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Global precipitation measurement mission answer key

Page 2 Page 3 Page 4 GPM (Global Rainfall Measurement) Mission Launch Spacecraft Mission Sensor Status Supplement Ground Segment Links GPM is a joint international U.S./Japan Earth Science Mission with the main agencies of NASA and JAXA, respectively. GPM is a follow-up and expanded TRMM (Tropical Rainfall Measuring Mission) launched on November 27, 1997 and is still in operation at the end of 2012 (in October 2005, NASA decided to continue the TRMM mission until at least 2009 and possibly until 2012). TRMM demonstrates the benefits of measuring rain from space. The overall goal of the GPM mission is to observe global precipitation more often and more accurately than TRMM. GPM will build on the work of TRMM and expand science from understanding tropical precipitation to using this understanding to improve climate, weather and hydrological forecasts on a global basis. 1) 2) 3) 4) 5) 6) 7) 8) 9) 10) 12) 13) 14) 15) 16) 17) 18) Higher Level Science Goals: Climate Change: Improving ongoing climate forecasting efforts by providing near-global measurement of precipitation, its distribution and physical processes. Providing this information is a key indicator of the global water cycle and its response to climate change - Weather Forecast: Improving the accuracy of weather and precipitation forecasts by more accurately measuring precipitation and hidden heating. These are the key factors required by computer models to obtain better weather predicates - flood/fresh water forecasting (water cycle): provide more frequent and complete sampling of Earth's precipitation. This will better predict flood hazards and provide life-dependent advice dependent on fresh water. The aim is to: (a) understand the horizontal and vertical structure of precipitation and its microphysical elements, and b) achieve global coverage of rains with significantly improved sampling of the dive cycle. Delivery of data products in real time (maximum 3-hour delay). The bias error should be 1/2 trMM (accuracy threshold) with an accuracy threshold of 25%. The project involves measuring the rainfall of the 4-D betting structure and the distribution of the fall sizes by 5 km of horizontal and 250 m of vertical resolution. NASA's GPM definition team has identified four main elements that are needed to develop an effective and viable program - in support of targets: 1) The main spacecraft that makes accurate measurements of precipitation, collects information on cloud dynamics and precipitation processes, and serves as a calibration reference for other instruments used in the GPM program to measure precipitation 2) Multi-satellite grouping, with each satellite equipped with a passive microwave radio, which measures precipitation and other forms precipitation during the Broad Measuring Swaths 3) Land Verification (GV) program, which provides ground truth verification and measurement verification at various locations on earth that are representative of precipitation events related to different climates and geolocations (e.g. tropical, oceanic) 4) precipitation processing system (PPS), which collects and processes measurements obtained by the core and constellation of spacecraft, and that distributes data about the spacecraft. The basic GPM configuration consists of NASA's main satellite to measure precipitation patterns and provide a standard of calibration for the constellation spacecraft, as well as constellations of several microsatellites consisting of NASA spacecraft and those provided internationally. The goal is to get frequent measurements of precipitation on a global basis (enough to address the diural cycle). In addition, the mission's architecture uses ground calibration/testing sites with a wide range of measurement instruments to measure precipitation. The Global Precipitation Data Center will produce and distribute precipitation maps, applications products and the quality of global climate products. The success of GPM depends largely on international partnerships. NASA-JAXA - GPM Phase Implementation Memorandum of Understanding signed July 30, 2009 - NASA and JAXA follow a dual gateway approach for GPM partnership building CNES/ISRO: CNES/ISRO/NASA Tripartite Meeting was held in June 2009 to formalize the participation of Megha-Tropiques in GPM - official agreement being developed by AEB/INPE: Brazil has G Satellite Constellation SPM in its National Space Plan for 2005-2014 - the final draft of the NASA/AEB joint research agreement in the EUMETSAT review: Confirmed data from MetOp MHS (Microwave Humidity Sounder) may be redistributed among NASA GPM partners and expressed interest in the formal GPM NOAA partnership: NASA is developing an Inter-agency agreement with NOAA Table 1: GPM Partnership Development (Ref). 12) 19) The U.S. GPM project was funded by NASA in early 2007, which includes the main observatory with a planned launch in 2014. The following spacecraft are members (or members of data) of the constellation GPM: 20) 21) - the GPM Core spacecraft provided by NASA and launched by JAXA (orbit tilt 65o and altitude 400 km) 22) - GCOM-W1 (Global Water/Wind Monitoring Mission) JAXA with launch on May 17, 2012. Data from AMSR-2 (Advanced Microwave Scanning Radiometer-2) on GCOM-W1. DMSP (Defense Meteorological Satellite Program) NOAA. The SSMIS (Special Sensor Microwave Imager Sounder) (F-16 since 2003, F-17 since 2006, F-18 since October 2009, (and F-19 to -20, not yet launched) will be key members of the constellation in Gpm. 23) - Megha Tropiques, joint French and Indian (ISRO) low slope (20o), a satellite measuring tropical precipitation (launch October 12, 2011). MADRAS data (Multi-frequency microwave scanning radiometer). 25) - MetOp-A EUMETSAT (launch October 19, 2006). MetOp-B was launched on September 17, 2012. Both spacecraft operate in a coplanary solar-synchronic orbit, phased 174o. NOAA-19 (NOAA-N') with launch on February 6, 2009 and into operation on June 2, 2009. Data from MHS (Microwave Humidity Sounder). 26) - NASA's Suo some nuclear power plant (NPOESS preparatory project) with the launch on October 28, 2011. - NOAA/NASA's JPSS (Joint Polar Satellite System), each equipped with a media (Conical microwave/sound image). The launch of the JPSS-1 spacecraft is scheduled for 2017. 27) Figure 1: GPM Mission Architecture Review (image credit: NASA) Figure 2: GPM Architecture Mission (image credit: NASA) 28) Figure 3: Estimated launch schedules and lifespan of GPM constellation satellites, with blue denoting the main phase of the mission and the yellow extended phase of the mission. GPM Core Observatory operations after the main phase of the mission are subject to science and satellite performance assessment after launch (image credit: GPM team, Ref. 18) GPM Core Spacecraft July 30, 2009 JAXA and NASA signed a memorandum of understanding (Memorandum of Understanding) to develop and operate activities for the GPM mission. The agreement was signed at the Kennedy Cosmodrome in Cape Canaveral, Florida. 29) 30) Joint Mission Agreements include: NASA to provide a nucleus (and companion spacecraft), a companion spacecraft launch, a U.S. ground system, and a precipitation data center. As for the instruments, NASA will make a conical scan, polarization sensitive, multi-frequency radiometer, GMI, both for the main and for the companion satellite. NASA will also participate in the development of algorithms and data verification activities. JAXA provide the DPR instrument for the main spacecraft, the launch of the main spacecraft and the flow of data from NASA's JAXA GCOM-B1 spacecraft. NASA's main GPM spacecraft has a LEGACY of TRMM. The core bus is being developed at NASA/GSFC. The CDR (Critical Design Review) mission took place on December 14-17, 2009. The spacecraft bus has an aluminum and composite design, the bus is modular and has a completely redundant avionics in accordance with the designation of reliability of Class B. The controlled antenna with a high level of amplification on the two-in-field boom provides almost continuous data transmission of scientific data from GMI and DPR instruments via TDRSS (Tracking and Data Relay Satellite System) in MA (Multiple Access) mode in 230 kbps and SA (Single Access) at a speed of 2300 kbps. - 1.95 kW. The spacecraft has a lifespan of 3 years with a purpose of at least 5 years of operation. Work. The spacecraft bus uses 12 hydrazine engines (4 forwards, 8 feet) for the regular orbital maintenance required for its 407 km high 65o tilt of orbit. The full-capacity propulsion system provides fuel beyond the 5-year cost requirement. In addition, the increased battery capacity to 200 A provides a mission life beyond 5 years of consumption. Figure 4: Artist execution of deployed GPM spacecraft in orbit (image credit: NASA) Figure 5: Review of the GPM Core spacecraft, bottom view shows the location of the instruments (image credit: NASA) ADCS (Attitude Definition and Control Subsystem): A set of the best sensors used to determine 3D ratio in space to ensure proper relationship control and earth control. GPM includes Star Trackers and IRU (Inertial Reference Unit) as the main source of relationship data. Two wide-angle star trackers are used to produce images of the sky, which are analyzed by a software algorithm that compares the acquired star pattern with the catalog to accurately determine the spacecraft's orientation in space. Star trackers are connected to 1,553 data boards to transmit accurate data on the attitude to the vehicle control system. 32) The IRU used on the GPM spacecraft is called the SIRU Reference System (Scalable IRU) provided by Northrop Grumman. The system uses gyroscopes to accurately measure changes in rotation on all three a downs to ensure the exact ratio and speed of the data to the spacecraft control system. The IRU is inherently redundant. Figure 6: SIRU Reference Photography (Image credit: Northrop Grumman) Two MSS (medium sun sensors) are also part of the GPM recommendation set. These sensors have a smaller field of view than the sun's rough sensors and provide higher accuracy in their measurements. These two blocks have a FOV (Field of Vision) of 17.5o and measure the position of the Sun with 2o accuracy. Two magnetometers are installed at GPM to determine the spacecraft's relationship to the Earth's magnetic field. Three magnetic torque rods with excess coils are used to create an angular pulse by triggering current through coils in the presence of the Earth's magnetic field. The torque-sucking currents are regulated by computers that control the current that passes through the coils in order to control the force generated on each axis. Magnetic torques are used during pulse dumps. The GPS receiver on board the GPM spacecraft determines the position, altitude and speed of the spacecraft for navigation, antenna guidance and scientific processing Relationship control is primarily provided by RWA (Build reaction wheels). The wheels rotate electric motors at variable speed, which changes when the manoeuvre relationship is accepted. Each RWA has a weight of 10 kg, kg, The engines are used to periodically desaturate the angular pulse - slowing down the reaction of the wheels and counteracting the resulting force with the help of engines, so that the wheels can be accelerated during standard relationship operations. CDDD (Control and Data Management Subsystem): FDDD is responsible for receiving and executing commands, payload system, au pairs and spacecraft management. Based on VxWorks' real-time operations, CDHS uses key components developed for the LRO (Lunar Reconnaissance Orbiter) mission. GPM uses Spacewire, 1553 data boards and the RS-422 analog system to transmit data inside the spacecraft. Household management data and scientific data are stored in a solid recorder until it falls or is processed and sent in real time. GPM is equipped with a PowerPC RAD750 single-card computer manufactured by BAE Systems of Manassas, VA. The processor can withstand doses of radiation that are a million times more extreme than what is considered fatal to humans. The RAD750 can tolerate 200-1000 krd. In addition, the RAD750 will not be affected by more than one event requiring intervention from Earth over a 15-year period. The RAD750 magic is designed to accommodate and relive all of these individual events. The ultimate goal is to have one upset allowed in 15 years. Disorder means intervention from Earth - one blue screen of death in 15 years. The RAD-750 was launched in 2001 and made its first launch in 2005 aboard the Deep Impact spacecraft. The processor has 10.4 million transistors. RAD750 processors run at up to 200 MHz, processing at 400 MIPS. The processor has the memory of the L1 2 x 32 kB cache (instruction and data) - to improve performance, several 1MB L2 cache modules can be implemented depending on mission requirements. Figure 7: PowerPC RAD750 Microprocessor Map Photo (image credit: BAE Systems) EPS (Electric Power Subsystem): GPM is equipped with two solar panels with four panels on each array. The arrays are attached to arrows, which are an interface with a second panel in order to individually tilt arrays to track the sun and optimize electricity production. Each panel has between 800 and 1,200 individual gallium-arsenide solar cells (the total area of solar panels is 26.5 m2). CSS (Rough Sun Sensors) are installed on arrays