sea during summer 2012 reflects increased evaporation in this region. Low salinity (light shades) in the Bay of Bengal during fall 2012 can, in part, be attributed to monsoon rains and freshwater input from major rivers. **Image credit:** NASA

Other Instruments Onboard SAC-D

The Aquarius/SAC-D mission is a true international partnership. Among the CONAE instruments on SAC-D is a Microwave Radiometer (MWR), which operates at 36.5 GHz and 23.8 GHz. Among other functions, data from MWR are being used to provide a *rain flag* for the Aquarius salinity retrieval algorithm. (The rain flag is an indicator that the accuracy of a measurement could be impacted by rain.) Other CONAE instruments include infrared and visible wavelength cameras to study forest fires and light pollution, and a data collection system. In addition, the Italian space agency [Agenzia Spaziale Italiana (ASI)] contributed an experiment called the Radio Occultation Sounder for Atmospheres (ROSA), and the French space agency [Centre National d'Études Spatiales (CNES)] contributed a space-particle-detection experiment called CARactérisation et Modélisation de l'ENvironnement (CARMEN 1).

Making the Measurement Possible

Aquarius senses energy emitted from the ocean surface, which is measured as an *equivalent brightness temperature* in Kelvin (K). To achieve the mission's science goals Aquarius detects change in brightness temperature of about 0.1 K. Careful instrument design (e.g., thermal control), data averaging, and avoidance and/or mitigation of contamination sources, such as radiation from the sun, are all required to achieve this level of precision.



Orbit Design:

Aquarius is in a seven-day repeat, sun-synchronous orbit with a 6:00 PM (ascending) equatorial crossing time and continually samples on the dark side of the day/night terminator to minimize reflected radiation and sun glint (i.e., backscatter).

Identical Radiometers:

Three onboard radiometers share a common 2.5-m (~8-ft) diameter antenna reflector. Together, the three radiometers continuously image a 390-km (~242-mi) swath, roughly perpendicular to the observatory's heading.

Rapid Sampling:

The Aquarius radiometers sample rapidly (10 microseconds per data sample) to help detect and mitigate radio frequency interference.

Polarized Measurements:

The Aquarius radiometers measure vertical and horizontal signal polarizations. The *third Stokes parameter*, a correlation between the two polarizations, is used to correct for *Faraday Rotation*, a change of the orientation of polarization in Earth's ionosphere.

Ocean Roughness Correction:

Aquarius has an onboard scatterometer with the same footprint as its radiometers. Scatterometer data help provide a correction for *ocean surface roughness*, the largest source of error for Aquarius' salinity measurements.