to provide a guide to tilt the array to achieve optimal lighting. Typically, CSS are images with a field of view of 85 o to determine the direction of the sun with a 10o error. electricity in various subsystems and payloads that use an adjustable, excess 28 volt electric bus with an operating range of 23 to 35 V. A special controller is used to regulate the state of the state 200 Ah Li-ion battery. Overall, GPM generates 1.95 kW in EOL (End of Life). Figure 8: Photo of the deployed GPM solar panel at NASA/GSFC (image credit: NASA) TCS (Heat Control Subsystem): GPM uses a combination of active and passive thermal control. Passive thermal control is carried out by the use of thermal coatings, coatings and multi-layered insulation, which prevents excessive heating of the satellite with sunlight and the scattering of heat in space in the shade. The outer layer of multi-layered insulation is used to minimize heat loss and is designed to protect the spacecraft from corrosion by atomic oxygen and electrical charging. The outer layer of MLI is made of German Black Capton. GPM uses tent blankets and slinky blankets to protect most of its non-irradiating surfaces. Active thermal control uses heat rejection systems as well as heaters and temperature sensors to keep the satellite running. Because all of the satellite's electronics generate heat, GPM must be equipped with a heat-rejection system. Most electronic components of the spacecraft reject heat through their base plates, which are installed on structural surfaces using the thermal interface of the material to improve heat transmission. The heat is then transported through the constant conductivity of the thermal pipes - the Avionics module uses one U-shaped and one S-shaped heat pipe, while the Power System electronics box has two L-shaped thermal pipes. The battery assembly has four dedicated heat pipes. Heat is rejected by radiators mounted on the side of the spacecraft, which never collides with the sun during nominal mission operations. These high-emission radiators include an avionics radiator, a pocket battery radiator, a lower-wheel-drive radiator, special radiators for two solar-powered power assemblies and separate radiators for the RF communications system. RCS (Reaction Control Subsystem): GPM uses a chemical propulsion system to control the ratio, reaction of the pulse wheel of the landfill and to maintain its low Earth orbit. A total of 12 engines have been installed on the spacecraft. Eight of these 12 engines are mounted on the amputee part of the satellite, while the remaining four engines are mounted on the front section. Four engines have 900 nozzles, the remaining eight have straight nozzles. All engines are used to control the ratio and pulse dumps, while orbital maneuvers use only four forward engines that collide with the same direction. The RCS uses high purity hydrazine fuel that is stored in a single composite Overwrap pressure tank vessel. He uses an outer shell of a graphite composite, a tank skirt consisting of composite with metal inserts and alloy liner Aluminum 6061. The tank is filled with 545 kg of hydrazine when running under pressure up to 27.6 bar. The tank is designed to operate under pressure up to 34.5 34.5 and a burst of pressure of 55.2 bar. The minimum flight pressure is 6.8 bar. The tank was built to maintain temperatures from 2 to 50 oC with a ten-year minimum shelf life of hydrazine inside without deteriorating performance. The pressure on the tank is carried out using 6.2 kg of high-pressure nitrogen. Engines generate traction from catalytic decomposition of hydrazine fuel using heated platinum/palladium catalyst beds. Running in blowout mode, the engines provide a maximum thrust of 44.5 N at a feed pressure of 27.6 bar and 13.3 N at 6.8 bar feed pressure. The engines are operated in an impulse mode to control the attitude and in stable condition mode for orbital maneuvers. The minimum duration of the engine pulse is 50ms, delivering a repetitive pulse bit. The thrust engine is calculated at around 5% for any given feed pressure. The pressure to control the relationship during the burns of the zV, the engines work on service cycles of 33, 67 or 83%, and then sustained state burns in a few seconds, while unloading the pulse requires service cycles of 17, 33 or 67% for a few seconds, separated by non-warming periods of up to a few minutes. The sustained combustion time of the orbit correction engines is 35 s at maximum feed pressure at the beginning of the mission and 70 s at the end of the mission when the minimum feed pressure has been reached. In general, the engines consume 0.06 kg/s of hydrazine during the 4th incineration without relationship control and 0.12 kg/s for manoeuvre with relationship control. The expected fuel consumption at the beginning of the mission is 1.4 kg/maneuver, which increases to 1.9 kg at the end of the mission. These drag make-up maneuvers will be performed every 12.4 days (on average). Space Bus (GSFC in development) Aluminum and composite structure, modular bus with excess Avionics Antenna Steerable high-profit antenna on dual loop boom Generation - Solar panels track the sun - 200 li-ion battery - 1.95 kW of power on EOL RCS (Reaction Control Subsystem) 12 engines (4 forwards, 8 feet), monopropent engines, MR-106L, 22 N, N Aerojet Rocketdyne to control the ratio of the size of the deployed spacecraft 13 m x 6.5 m x 5 m. Spacecraft with a weight of 3,850 kg. The GPM HGA (High Gain Antenna) system is equipped with a deployable boom that facilitates the spacecraft's highly-borrowed antenna antenna, which is mounted on a two-axis carb mechanism for targeting the antenna to communicate with NASA's TDRSS (Satellite Data Tracking and Transmission System). Load and household data real-time transmitted via TDRSS MA (Multi-Access), which allows the TDRS satellite to transmit multiple users with lower data speeds. Saved scientific data with link via SA (Single Access) service TDRSS, which uses dedicated antennas on TDRS satellites to achieve high data speeds. TDRSS data is transmitted to White Sands, New Mexico, from where GPM data is transferred to the MOC (Mission Operations Center), which then distributes the acquired data of the tool for processing and publication. For real-time downtime, tool data will be available within 15 minutes to provide near-real-time coverage. It is expected that typical data from measurement to user availability will be within 15 minutes. The main application of GMI short-delayed data is designed to be integrated into the NRT (Near-Real-Time) global precipitation map, which is based on measurements by all radiometric GPM constellation spacecraft and with a total delay of less than 3 hours of rain map data. The command link is also carried out through the HGA system in nominal mission modes. GPM is equipped with all-direction S-band antennas that are used to communicate with ground stations. These antennas are used for downlink telemetry and uplink commands and in the case of safe modes spacecraft. Project Development Status: In early March 2012, GMI (GPM Microwave Imager), built by BATC (Ball Aerospace and Technologies Corp.) boulder, CO, arrived at NASA/GSFC. 33) 34) - In March 2012, NASA/GSFC delivered the DNR precipitation radar (two-frequency precipitation radar) JAXA. After the installation of the DNR on the main GPM spacecraft, NASA will perform tests of the spacecraft system at the GSFC. 35) DNR's integration into the GPM spacecraft was successfully completed in May 2012. 36) 37) - In October 2012, the GPM spacecraft completed its first full CPR (Comprehensive Performance Test) since October 4, 2012 at NASA/GSFC. The tests lasted 24 hours a day, seven days a week and lasted ten days, as the entire spacecraft was put through its paces. 38) Figure 9: A photograph of the DPR instrument integrated into the GPM Core Observatory (image credit: NASA) 39) - The main GPM spacecraft completed its first integrated performance test in October 2012 and a thermal vacuum test in January 2013. In May 2013, EMI/EMC tests were completed at NASA/GSFC (Goddard Space Flight Center). 40) 41) The GPM Core satellite successfully completed vibration tests in July 2013 at NASA/GSFC, Greenbelt, MD. The tests ensure that the spacecraft can withstand the vibrations caused by the JAXA H-IIA rocket during the satellite launch in early 2014. Sitting on a specialized mobile platform, the GPM spacecraft was suddenly back and forth in each of the three spatial orientations at the GSFC. 42) Figure 10: GPM attached to a shaker table for horizontal vibration testing (image credit: NASA) - November 23, 2013, a a C-5 transport aircraft with the main GPM (Global Precipitation Measurement) landing at Japan's Kitakyushu Airport. From Kitakyushu Airport, the spacecraft was loaded onto a barge bound for the JAXA Tanegashima Space Center on Tanegashima Island in southern Japan, where it will be ready to launch in 2014 on an H-IIA rocket. 43) Figure 11: Photo A C-5 transport aircraft carrying the GPM observatory landing at Kitakyushu Airport (Photo: JAXA, NASA) - December 26, 2013 NASA and JAXA announced the launch date of GPM. They chose February 27, 2014 as the launch date and launch window of the Japanese H-IIA rocket carrying the Global Precipitation Measurement (GPM) of the main satellite observatory from JAXA to the Tanegashima Space Center. 44) Figure 12: GPM Core Observatory in a clean room at the Tanegashima Space Center, Japan (image credit: JAXA) Launch: GPM Core Observatory was launched on February 27, 2014 (at 18:37:00 UTC) on H-IIA No. 23 of the JAXA launch vehicle from the Tanegasak Space Center, Japan. JAXA sponsored the launch of the H-IIA vehicle from the Tanegashima Space Center, Japan, with MH (Mitsubishi Heavy Industries, Ltd.) as a service provider. 45) 46) 47) 48) 49) 50) 51) MHI is Japan's largest aerospace and defense contractor, MHI manufactures H-II family of missiles for JAXA and has been responsible for conducting H-IIA launches since 2007 - taking over launches of the more powerful H-IIB as well as in 2013. The secondary Japanese payloads shown by JAXA in the GPM Core mission were: 52) - ShindaiSat (Sputnik of Sinshu University), microsatellite (35 kg) to demonstrate LED light as an optical communication. - NANOSatellite technology mission STARS-2 (Space Tethered Autonomous Robotic Satellite-2) Of Kagawa University, Takamatsu, Kagawa, Japan - TeikyoSat-3, microsatellite bioscience (20 kg) of Teikyo University and ITF-1 (Imagine Future-1), 1U CubeSat University Tsukuba, Tsukuba, Japan. - OPUSat (Satellite university of Osaka Prefecture), satellite 1U CubeSat and INVADER (satellite INteractiVe for experimental research in art and design) University of Art Tama, 1U CubeSat and KSat-2 (Sputnik of Kagoshima-2 University), CubeSat mission with a mass of 1.5 kg. 53) The orbit of the main satellite: non-solar-synchronous orbit, altitude 407 km, tilt 65o. Orbit of the main spacecraft cuts through the orbits of the constellation spacecraft, tries the latitudes where almost all precipitation occurs, , and a sample of different times of day. Figure 13: The picture compares the area covered by three orbits trMM (yellow) compared to the three orbits of the GPM Core Observatory (blue), credit image: NASA) NASA 54) Orbit of constellation satellites: Solar-synchronous (polar) circular orbit, altitude 635 km. Constellation is actually a collection of spacecraft, most with GPM (e.g. DMSP S/C series). Many spacecraft are solar-synchronous, but their altitudes and orbital periods are different. The orbit of the DMSP spacecraft is 833 km and GCOM-W is 802 km. Different orbital periods cause ground tracks to move relative to each other, oscillating between overlapping coating and missed coverage. Figure 14: A schematic look at the geometry of observations using GPM CORE instruments (image: NASA) Mission: September 10, 2020: Lake Victoria is the largest lake in Africa and a lifeline of economic and food security for approximately 30 million people living near its shores in Uganda, Kenya and Tanzania. But it also kills lives. Cyclical, daily weather conditions around the lake create severe overnight thunderstorms that kill about 3,000 to 5,000 fishermen a year. 55) - It's certainly one of the most stormy places on Earth, said Wim Thieri, a climatologist at the University of Vriye in Brussels who has studied Lake Victoria for several years. Almost every night, you see these severe thunderstorms and sometimes even a water tornado develops over the lake because it's a really favorable environment for storms. Figure 15: This animation shows rainfall around Lake Victoria through a typical 24-hour period during the rainy season (March, April and May). It is a precipitation rate calculated every half hour and averaged for 18 years (2000-2018). The data comes from the latest integrated multisatellite search algorithm GPM (IMERG), which was released in late 2019 and is one of the longest continuous records of high-resolution precipitation data. The IMERG product combines data from the Tropical Precipitation Measurement Mission (TRMM), which operated from 1997 to 2015, and the Global Precipitation Measurement (GPM) satellite. that has been collecting data since 2014. Both missions were joint efforts of the Japan Aerospace Exploration Agency (JAXA) and NASA (image credit: NASA Earth Observatory, Images and videos by Joshua Stevens using Global Precipitation Measurement (GPM) Mission Data courtesy of Jackson Tan/USRA/NASA/GSFC. The history of Kash Patel) - Having a nearly 20-year record helps us focus on medium-term long-term models, as opposed to year-on-year variability, said Jackson Tan, a USRA researcher at NASA's Goddard Space Flight Center who recently published an article about the latest IMERG product. The longer record is more representative of the region's climatology. 56) - Cold weather near Lake Victoria is usually characterized by daytime storms over surrounding lands and intense overnight storms over the lake. Storms are associated with a combination of lake location, size and nearby topography. Similar day and night models also appear over the lakes surrounding Lake Lake but less pronounced because of their smaller size. We don't have too many large lakes located across a tropical belt like Lake Victoria to observe this weather behavior, said Chris Bedka, a climatologist at NASA's Langley Research Center. Lake Victoria is special because these storms are such a recurring and daily phenomenon for several times a year. - In general, thunderstorms here are formed through the interaction of cold and warm air masses. Daytime breezes flow from the relatively cool surface of Lake Victoria towards hotter, sun-baked land. Warm air above the ground rises higher into the atmosphere; When it is cooled, water vapor condenses into small drops of water and clouds. The chilled air dips lower in the atmosphere to compensate for the updrafts. If this cycle of lifting and immersion of air or the convection process is intense, it can create a thunderstorm. The storm continues to develop as long as it has warm air refueling it from below. Figure 16: In animation, precipitation spikes above the ground around 4:30 p.m. EAT (16:30 p.m. local time), when thunderstorms are usually most active due to daytime surface heating from the sun. Precipitation is particularly evident in the northeast and west of Lake Victoria, where mountain ranges also help drive upwards of warm air masses (image credit: NASA Earth Observatory) - Reverse process at night. When the sun sets, the earth cools, but Lake Victoria remains warm (the water retains heat longer than the ground). The temperature difference between the lake and the air above the ground causes the breezes to develop and blow towards the lake. When wind-controlled air masses converge over the lake, they rise in the process of convection, which causes thunderstorms. - The lake is a repository of moisture and it is really hot and humid. But in order to cause a thunderstorm, we need to raise the warm air, Bedka said. Converging air currents set things in motion. We're actually able to predict many of these extreme night thunderstorms by looking at daytime conditions on land, said Thieri, who co-authored a study with Bedka that demonstrated the ability to predict overnight storms. We found that the intensity of the storms occurring in the afternoon could tell us something about what we can expect at night over the lake. -- According to Teri and Bedka, severe daytime storms lead to stronger night storms. As Teri explained, afternoon thunderstorms bring more rain and moisture over land. When the breezes blow from the land towards the lake at night, they carry that extra moisture, which provides more fuel for thunderstorms. In the afternoon thunderstorms also cool the ground's surface, creating an even greater temperature difference between the ground and the lake, leading to stronger land breezes at night. -- Having this data half an hour, we can see storms grow and spread across the lake, said Bedka. You will never know or understand this complete process unless you have such a frequent sample through such long record data. - July 23, 2020: The precipitation that accompanies Asia's summer monsoon plays an important role in the region's economy by replenishing aquifers, generating hydroelectricity, and providing water to crops. In some years, however, rainfall is breaking records in places. That was in 2020. By mid-July, severe flooding affected millions of people across southern and eastern Asia. 57) Figure 17: This map shows the accumulation of precipitation throughout the region from June 1 (the beginning of the summer monsoon season) to July 20, 2020. These data are remotely completed estimates from the Comprehensive Multi-Satellite Search for GPM (IMERG), a product of the Global Precipitation Measurement Mission (GPM). The darkest reds point to places where GPM detected rainfall of more than 100 cm (40 inches) during this period. Due to the averaging of satellite data, local precipitation can be significantly higher when measured from the ground (NASA Earth Observatory, image of Joshua Stevens, using IMERG data from the Global Precipitation Mission (GPM) at NASA/GSFC. According to the World Meteorological Organization, 15 centimeters (6 inches) more rain fell in many parts of central, northern and northeastern India by mid-July. The northeastern Indian state of Assam, for example, received a total of 89 cm (35 inches) of rain between June 1 and July 22, about 20 percent more than usual. The rainfall caused deadly flooding that cut off villages and displaced thousands of people. Animals, including rare single-horned rhinos, were also reported to have drowned when water levels rose in Kaziranga National Park in Assam. - Since the beginning of June, unusually strong stationary weather systems have often endured storms and heavy rainfall across south-central and eastern China. Dozens of rivers and lakes swelled to record highs. Lake Poyan, for example, reached a record level of 22.6 meters on July 13, exceeding the average annual high of 19.2 meters. Throughout the region, floods and landslides threaten villages and affect millions of people. - Monsoon rains also doused Japan. In just one week to July, parts of western Japan experienced three times as much rain as they did during the month. The deluge triggered floods and landslides, which news reports said led to the highest number of deaths in more than three decades as a result of torrential rains. - The monsoon is a familiar model in mid-latitudes, occurring along with seasonal changes in the atmospheric circulation. This year The summer monsoon systems in Asia were particularly strong and immobile, allowing them to get even more moisture from the Indian and Pacific Oceans and deliver it to dry. Scientists continue to investigate changes in the Asian monsoon system, which occur year after year, as well as for millions of years. June 6, 2020: The 2020 Atlantic Hurricane Season begins with a busy life. By the first week of June, Tropical Storm Arthur had already cleared North Carolina, Tropical Storm Berta had battered South Carolina, and the third named storm of the year, Cristobal, was raining heavy rain on the Yucatan Peninsula. 58) - The storm first developed in the Pacific Ocean in late May as Tropical Storm Amanda, spinning off the southern end of a seasonal low pressure pattern called the Central American gyre. After landing in Guatemala and causing deadly floods in El Salvador, Amanda weakened and became less organized as she crossed Central America. It then reorganized and began to intensify as it reached the Atlantic Ocean and collided with the northern end of the whirlpool. While lingering over the Yucatan Peninsula for several days, the storm dropped huge amounts of rain on parts of Mexico, Belize and Guatemala. - According to the U.S. National Hurricane Center, the storm fell to 65 cm (25 inches) of rain in parts of Mexico; some places in Guatemala and El Salvador were 90 cm (35 inches). Deadly flooding has flooded hundreds of homes in El Salvador, prompting the country's president to declare a state of emergency. - The National Hurricane Center's forecast model shows the storm moving north over the Gulf of Mexico toward Louisiana and other Gulf Coast states from June 6 to June 8. Figure 18: The map shows the accumulation of precipitation in Central America from May 27 to June 5, 2020. Precipitation was particularly intense in the Mexican states of Yucatan, Campeche and quintana Roo. These data are remotely counted estimates that come from a comprehensive multi-track search for GPM (IMERG), a product of the Global Precipitation Measurement (GPM) mission. Local precipitation can be significantly higher when measured from the ground (image credit: NASA Earth Observatory, Image by Joshua Stevens, using IMERG data from the Global Precipitation Mission (GPM) at NASA/GSFC. Adam Wheland's Story - January 25, 2020: For much of the Australian summer of 2019-2020, plumes of smoke from wildfires billowed from southeastern Australia in such large quantities that the earth was barely visible in satellite imagery. In mid-January, some of these plumes were finally suppressed by a few days of much-needed rainfall. 59) - According to news reports, the largest accumulation in NSW was north of Sydney, where rainfall averaged 20 to 30 cm in Victoria, areas Melbourne got a month's worth of rain in one day. Teh Teh however, the system was spotty and less than a centimetre of rain fell along the south-east coast. - Rain could not put out every fire, but it helped reduce the number. According to the NSW Rural Fire Service, 64 fires (16 non-containable) were burning across the state on 21 January. That's according to 88 fires (39 incontinence) on January 15. - When the rain ended, the totals were not enough to bring any area out of the drought. This is a cause for concern as the Bureau of Meteorology said on 21 January that high temperatures and gusty winds had again increased the fire danger in NSW, Victoria and southern Australia. Figure 19: Bushfire counts plunged in mid-January when much-needed rainfall poured on NSW and Victoria. The map shows the accumulation of precipitation from January 15 to 21, 2020 in NEW SOUTH Wales and neighbouring states. These data are remotely counted estimates that come from a comprehensive multi-track search for GPM (IMERG), a product of the Global Precipitation Measurement (GPM) mission. Local precipitation could be significantly higher when measured from the ground (image credit: NASA Earth Observatory, image of Joshua Stevens, using IMERG data from the GPM mission at NASA/GSFC. Story by Katherine Hansen) - October 16, 2019: NASA's Precipitation Measurement Missions (PMM) have been collecting rain and snowfall from space for nearly 20 years, and for the first time in 2019, scientists can access the entire PMM record in the form of a single set of data. 60) Figure 20: Ten satellites in the Constellation Of Global Precipitation Measurement provide unprecedented information about rain and snow across the Earth (credit image: NASA Science Studio) - PMM includes two missions - The Tropical Precipitation Measurement Mission (TRMM), which orbited Earth from 1997 to 2015, and its successor, the NASA-JAXA Global Precipitation Measurement Mission (GPM), which has been collecting data since 2014. This year, however, GPM updated its data algorithms to calibrate and incorporate TRMM data into its release, giving researchers, fashion designers and meteorologists access to the entire 19-year record. - Being able to compare and contrast past and current data, researchers are better informed to make climate and weather models more accurate, better understand normal and extreme rains and snowfalls around the world, and strengthen applications for current and future disasters, diseases, resource management, energy production and food security. Figure 21: Being able to compare and contrast past and present data, researchers can make climate and weather models more accurate, better understand normal and extreme rains and snowfalls around the world, and strengthen applications for current and future disasters, diseases, energy production and food security (video NASA's Goddard Space Flight Center/Ryan Fitzgibbons monitors precipitation to improve the world - GPM provides a four-dimensional view of rain, snow, sleet and storms from space: it not only records the size of droplets or pellets, but also how strong the precipitation is and how they change over time. This perspective is used not only for global science, like the study of the Earth's water and energy cycles and the spotting of extreme weather around the world, but it is also useful for studying individual events such as hurricanes or droughts. - The GPM Signature Algorithm is IMERG (Integrated Multi-satellitE Extracts for GPM). IMERG calibrates and combines data from its main satellite, the GPM Core Observatory and GPM Constellation, a group of international satellites that contribute data to GPM, as well as perform their own missions. While the full IMERG product requires time to process and prepare, it also generates a near-real-time summary of global rainfall every half hour, which is useful for time-sensitive applications such as weather forecasting and emergency recovery. - Researchers, emergency services, health care workers, and resource managers use IMERG data to see how precipitation has shaped events in the past to help them prepare for similar events in the future. By creating a reliable, multi-decade baseline of precipitation and snow, IMERG shows how precipitation can deviate from normal, informing models that predict yields, disease outbreaks and landslides. IMERG data also supports applications such as water management, says Andrea Portier, GPM Application Coordinator. For example, in the Country of Navajo, located in the southwestern United States, precipitation data are critical for water managers who control water scarcity for agriculture, drink and animal care. GPM rainfall measurements and maps help them know which areas are at risk of drought. Figure 22: For the Navajo nation in the southwestern United States, precipitation data are critical for water managers who control water scarcity for agriculture, drink and animal care. Measurements of GPM precipitation and maps help them know which areas are threatened by drought and need additional assistance (photo credit: NASA/Amber McCullum) Looking back to predict the future - Studying IMERG data from a longer-term perspective gives scientists a different perspective: Which regions have received the most or least rainfall, where do the biggest storms strike, how does rainfall change during the season? - Over the past five years, with GPM, we have had a multisatellite accurate data set that covers almost world, said George Huffman, LEAD scientist at IMERG and deputy scientist of the GPM project. But five years is a short time. We should have had something more... expanding multi-track record throughout all two missions gives us a chance get long-term statistics and analyze past conditions. - One important application for past precipitation data is weather and climate modeling, the basis for studying short-term weather and long-term climate at regional and global levels. Scientists use sophisticated computer programs to analyze large amounts of observed data on air temperature, atmospheric pressure, wind, precipitation, soil moisture and many other variables. These computer programs then generate forecasts for short-term weather or long-term climate. We need the past to model the future. The past gives us the basic level we need to understand future events, said Dalia Kirschbaum, GPM's deputy research manager for the applications project. For example, in the case of extreme weather conditions such as hurricanes, we can better understand what extreme means if we have a baseline for comparison. This update is an important milestone, supporting more accurate rainfall estimates that can be used as ground truth in working towards more accurate forecasts for the future. - Another set of processes the team hopes to understand more completely changes in precipitation from day to night and during the season. One of the important things we're looking for is understanding how the Earth system works, Huffman said. GPM gives us information about what the environment is doing and allows us to look at how precipitation can interact with other variables in the Earth's system, such as soil moisture, air quality and vegetation. - Looking back to see where rain and snow has fallen in the last 19 years, scientists can help people around the world prepare for the future, from localized short-term drizzles to large-scale, tithing patterns. - Data from both GPM and TRMM are free and publicly available. The PMM website lists access points for different datasets and provides tutorials and webinars on how to download and use them. Textbooks range from basic access to and use of data to specific applications such as flood management, agriculture, monitoring and disease response. IMERG will continue to provide life data for the GPM mission, which is expected to last until the mid-2030s or beyond. February 27, 2019: Five years ago, on February 27, 2014, aboard japan's H-IIA rocket launched the Global Precipitation Measurement Base Observatory (GPM), a joint NASA and JAXA (Japan Aerospace Exploration Agency) satellite project. Since then, advanced instruments at GPM have provided advanced measurements of rain and snow particles in the clouds, Earth's precipitation patterns, extreme weather conditions and many ways of precipitation around the world affect society. Among the uses of these opuses help outbreaks in developing countries, global crop reports and the identification of endangered Amazon rivers. 61) Figure 23: 27 February 2019 we celebrate five five in orbit for the NASA/JAXA GPM mission (Global Precipitation Measurement) (video credit: NASA Goddard/Ryan Fitzgibbons) - Unlike many NASA missions that are research satellites with delayed data delivery, GPM has been designed to get data for scientists, operatives and application users as soon as possible for social benefit. This would help answer questions such as: Where is this hurricane? Will there be flooding? Should I water my crops? - GPM quickly receives data from the 12-member TDRS satellite group, which serves as an information pipeline between satellites orbiting the Earth and NASA ground stations. On average, GPM can take 1 to 3 hours to get data into the hands of users, but in an emergency, the average delivery time can be pushed between 15 and 90 minutes. - The mission's main satellite, the Main Observatory, has two instruments: the two-frequency precipitation radar (DPR) and the GPM microwave sample (GMI). - JAXA operates the DNR, which uses two radar frequencies to measure precipitation in clouds, recording data on the size, shapes and norms of snow and rain particles. Using two radar strips, DNR detects precipitation ranging from light and heavy, and gives a three-dimensional picture of where and how many raindrops, snowflakes or ice pellets of various sizes are distributed throughout the storm cloud. - NASA-operated GMI uses 13 channels to measure microwave energy emitted in GMI's field of view, including precipitation in the atmosphere. As in DNR, GMIs can measure different types of precipitation and severity. Low-frequency channels measure moderate and heavy precipitation, while higher frequencies measure moderate-light precipitation. - The combination of DPR and GMI gives scientists and meteorologists a new understanding of precipitation processes at both micro-particles in the clouds and at macro-regional (regional and global) levels, making precipitation estimates and forecasts more accurate. - The main source of GPM data is the Main Observatory, but the mission receives data from the constellation GPM, which consists of satellites with microwave sensors from the United States, Japan, India and Europe. Most of these satellites have unique targets and supervisory bodies, but by sharing their microwave data with GPM, they expand the global reach and sequence of the mission. - Satellite data is combined with ground-based data to create the final product, Comprehensive Multisatellite Search for GPM (IMERG), which is used for weather forecasting, climate models, water management and extreme weather forecasting. While the full IMERG data product takes time to clean up and prepare, an almost real-time visualization of the current global rainfall is available every 30 minutes in the regional (10 km by 10 km). - GPM ground-based verification system criterion for measuring the quality of satellite data. Instead of relying only on satellite data to measure precipitation and develop forecasts, the GPM team compares space data with information collected by the National Oceanic and Atmospheric Administration's (NOAA) ground radar, traditional rain sensors and disdromters, or drop-size measurement tools. When land and space data diverge, the team explores differences and updates the algorithm to make future data collection more accurate. - With accurate GPM estimates of where, when and how precipitation falls around the world, scientists are learning about the inner workings of rain clouds, which improves weather and climate forecasts. - In 2017, data visualizers and scientists worked together to create one of the first 3D models of the hurricane, which mapped not only precipitation, but also the size and types of particles. GPM data also play a key role in creating disaster forecasting models, such as the Landslide Risk Assessment Model for Situational Awareness (LHASA), which warns of imminent landslides based on heavy rainfall data. GPM helps inform everyday decisions - Do you need to evacuate? - and long-term planning - How do precipitation patterns change in a warming climate? - GPM has advanced scientists' understanding of the Earth's water and energy cycles in the first five years, and it is just beginning. The mission is expected to last until the mid-2030s. If this forecast is true, GPM will continue to rain down valuable data for years to come. December 21, 2018: Tropical Cyclone Kenanga in the southern Indian Ocean is currently on a downward trend, and NASA's main GPM satellite has provided a look at precipitation and cloud heights within the storm. 62) - On December 20, 2018, NASA's GPM satellite passed over Tropical Cyclone Kenanga and captured a storm that began to weaken as predicted. The GPM satellite had an excellent view of Kenanga when the maximum sustained wind of a tropical cyclone was at a speed of 90 knots (166 km/h). A GPM pass showed the eye of the storm, visible the day before, has since filled in inches - GPM tools including microwave imager (GMI) and dual-frequency precipitation radar (DPR) showed that powerful storms south of central Kenanga still produce very heavy rainfall at a rate of 214 mm/h in the area. Rainfall in the northern half of the storm has decreased significantly. The GPM 3-D view of Kenang (Figure 24) looks southwest and was received by the DPR Ku-band radar on the satellite. It showed extremely powerful storms south of the Kenanga deteriorating eye returned very strong reflectivity values that help match the severity of the storm and rainfall. Stormy tops of the eye wall, Untouched on the west side of the cyclone reached an altitude of 12.7 km. - December 21 at 10am .m EST (1500 UTC) Tropical Cyclone Kenanga was located about 672 nautical miles southeast of Diego Garcia and tracked to the west. Maximum sustained winds have dropped to 60 knots, so there is now a tropical storm. - The Joint Typhoon Warning Center predicts that Kenanga will continue to weaken rapidly as dry air in the storm becomes colder and heavier causing downdrafts. It is dry air higher in the air, which contributes to stronger convective wind gusts and therefore severe storms. Kenanga is forecast to dissipate in the next 72 hours as it tracks the northeastern periphery of Tropical Cyclone Cilida. Figure 24: GPM has observed powerful storms south of central Kenang on December 20, still producing very heavy rainfall at a speed of 214 mm/h in the area. Rainfall in the northern half of the storm has decreased significantly. Stormy eye wall peaks that remained untouched on the west side of the cyclone reached an altitude of 12.7 km (photo: NASA/JAXA, Hal Pierce) - December 4, 2018: Heavy rainfall recently fell in areas of California that were recently devastated by deadly wildfires such as Camp Fire and the Woolsey Fire. This flood of rainfall has led to evacuations in burn areas such as Butte County, where a deadly camp fire struck this month. NASA used data from GPM satellites and other sources to calculate recent rainfall. 63) Figure 25: NASA IMERG rainfall estimates show the heaviest concentration of precipitation in northern central California, northwest of Sacramento (between Mendocino and Plamas National Forests), where rainfall was between 160 mm and 240 mm. Less rainfall fell, up to 160 mm from the Sierra National Forest and areas north of Fresno, north of the Pmumas National Forest. This heavy rainfall fell in the national forests between Plamas and the Sierra, and included: Eldorado, Stanislaw, and Yosemite National Forests (image credit: NASA/JAXA, Hal Pierce) - At NASA/GSFC in Greenbelt, Maryland, NASA's IMERG (Integrated Multi-satellitE extraction for GPM) data was used to show overall rainfall estimates in the western United States. Various satellites in the constellation of the GPM (Global Precipitation Measurement) provide data calibrated by measurements from the Observatory's GPM Core Observatory and rain sensor networks around the world. GPM is a joint mission between NASA and JAXA (Japan Aerospace Exploration Agency). IMERG data is generated in near-real time at half an hour interval using NASA's precipitation processing system. - NASA Goddard Space's analysis showed general estimates of precipitation accumulation using IMERG data, for a seven-day period from November 23-30, 2018. - NASA IMERG estimates show heavy precipitation in northern central California, in an area northwest of Sacramento, between the National Forests of Mendocino and Pmumas, where rainfall ranged from 160 mm to 240 mm. - Flash floods, debris flows and landslides were forecast in areas where deadly wildfires have deprived vegetation. On the positive side, these Pacific storms are expected to weaken wildfires and replenish the Sierra Nevada snowpack. This snowpack is an important source of water for California's creeks and rivers. August 22, 2018: Abnormally heavy monsoon rains soaked in southeast Asia, leading to the worst flooding in Kerala since 1924. The event, which began with rains on August 8, 2018, displaced more than 300,000 people, killed hundreds, damaged more than 50,000 homes across the region and seriously affected 13 of the 14 districts in Kerala. Although it brought the most intense flooding in the region this summer, the rain was one of many high rainfall events in Kerala this monsoon season. 64) - The August rain in Kerala has played a role in nearly once-in-a-century flooding, though flooding worsened when water was cleared of several full dams. Instead of gradually releasing water into the snow, the authorities were forced to open 80 dams in the region, including the Idukki Dam, which is one of the largest arched dams in India. Thirty-five of these dams were opened for the first time. The dam emissions came too late, and it coincided with the torrential rain that was coming said Sujay Kumar, a researcher at NASA's Goddard Space Flight Center. - Intense precipitation has also hit other parts of south-east Asia. In mid-July and August, torrential downpours began in eastern Myanmar, killing 150,000 people in a month and forcing 150,000 people to flee their homes. The floods were the worst in 30 years. The Bago and Sittaung rivers have grown to their highest level in more than five decades, and the Sittaung River is 7 feet above dangerous levels in the areas. - These precipitation data are remotely sound estimates from The Integrated Multisatellite Search (IMERG), a product of the Global Precipitation Measurement Mission (GPM). The GPM satellite is the core of the precipitation observatory, which includes measurements from NASA, the Japan Aerospace Exploration Agency and five other national and international partners. Local precipitation can be much higher when measured from the ground. Figure 26: The image shows the accumulation of precipitation based on satellites from July 19 to August 18, 2018. Precipitation peaked in Kerala on 20 July and again reached an abnormally high level between 8 and 16 August. Since the beginning of June, the region has experienced 42 per cent more rainfall than usual during this period. In the first 20 days of August, 164 percent more precipitation than usual (Photo: NASA Earth Observatory, images by Joshua Stevens, using IMERG IMERG from GPM (Global Precipitation Mission) to NASA/GSFC, the story of Kasha Patel) - July 10, 2018: After they soaked in just a few days with double rainfall falling in normal July, some parts of Japan face their worst flooding in 35 years. Storms and floods have caused deadly landslides and numerous deaths, while millions have been forced to flee their homes and businesses. Prime Minister Shinzo Abe has called 73,000 nationwide rescuers for emergency relief as forecasters forecast additional landslides and rains this week. 65) - These precipitation data are remote-sensitive estimates that come from IMERG (Integrated Multi-satellitE Extracts), a product of the GPM mission (Global Precipitation Measurement). The GPM satellite is the core of the precipitation observatory, which includes measurements from NASA, the Japan Aerospace Exploration Agency and five other national and international partners. Local precipitation can be much higher when measured from the ground. - The rains appear to have been caused by warm, humid air emanating from the Pacific Ocean and the remnants of Typhoon Prapirun, which strengthened the seasonal rain front. Figure 27: This map shows the accumulation of precipitation from .m 3(Japanese Standard Time) July 2 to July 3 .m July 9, 2018. Thirteen prefectures on the Japanese mainland received deadly rainfall. Hiroshima and Okayama, in the southern part of Honshu Island, were among the worst flooded areas (image credit: NASA Earth Observatory image Joshua Stevens, using IMERG data from the GPM mission at NASA/GSFC, text Kasha Patel) - May 31, 2018: Subtropical storm Alberto brought soaking up precipitation in the southeastern United States through the Tennessee and Ohio Valley. Using a variety of data collection resources, including a global precipitation measurement mission or a major GPM satellite, NASA estimated the amount of precipitation created by Alberto on his way. By May 31, Alberto had become a postropical cyclone that had moved northeast of lower Michigan. 66) Figure 28: IMERG rainfall estimates were compiled for a one-week period from May 23 at 4:30 a.m. EDT (08:30 UTC) on May 30 at 4am.m. EDT (08:00 UTC) showed over 500 mm of rain (20 inches) over the northwestern Caribbean. Rainfall of 5 to 15 inches (shown in dark red, purple and pink) cover much of western Cuba (image credit: NASA/JAXA, Hal Pierce) - Alberto History: Alberto is formed from a wide area of low pressure on the surface that was located above and around the Yucatan Peninsula. Since the low pressure area is under the influence of a nearby upper-level trough, Alberto was designated as a subtropical storm by the National Hurricane Center (NHC) on the morning of Friday 25 May, which is quite unusual, and most subtropical storms form at higher latitudes. The storm originally formed just east east Yucatan Peninsula. - A large subtropical ridge over the southwest Atlantic sent Alberto north to the track, and the storm brushed off the far western tip of Cuba on Saturday May 26, before the center re-formed as it moved north into the southeastern Gulf of Mexico as another minimal subtropical storm with maximum sustained winds of about 40 mph. The storm remained under the influence of the upper level of the trough (extended low pressure area) with most active thunderstorms located well east of the center. - Finally, as it passed through the central bay around noon on May 27, Alberto showed signs of strengthening with thunderstorm activity getting closer to the center and starting to wrap around the west side of the storm. However, despite some intensification, the NHC reported that dry air wraps around the storm and inhibits thunderstorms and therefore Alberto's ability to strengthen. As a result, Alberto made a touchdown the next day On May 28 on the northern Gulf Coast as a subtropical storm with maximum sustained winds of 45 mph . - the center made landfall near Laguna Beach in Florida for a beggar about 4 p.m..m. CDT also began tracking the northwest through downtown Alabama, where it weakened into depression before moving to central Tennessee. - Assessment of Alberto Precipitation Track: At NASA/GSFC (Goddard Space Flight Center) in Greenbelt, Maryland, IMERG (Integrated Multi-satellitE Extracts for GPM) is used to assess precipitation from a combination of passive microwave sensors, including the GMI microwave sensor aboard the GPM satellite, and geostationary IR (infrared) data. GPM is a joint satellite mission between NASA and the Japan Aerospace Exploration Agency. May 4, 2018: Heavy seasonal precipitation has recently caused flooding in Kenya, and NASA has analyzed and estimated the total rainfall using data from a set of satellites and sensors. 67) Figure 29: From April 27 to early May 4, 2018, NASA's IMERG product calculated precipitation over East Africa. IMERG estimates that total rainfall in some areas off the Indian Ocean coast exceeds 430 mm. Over western Kenya and eastern Uganda, IMERG estimates that rainfall is often more than 200 mm (Photo: NASA/JAXA, Hal Pierce) - Heavy rainfall has displaced more than 244,000 people. The deluge followed a severe drought that affected East Africa in 2017. The death toll from floods and landslides is estimated to have recently risen to about 100. - At NASA's Goddard Space Flight Center in Greenbelt, Maryland, NASA's IMERG (Integrated Multi-Satellite for GPM) created a combined sediment product from the constellation mission GPM (Global Precipitation Measurement) Estimates of precipitation accumulation were calculated and summarized for the period from April 27 to the beginning of May 4, 2018. - During this period, Kenya suffered heavy seasonal precipitation. IMERG estimates that total rainfall in some areas off the Indian Ocean coast exceeds 430 mm. Over western Kenya and eastern Uganda, mERG estimates that rainfall is often more than 200 mm. IMERG data are produced using satellite data in the constellation GPM and are calibrated using measurements from the GPM Core satellite, as well as rain networks around the world. May 2, 2018: The North Shore of the Hawaiian island of Kauai, according to preliminary data, set a national record for the amount of precipitation in 24 hours. Rain gauges in Waip, about a mile west of Hanalei on the north shore, recorded 49 inches (124 cm) on April 14 and 15 - more rain than during Hurricane Harvey over Texas in September 2017. 68) - Intense precipitation cut the path through Hanalei, which received 28 inches (713 mm) of rain. The U.S. Army and National Guard airlifted more than 220 people from the Haen and Vainia districts after the Kuhio Highway, the only road leading to them, was blocked by landslides. The ocean water around Kauai was an unusual shade of orange during the week after the storm because the red-orange clay from the mountain peaks was swept into the water by the rain. Floodwaters took away bison, some of which were rescued from the ocean. - Torrential rain began on April 12, when an elongated area of low pressure disrupted the normal flow of northeast trade winds over Oahu. This caused heavy rainfall as the system strengthened and moved slowly over Kauai. The rain lasted until April 19. - The GPM satellite is the core of the Precipitation Observatory, which includes measurements from NASA, the Japan Aerospace Exploration Agency and five other national and international partners. Local amounts can be much higher when measured from the ground. - Emergency crews are working to clear thousands of pounds of dirt and debris from the Kuhio Highway. Officials plan to open one lane on May 7 for emergency vehicles, but officials have not said when public roads will reopen. Figure 30: This map shows the accumulation of precipitation over the Kauai area from April 12 to 19. These precipitation data are remotely sensitive estimates, which comes from a comprehensive multi-track search for GPM (IMERG), the product of the global precipitation measurement mission (credit image: NASA Earth Observatory, image by Joshua Stevens, using IMERG data from the Global Precipitation Mission (GPM) at NASA/GSFC, kashi Patel story) - March 22, 2018: For the first time scientists can look at the threat of landslides anywhere in the world in real time, thanks to satellite data and new models A model developed at NASA/GSFC (Goddard Space Flight Center) in Greenbelt, Maryland, assesses potential landslide activity caused by precipitation. Precipitation is the most common trigger for landslides worldwide. If the conditions beneath the Earth's surface are already unstable, torrential rains act as the last drop that causes mud, rocks or debris - or all put together - to move quickly down the mountains and hillsides. 69) - The model is designed to enhance our understanding of where and when landslide hazards are present and improve estimates of long-term models. The global analysis of landslides over the past 15 years using the new LHASA (Landslide Hazard Assessment for Situational Awareness) was published in a study published online March 22 in the journal Earth's Future. 70) (UP) -- Landslides can cause widespread destruction and fatalities, but we don't really have a full sense of where and when landslides can occur to inform disaster response and mitigation, said Dalia Kirschbaum, a landslide expert in Goddard and co-author of the study. This model helps determine the time, location and severity of potential landslide hazards almost in real time around the world. Nothing like this has ever been done before. - The model assesses potential landslide activity, first identifying areas with strong, persistent and recent precipitation. Precipitation estimates are provided by a multi-track product developed by NASA using the NASA and JAXA GPM (Global Precipitation Measurement) mission, which provides precipitation estimates worldwide every 30 minutes. The model takes into account when GPM data exceeds the critical precipitation threshold by looking back on the last seven days. - In places where precipitation is unusually high, the model then uses a susceptibility map to determine whether the area is prone to landslides. This global susceptibility map is designed using five features that play an important role in landslide activity: if roads have been built nearby, if trees have been removed or burned, if a large tectonic fault is nearby, if the local base is weak, and if the slopes are steep. - If the susceptibility map shows that the area with heavy precipitation is vulnerable, the model now creates a highly identifiable area as having a high or moderate probability of landslide activity. The model produces new nowcasts every 30 minutes. Figure 31: This animation shows the potential landslide activity per month on average over the past 15 years, as estimated by NASA's LHASA (a model of landslide hazard assessment for situational awareness) model. Here you can see landslide trends around the world (image credit: NASA/GSFC/Science Imaging Studio) - Study long-term trends when the output model has been compared to landslide databases since 2007. Team analysis reveals global 'landslide season' with peak landslides in July and August are most likely related to the Asian monsoon seasons and tropical cyclones in the Atlantic and Pacific Oceans. The model was able to help us understand the immediate potential dangers of a landslide in a matter of minutes, said Thomas Stanley, a landslide expert at the USRA (Universities Space Research Association) in Goddard and co-author of the study. It can also be used for a retroactive look at how potential landslide activity is changing globally seasonally, annually or even in the decathlon in a way that was not possible before. - March 1, 2018: The main satellite of the GPM (Global Precipitation Measurement) mission provided forecasters with an opportunity to look at precipitation in storms that doused Arkansas and Tennessee. 71) - The NOAA National Weather Service has issued flood warnings and flood warnings for large areas of Arkansas and Tennessee on March 1. Much of the Ohio Valley and Mississippi Valley received flash flooding over the past week. Arkansas has seen more rain than any other state. Figure 32: February 28, 2018 at 11:15 p.m. GPM data was used to create 3D species that showed severe storms stretching from Oklahoma to.m southwest Arkansas. Storm peaks in the area were shown GPM to reach heights above 9 km (image credit: NASA/JAXA, Hal Pierce) - Life-threatening flood conditions have led to more than 10 inches (254 mm) of rain falling in vast areas of central Arkansas. - The satellite of the main GPM observatory had a great view of the storms that caused flooding in Arkansas.m when it flew over the state on Wednesday, February 28, 2018 at 23:15 Moscow time (March 1 at 05:15 UTC). The precipitation analysis was based on data obtained by the satellite using GMI (GPM Microwave Imager) and DPR (Double Frequency Precipitation Radar). The GPM radar passed right over the storms, which were falling heavy rain over southwestern Arkansas. The GPM radar (DPR) showed that some of these storms were dropping rain by more than 5.1 inches (20.7 mm) per hour. GPM is a joint mission between NASA and the Japan Aerospace Exploration Agency JAXA. January 11, 2018: Winter rains falling on newly burned ground trigger deadly landslides in Santa Barbara County, California, on January 9. NASA has calculated precipitation between January 8 and January 10, 2018, and calculated the potential for landslides. 72) Figure 33: NASA's IMERG (Integrated Multi-Satellite Search for GPM) analysis on January 8 to 10, 2018 showed that the heaviest rainfall occurred over the Sacramento Valley, where more than 8 inches (203 mm) were indicated. Rainfall total of 5 inches (127 mm) has been reported in Ventura County (image credit: NASA/JAXA/Hal Pierce) - NASA Goddard Space Flight In Greenbelt, Maryland, a potential landslide map was created by Global LHASA (Landslide Hazard Situational awareness model, a model that combines precipitation data from the GPM (Global Precipitation Measurement) satellite with a global map of landslide susceptibility. LHASA gives a broad overview of the dangers of landslides in near real time, but information on specific locations should be obtained prior to emergency operations or construction projects. - At least 17 Southern Californians have been killed by deadly landslides. The storm, which is coming from the Pacific Ocean, has rained heavily on soil that was battered by wildfires last month. Heavy rainfall weakened surface sediments in Santa Barbara County early Tuesday morning, January 9 caused deadly landslides. According to the California Department of Transportation Part 101, the main highway connecting northern and southern California was closed due to mud and debris. - NASA's GPM satellite provides information on precipitation from orbit in space. GPM is a joint mission between NASA and JAXA (Japan Aerospace Exploration Agency). GPM also uses a constellation of other satellites to provide global precipitation analysis that is used in precipitation calculations. - In NASA/GSFC, precipitation analysis was built using NASA IMERG (Integrated Multi-satellitE extracts for GPM) data. Precipitation data from satellites in the constellation GPM between 8 and 10 January 2018 were used to create a precipitation map. The analysis showed heavy rainfall that occurred over California over the past three days. Figure 34: A map of landslide potential was created by the global LHASA model (Landslide Hazard Assessment for Situational Awareness). LHASA gives a broad overview of the dangers of landslides in near real time (image credit: NASA) - November 22, 2017: As intense rainstorms moved to Jeddah, Saudi Arabia November 21, NASA's GPM (Global Rainfall Measurement) Mission Main Satellite analyzed severe storms. Heavy downpours led to the closure of schools and universities, and the Directorate General of Meteorology and Environment predicted that heavy rains would continue for several days. 73) - NASA's GPM Core Observatory satellite observed precipitation from space using the first DPR Space Cou/Ka-band (Two-frequency precipitation radar) and multi-channel GMI (GPM Microwave Imager). The satellite passed over the western part of Saudi Arabia on November 21, 2017 at 01:23 UTC . GMI and DPR collected data that showed heavy rains within the powerful storms that were heading towards Jeddah, Saudi Arabia. - GMI indicated that an intense thunderstorm over Saudi Arabia north of Jeddah was raining at a rate of more than 115.5 mm/h. In the DNR, rainfall fell in a storm located over the Red Sea, which was going at a speed of more than 90 mm per hour. Illustration 35: November 21 at 01:23 GPM points to severe thunderstorm it rained over Saudi Arabia north of Jeddah at a speed of more than 115.5 mm/h. GPM's DPR swath (shown in light shades) measured precipitation in a storm located over the Red Sea that produces rain at a speed of more than 90 mm/h (image credit: NASA/JAXA, Hal Pierce) Figure 36: This 3-D image of precipitation in storms over western Saudi Arabia on November 21 was created using GPM's DPR Ku-band tool. GPM found that several storm peaks in the Red Sea reached heights above 10 km (Photo: NASA/JAXA, Hal Pierce) - September 23, 2017: When Hurricane Maria hit Puerto Rico on September 20, 2017, meteorologists expected it to deliver huge amounts of rain in a short period of time. Satellite data confirms that this is exactly what happened. 74) - Map 37 shows cosmic measurements of precipitation in the Caribbean near Puerto Rico. It shows measurements from the evening of September 18 to the evening of September 20. The brightest areas reflect the highest rainfall - up to 500 mm in places. - On September 21-22, the rain bands, having been drizzling after the storm, continued to bring heavy rain to the island. The National Hurricane Center reported catastrophic flooding, especially in mountainous areas, and noted that landslides were to be expected. The mountainous terrain directs floodwaters into streams and rivers. Gages in these rivers show that many, such as the Rio Grande de Manati, have reached record highs. - After Hurricane Maria left Puerto Rico, it moved to the Dominican Republic and hit parts of the island with strong winds and rain. According to media reports, at least 150-300 mm was observed in most parts of the island, with 500 mm in some areas. - These measurements are the result of the GPM (Global Precipitation Measurement) mission, which is a partnership between NASA, JAXA (Japan Aerospace Exploration Agency) and five national and international partners. Rainfall results are regional, remotely-sensitive estimates. Each pixel shows 0.1o of the globe (about 11 km at the equator), and the data is mediated for each pixel. Individual terrestrial measurements within the pixel may be much higher or lower than the average. - The data for the map comes from IMERG (Integrated Multi-Satellite Extracts for GPM), a product of the American scientific group GPM. IMERG collects precipitation estimates using passive microwave and infrared sensors on several satellites, as well as monthly surface precipitation sensor data to estimate precipitation between 60o north and south latitudes. Figure 37: IMERG rainfall map of Hurricane Maria in the Caribbean near Puerto Rico, purchased from GPM September 19-21, 2017 (image credit: NASA Earth Observatory, image by Joshua Stevens, using IMERG data from GPM at NASA / Caption Katherine Hansen) - August 30, 2017: NASA's GPM mission team has prepared the accumulation of graphics and unique types of Harvey's structure at various stages of development and fall. GPM products help identify the center of circulation and extensive convection of the eye wall, and these images are provided to the NOAA National Hurricane Center (National Oceanic and Atmospheric Administration) through NASA's SPoRT (Short-Term Research and Transition) and NRL (Marine Research Laboratory). Based at NASA/MSFC (Marshall Space Flight Center) in Huntsville, Alabama, SPoRT is a project to transition unique observations and research capabilities to the operational meteorological community to improve short-term forecasts on a regional scale. 75) Figure 38: NASA's GPM Core Observatory captured these images of Hurricane Harvey at 6:45 a.m. CDT (1145 UTC) and 4:25 p.m..m. CDT (2125 UTC) on August 27, nearly two days after the storm made landfall near Victoria, Texas. The image shows rain indicators obtained from the GMI GMI microwave imager (outer band) and two-frequency precipitation radar or DPR (inner band) superimposed on advanced infrared data from the NOAA GOES East satellite (image: NASA Science Studio Imaging) - June 16, 2017: At least 156 people in Bangladesh were killed in the past week as a result of landslides and flooding caused by heavy rainfall. NASA has calculated the amount of precipitation that has fallen using satellite data. 76) Figure 39: From 12 to 14 June 2017, the heaviest estimates of the accumulation of precipitation (purple) IMERG were found over the south-east of Bangladesh. IMERG estimates that rainfall exceeds 510 mm (photo: NASA/JAXA, Hal Pierce) - Monsoon precipitation was particularly strong over the area, which includes southeastern Bangladesh, northeastern India and western Burma (Myanmar). The disaster follows quickly on the heels of the deadly Cyclone Mora, which hit the same area a couple of weeks ago. - This precipitation analysis was done at NASA's Goddard Space Flight Center in Greenbelt, Maryland, using NASA's Near Real-Time IMERG (Integrated Multi-satellitE Retrievals) data. GPM is a global mission measuring the precipitation of a satellite and constellation of satellites that are operated by both NASA and the Japan Aerospace Exploration Agency or JAXA. - These IMERG data were collected between June 12 and June 14, 2017. The heaviest estimates of IMERG's rainfall were located over southeastern Bangladesh. IMERG estimates that rainfall has been more than 510 mm. It is expected that the monsoon precipitation will continue to affect the area. The IMERG precipitation results were adjusted to reflect observed values in other similar extreme precipitation events. May 17, 2017: Heavy rainfall in recent times large-scale flooding and landslides in Jamaica. Sometimes showers from trade winds are normal in Jamaica, but the last recent from the slow-moving gutters were unusually heavy. A 1009 MB low pressure center located in the western Caribbean breaks normal trade winds over Jamaica today. 77) - This precipitation analysis was based on data from NASA's IMERG (Integrated multi-satelliE retrievals for GPM). Almost real-time data were used in estimates of rainfall accumulation in the Caribbean. This analysis covers the period from 13 to early May 17, 2017. Precipitation of more than 239 mm was shown by IMERG data stretching from southern Jamaica to south-west Haiti. Some precipitation totaling more than 12 inches (304.8 mm) was estimated in the waters between Jamaica and southwestern Haiti. The IMERG precipitation results in this analysis were adjusted to reflect observed values in other similar extreme precipitation events. - IMERG is a single U.S. algorithm that provides a multi-track precipitation product. IMERG works twice in near-real time, with the Early multi-satellite product being created about 4 hours after observation, and the multi-satellite product Late is available about 12 hours after observation. Figure 40: IMERG analyis heavy rainfall in the Caribbean Sea between 13 and 17 May 2017 (photo: NASA/GSFC, Hal Pierce) - March 23, 2017: GPM's main observatory measures the heavy rainfall that caused extensive flooding and loss of life in Peru. Extreme flooding and frequent landslides in March forced many to flee their homes. Off the coast of Peru, an El Nino with warm ocean waters. This extremely warm water off the west coast of Peru has been blamed for contributing to the development of these storms. Equatorial SSTs (Sea Surface Temperature) are near average elsewhere in the central and eastern central Pacific. 78) - When the GPM Observatory satellite flew over Peru on March 20, 2017 at 0826 UTC, GPM identified storm locations that fall heavy precipitation over northwestern Peru. Data collected by GMI (GPM Microwave Imager) and DPR (Double Frequency Precipitation Radar) during this passage showed that very heavy precipitation was falling in the area. Data from the GPM (DPR Ku-band) radar show that some storms are raining at an extreme speed of more than 137 mm/h. These extreme precipitation figures were detected in a line of storms stretching southwest from the coast of Peru. - The DNR ku-band was also used to study 3D precipitation patterns during storms near and over northwestern Peru. The GPM examination showed that several storms in the Pacific Ocean had cloud peaks reaching altitudes above 13 km. GPM is a joint mission of NASA and the Japanese space agency JAXA. - DATA IMERG (Integrated multi-satellite extracts for GPM) were used for rainfall in areas that were not covered by the GPM GPM core satellite strip. These estimates are the result of combining precipitation measurements with the constellation of research and operational satellites. These precipitation estimates were obtained by NASA's precipitation system every half hour. - These data were made in animations at NASA/GSFC (Goddard Space Flight Center) in Greenbelt, Maryland and showed real-time IMERG rainfall estimates based on data collected between March 14 and 21, 2017. An animation of the data over seven days showed scattered storms raging over Peru and Brazil and moving over Peru. The animation showed rainfall of 25 mm to 50 mm per hour in many storms. - On 18 March, the National Meteorological and Hydrological Service of Peru noted that from 19 to 25 March, rains will intensify on the north coast and on the entire western slope of the Sierra. On the north coast (La Libertade, Lambayeke, Piura and Tambe), heavy rains accompanied by lightning will intensify between 19 and 23 March. In the interior of Piura and Lambayek, rainfall is expected to exceed 150 mm/day; while in the coastal areas of Piura, Lambayeke, Tambe and the interior of La Libertad, it can exceed 50 mm/day. - A devastating downpour has killed 67 people in Peru and forced thousands more to evacuate due to heavy rains that damaged 115,000 homes and destroyed more than 100 bridges in Peruvians in the worst flooding in recent times. The disaster, which came after a period of severe drought, has been blamed for abnormally high temperatures in the Pacific Ocean and has drawn criticism that the country is ill-prepared for the growing challenges of climate change. 79) Figure 41: When the main satellite of the GPM Observatory flew over Peru on March 20, 2017 at 0826 UTC, GPM identified the locations of storms that were dropping heavy rainfall over northwestern Peru (image credit: NASA/JAXA, Hal Pierce) - March 3, 2017: Precipitation from spring showers in the U.S. from February 25 to March 1 were analyzed by NASA using data from the Global Rainfall Measurement Mission or GPM Satellite (Figure 42). 80) - On February 27, 2017, GPM is 3 years in orbit. - Record warm temperatures this winter have caused plants to bloom early in the eastern United States. Unfortunately, this has also led to the formation of spring severe thunderstorms and deadly tornadoes. Several tornado sightings have been made in three of the last seven days. On Saturday, February 25, 2017, devastating tornadoes were reported in Maryland, Pennsylvania and Massachusetts. - On February 28, twisters were reported in Arkansas, Iowa, Illinois and Michigan. Three people have been killed in Illinois and four others have been injured in Arkansas as a result of a tornado outbreak. Severe weather conditions on March 1, 2017 also included reports of tornadoes in Ohio, Tennessee, West Virginia, Kentucky and (Integrated multi-satellitE retrievals for GPM) data were used to show the amount of precipitation that occurred during the past week. The analysis was conducted at NASA/GSFC (Goddard Space Flight Center) in Greenbelt, Maryland. Intense downpours from storms during this period led to flash flooding in several states. - The satellite of the main GPM Observatory had a good view of the severe weather conditions as it moved into the Appalachian Mountains on March 1, 2017 at 15:25 UTC (10:25 .m EST). The GPM satellite measures rain and snow using GMI (GPM Microwave Imager) and DPR (Double Frequency Precipitation Radar). GPM's DPR measured rain falling at speeds of more than 159mm per hour as powerful storms moved through Tennessee and Kentucky. The storm's height of more than 9.8 km was detected by GPM radar when it cut through these severe thunderstorms. - Due to above average temperatures, frozen precipitation, besides hail, was unusual over the eastern United States in the GPM analysis. Radar data from GPM (DPR) showed that the average freezing altitude was above 3 km. In Alabama, the freezing rate was much higher. According to GPM, it exceeds 4 km. Figure 42: This image of GPM precipitation, combined with infrared cloud data from the GOES-West NOAA satellite, shows a line of storms that stretched from Pennsylvania to Alabama on March 1, 2017. Red areas indicate rainfall of up to 50 mm per hour (photo credit: NASA/JAXA, Hal Pierce) - January 13, 2017: Widespread flooding has recently killed dozens of people in southern Thailand. Frequent and persistent downpours have led to record rainfall, and NASA has calculated rainfall in the region from January 5 to January 12, 2017. The main satellite of the GPM mission (Global Precipitation Measurement) is part of a constellation of satellites that can measure precipitation from space. GPM is a joint mission of NASA and JAXA and the data is entered into NASA's IMERG (Integrated Multi-satellitE Extracts for GPM) product data. 81) - Precipitation has increased significantly over Thailand during this Year of La Nina 2016. Very low rainfall occurred over Thailand during last year's El Nino event. At NASA/GSFC (Goddard Space Flight Center) in Greenbelt, Maryland, an analysis of precipitation anomalies was done by comparing the former TRMM (Tropical Rainfall Mission) calibrated rainfall climatology with a near-real-time multi-satellite analysis of precipitation data collected over thirty days. - TMPA (TRMM-based, almost real-time Multi-track rainfall analysis) has been used to monitor precipitation over the global tropics for years. By subtracting long-term average precipitation or climatology, precipitation anomalies can be constructed to show deviations from the normal pattern. - The TRMM mission was in service from 1997 to April 2015 It was designed to measure precipitation over the global tropics, using both and active sensors, including the first and at that time only precipitation radar in space. A combination of passive microwave and active radar sensors has been used to calibrate precipitation estimates from other satellites to expand coverage. The TRMM satellite has produced more than 17 years of precipitation measurements that have made a valuable contribution to global precipitation climatology. Figure 43: NASA has calculated the amount of precipitation over southern Thailand from January 5 to January 12, 2017. Extreme precipitation totaling more than 700 mm was found over the Gulf of Thailand. The highest rainfall over land was more than 500 mm on the east coast of the Malay Peninsula in the Bang Safang area (image credit: NASA/JAXA, Hal Pierce) Figure 44: In this rainfall analysis, the panel left shows precipitation moving away from normal during the 2016 El Nino event. A panel on the right shows an extreme increase in precipitation over southern Thailand during the current La Nina event (image credits: NASA/JAXA, Hal Pierce, Ref. 81) July 26, 2016: Most Hawaiian islands have been spared serious damage from Tropical Storm Darby. The location of the Darby Highway through Hawaii has resulted in Hawaii and Oahu being hardest hit. Flash flooding was widespread on the island of Oahu due to 177.8 mm of rain spilling over the island. The Interstate H-1 was flooded in some places. Lightning damage was reported in Kaneoha on the windward side of Oahu. 82) Figure 45: Estimates of precipitation accompanying Tropical Storm Darby were obtained using DATA from NASA IMERG (Integrated Multi-satellitE Retrievals for GPM). These IMERG precipitation accumulations were calculated between July 19 and July 26, 2016. IMERG estimates that Darby sometimes receives extremely heavy rainfall. The highest rainfall during this period was north of Oahu, where 480 mm fell (photo: SSAI/NASA/GSFC, Hal Pierce) - March 31, 2016: Not all raindrops are created equal. The size of the raindrops depends on several factors, including where the cloud that produces the droplets is located on the globe and where the droplets occur in the cloud. For the first time, thanks to a joint mission between NASA and JAXA GPM (Global Precipitation Measurement), scientists have received three-dimensional images of raindrops and snowflakes around the world from space. With new global data on the size of raindrops and snowflakes this mission provides, scientists can improve precipitation estimates from satellite data and numerical weather forecast models, helping us better understand and prepare for extreme weather events. 83) - The distribution of the size of the droplet is one of the many factors that determines how big the storm will grow, how long it will last and how much rain it will end produce, said Joe Joe NASA/GSFC (Goddard Space Flight Center) in Greenbelt, Maryland. We have never been able to see how the size of water droplets are changing around the world until now. - Storm clouds contain a wide range of drop sizes that end up falling like rain or snow. In general, in the cores of clouds, droplets tend to be larger because they collide with each other and aggregate when falling on the Earth's surface, while smaller droplets occur at edges and at higher altitudes. The drops are usually small when they miss collisions with others or disintegrate. Scientists call the number of droplets and snowflakes of different sizes in different places in the cloud the distribution of particle sizes. - In order to know exactly how much precipitation falls during a storm, scientists need to understand the ratio of large droplets to smaller or medium droplets. Previously, researchers had to make assumptions about the ratio because earlier studies were conducted in isolated locations and global data were limited, Munchak said. Without knowing the attitude or attitude of these big droplets to smaller or medium droplets, we may have a big mistake in how much rain we know has fallen, and that can have some big implications for knowing long-term accumulations that can help with flash flood forecasts, Munchak said. - Using 3D images of the distribution of GPM drop sizes, scientists can also gain an idea of the storm's structure and how it will behave. The distribution of drop sizes affects the growth of the storm, changing the rate of rain evaporation when it falls through dry air, Munchak said. Smaller droplets, for example, will usually evaporate faster and then cool the air more. This leads to a stronger stream of downward moving air, which can cause destructive winds when they reach the ground. However, these same downdrafts can prevent up flowing air, which fuels the storm and cause the storm to weaken or dissipate. Figure 46: This is a conceptual image showing how the size and distribution of raindrops varies within the storm. Blues and greens are small raindrops measuring 0.5-3 mm. Yellow, orange and red are large raindrops measuring 4-6 mm. Storm with a higher ratio of yellow, oranges and reds will contain more water than a storm with a higher ratio of blues and greens (image credit: NASA/GSFC) - March 3, 2016: Heavy rainfall recently caused floods, landslides and power outages in some parts of Peru. NASA's IMERG (Integrated Multisatellit Extracts for GPM) measured that precipitation using a combined sediment product from a constellation of satellites. 84) - GPM is a global precipitation measurement mission that is a satellite jointly NASA and JAXA (Japan Aerospace Exploration Agency) and is used in NASA data IMERG. GPM provides the next generation of rain observations and all over the world every three hours. - Extremely heavy precipitation was reported in northern Peru on 26 February and 27 February 2016. Thousands of people have been left homeless and at least two people have reportedly been killed by bad weather. A strong El Nino has been partly blamed for abnormally high rainfall in the area. - NASA IMERG data collected between February 23 and 29, 2016 were used to estimate rainfall in this area of South America. Total precipitation estimates for this period were more than 700 mm. These extreme precipitation estimates were shown east of Asnes in south-eastern Peru and Bolivia. - The satellites used in IMERG include the DMSP series from the U.S. Department of Defense, GCOM-W from JAXA, Mega-Tropiques from CNES (Center for National D'etudies Spatiales) and ISRO (Indian Space Research Organization), NOAA Series of Satellites, Suomy-APP from NOAA-NASA, and MetOps from EUMETSAT (European Organization for Exploitation). All instruments (radiometers) aboard the constellation partners are recalibrated with information from the GMI GPM Core Observatory (GPM Microwave Imager) and DPR (Double Frequency Precipitation Radar). - On 3 March, the National Weather and Hydrological Service of Peru reported that rain was forecast to continue along the northern coast. The Service reported that a total of 110 mm of rain was recorded at Lancones station in 10 hours, while 60 mm of rain fell in the town of Tambov. Figure 47: NASA IMERG data collected between February 23 and February 29, 2016 were used to estimate rainfall in this area of South America. The highest rainfall during this period was more than 700 mm (27.6 inches). These extreme precipitation estimates were shown east of Tesa in southeastern Peru and Bolivia (image credit: NASA, JAXA, SSAI, Hal Pierce) - December 10, 2015: NASA's GPM mission and other satellites collected data on extreme precipitation in the Pacific Northwest. Continued rainfall training in the area caused flooding in the Portland, Oregon area, with at least one person killed. Western Washington is also on a flood alert due to the deluge. 85) - Riding a pumped jet stream, a convoy of wet storms has battered and soaked the Pacific Northwest over the past week, said Bill Patzert, a climatologist at NASA/JPL (Jet Propulsion

Laboratory) in Pasadena, California. After years of regional drought, all these rains and mountain snow whipped many Washington and Oregon communities out of extremely dry flood conditions and even landslides. Once again, the old adage: Great droughts end in great floods comes to mind. Patzert said this heavy moisture hose occurs in the far western Pacific. Sweeping out of the tropics, meteorologists cite these relatively moisture laden with rain and producers as atmospheric rivers. For the states of the west coast of the United States, these storms supply up to 50% of their water supply. They can be fast and violent and harmful, but play a big role in maintaining our water reserves in the normally dry West, Patzert said. - Precipitation from December 2 to December 9, 2015 was measured based on NASA's Integrated Multi-satellitE Retrievals for GPM data. IMERG found that more than 160 mm of rain fell across Washington state in many areas of northern California. Even more extreme precipitation has been measured by IERG over the open waters of the Pacific Ocean, where the total rainfall over the past week was more than 310 mm. - IMERG creates a combined product of precipitation from the constellation of GPM satellites. These satellites include DMSPs from the U.S. Department of Defense, GCOM-W from JAXA, Megha-Tropiques from CNES and ISRO (Indian Space Research Organization), NOAA Suomi-APP series from NOAA-NASA, and MetOps from EUMETSAT (European Organization for the Exploitation of Meteorological Satellites). All instruments (radiometers) on board the constellation partners are recalibrated with information from GPM Microwave Imager) and DPR (Double Frequency Precipitation Radar). - On December 9, the region had many hours and warnings. Flood watches, warnings and flood recommendations were in effect for parts of the Pacific Northwest as well as parts of northern California and northern Idaho. Winter storm watches and warnings were in effect for the Sierra Nevada range in California and parts of the intermountain west. Strong wind watches, warnings and wind advisories were in effect for parts of the northwest U.S., especially in higher ground. Figure 48: NASA's IMERG measured precipitation from December 2 to 9 and found More than 310 mm of rain fell over the open waters of the Pacific Ocean (photo: NASA/JAXA/SSAI, Hal Pierce) - December 1-2, 2015 in the Indian city of Chennai, more rain fell in 24 hours than on any day since 1901. The deluge followed a month of persistent monsoon rains that were already well above normal for the Indian state of Tamil Nadu. At least 250 people were killed, several hundred seriously injured, and thousands of people were injured or displaced by the ensuing flooding. 86) - Precipitation data in Figure 49 is derived from IMERG (Integrated Multi-Satellite Extracts for GPM), a product of the global precipitation measurement mission. The brightest shades on the maps represent rainfall approaching 400 mm over a 48-hour period. These remote-sense regional estimates may differ from those measured by terrestrial weather stations. By Hal Pierce, a scientist with NASA's GPM/GSFC (Goddard Space Flight Center), had the highest rainfall of more than 500 mm in an area off the southeast coast. - Meteorologists in India and abroad explained the rains with a super-charged northeast monsoon. In winter, prevailing winds blow from northeast to southwest across the country, which usually has the effect of drying out in most places, especially inland. But these northeasterly winds also blow over the warm waters of the Bay of Bengal, where they evaporate a lot of moisture from the sea and dump it over southern and eastern India. Coastal eastern India receives 50-60% of its annual rainfall during the winter monsoon. - In 2015, this trend was reinforced by record-warm seas and the long-distance impact of El Nino. According to Weather Underground blogger Bob Henson, 1,218.6 mm of rain fell in The City of Chennai in November 2015. The Bureau of Meteorology of India noted that precipitation in the eastern states is 50-90 percent above normal. Then another 345 mm fell on Chennai during the storm On December 1-2, which was fueled by a low pressure system at sea. Figure 49: GPM Based rainfall estimates over southeastern India on December 1-2, 2015 (image credit: NASA Earth Observatory, Joshua Stevens) - November 4, 2015: Image Figure 50 shows satellite precipitation estimates from a particularly large storm that passed over the area on October 18. Precipitation data are derived from GPM/IMERG (Global Precipitation Measurement/Integrated Multi-Satellite Retrievals), one of the products of the global precipitation measurement mission. Green-and-white colors represent the highest rainfall, which in some areas reached more than 70 mm during the 24-hour period displayed in the animation. These remote-sense regional estimates may differ from those measured by terrestrial weather stations. Parts of Death Valley National Park in California were particularly hard hit. 87) Figure 50: In October 2015, a series of storms passed through the southwestern United States and brought a torrent of rain to the area's desert valleys, October 18-19, 2015 with GPM/IMERG (photo credit: NASA Earth Observatory, USGS) - October 5, 2015: NASA's GPM/JAXA satellite measured record rainfall over the Carolinas from September 26 to October 5 from a plume of moisture from Hurricane Joaquin as it was over the Bahamas and moved to Bermuda. IMERG (Integrated Multi-Track Extraction for GPM) showed the highest rainfall of about 1,000 mm (39.3 inches) in a small area in South Carolina and precipitation between 700 and 900 mm (27.5 and 37.4 inches) on a large area in South Carolina. 88) Figure 51: Mission GPM recorded a '1000 Year' rainfall event heaping death and destruction in wide areas of South Carolina Nor'easter freak action and hurricane Hurricane (Credit: SSAI/NASA/JAXA, Hal Pierce) - April 2, 2015: GMI (GPM Microwave Imager), built by BATC (Ball Aerospace and Technologies Corp.) under contract for NASA, in its first year in orbit acted flawlessly as the most accurately calibrated radiometer in the twelve-track constellation GPM. GMI provides a calibration standard that will significantly improve the accuracy of precipitation data measured by other radiometers in the constellation. 89) - As an important part of the international satellite mission, GMI captures the next generation of observations of rain and snow around the world every three hours. The GPM Core Observatory reports unprecedented 3-D hurricanes and blizzards and monitors and contributes to the monitoring and forecasting of weather events such as droughts, floods and landslides. February 27, 2015: NASA's GPM Core Observatory and JAXA, launched from the Tanegashima Cosmodrome in Japan, February 27, 2014, celebrate their first year in orbit. 90) - Last month, NASA released the agency's most comprehensive global product for rain and snowfall to date from the GPM mission, made with data from a network of 12 international satellites and the Main Observatory. The main observatory acts as a tune for other satellites, providing an almost global picture of rain and snow called IMERG (Integrated Multisatellite Extracts for GPM). Figure 52: The GPM Mission produced its first global map of precipitation and snowfall from April to September 2014 (image credit: NASA/GSFC, video seen in Ref. 90) - Precipitation Processing System (PPS) began producing updated GPM radiometer products as of December 4, 2014 due to an error detected in the solar angle calculation tool in the GLOBAL LOCation instrument PPS. This is considered a minor update, with the product version added only in the letter. 91) November 2014: The GPM mission provides rainfall rates almost everywhere in the world. 92) - In the evening and afternoon of August 6, 2014 (Figure 53) the satellites TRMM and GPM saw a swarm of thunderstorms over part of the Sahara Desert, where rain is particularly rare. Each satellite showed a different cluster structure, possibly due to a different time of day or another part of the cluster they were observing. Figure 53: Rare thunderstorm over the Sahara on August 6, 2014, acquired by GPM (image: NASA) - As of September 4, 2014, data from nasa/JAXA GPM are freely available through NASA's precipitation processing system at the Goddard Space Flight Center in Greenbelt, Maryland. Scientists and fashion designers (registered users) can use new GPM data for weather forecasts, assessing the accumulation of snow cover for freshwater resources, forecasting floods and landslides, or tracking hurricanes. 93) - The most accurate and data on rain, snowfall and other types of precipitation ever collected at present are available to the public. This new resource for climate research, weather forecasting and other applications is based on observations by the GPM Core Observatory, a joint NASA and JAXA mission, with the participation of a constellation of international partner satellites. 94) - July 8, 2014: The GPM spacecraft flew over Hurricane Arthur five times between July 1 and July 5, 2014. Arthur is the first tropical cyclone of the 2014 Atlantic hurricane season. Five GPM passes over Arthur for the first time a precipitation measuring satellite was able to follow a hurricane through its full life cycle with high-resolution measurements of rain and ice. In the July 3 image, Arthur was off the coast of North Carolina. GPM data showed that the hurricane was asymmetrical, with a spiral of weapons called rain bands, on the east side of the storm, but not on the west side. 95) - Observations of the GPM Core storm spacecraft, such as Arthur, will also help scientists decipher some of the most difficult questions about hurricanes, such as how and why they intensify. Hurricane intensity is one of the most difficult aspects to forecast and is an area of active research that GPM observations will contribute to. Figure 54: 3-D view of Hurricane Arthur in July 2014, taken from instruments aboard nasa/JAXA GPM Observatory (credit image: NASA) - April 11, 2014: The main observatory of the Global Precipitation Measurement Mission is operating normally. The calibration of DNR (two-frequency precipitation radar) and GMI (GPM Microwave Imager) continues. 96) March 25, 2014: NASA and JAXA release the first images taken by the GPM sensor. Images show precipitation falling inside the Cyclone on March 10 over the Pacific Northwest Ocean, about 1,600 km east of Japan. The data was collected by two instruments of the GPM Core Observatory: JAXA in DPR (Two-frequency precipitation radar), which emitted a three-dimensional cross-section of the storm; and NASA's GMI (GPM Microwave Imager), which observed precipitation across a wide swath. 97) 98) Figure 55: An image of an extratropical cyclone off the coast of Japan observed on March 10, 2014 by the GMI instrument (credit image: NASA/JAXA) Legend in Figure 55: Colors show the speed of rain: red areas indicate heavy rainfall, while yellow and blue indicate less intense precipitation. The upper left blue areas indicate falling snow. In addition to seeing all kinds of rain, GMI's technological advances allow the tool to identify rain structures as small as about 5 to 15 km across. This higher resolution is a significant improvement over the capabilities of an earlier instrument flying on the TRMM (Tropical Precipitation Measurement Mission) launched in Year. Figure 56: 3D view inside an extratropical cyclone Cyclone The coast of Japan, observed on March 10, 2014 by the DPR (image: JAXA) Legend in figure 56: Vertical cross-section about 7 km high shows the speed of rain: red areas indicate heavy precipitation, while yellow and blue indicate less intense precipitation. These first images of the GPM Core Observatory were taken within the first few weeks after launch, when mission controllers at NASA's Goddard Mission Operations Center put the spacecraft and its scientific instruments through their pace to make sure they were healthy and functioning as expected. The engineering team calibrates the sensors, and Goddard's team in the precipitation processing system checks the accuracy of the data. - GPM scientific data is expected to be available from September 2014, when all elements have been calibrated and tested. On March 17, 2014, the team performed the first planned GPM reversal to change the spacecraft's orientation to 180o. Yaw is a left/right orientation in the horizontal plane of the spacecraft's motion. The spacecraft is now flying backwards. Yaw maneuvers will be performed approximately every 40 days for the thermal control of spacecraft, as the angle between the orbit of the spacecraft and the Sun changes. This keeps the side of the spacecraft, which is designed to stay cold from overheating. Yaw manoeuvres are performed mainly using the spacecraft's reaction wheel (Ref. 99). - On March 19, 2014, the team performed a 50-s maneuver, increasing the speed to increase the altitude of its orbit using its engines. GPM has twelve engines: four forward and eight aft. The March 19 maneuver was the first maneuver made using forward engines, as the spacecraft is now in the opposite orientation after a U-turn. March 8, 2014: The DPR tool is activated, and teams at NASA/GSFC's mission operations and support room in Greenbelt, md, begin the instrument verification period. DNR data is sent through the Goddard Precipitation System at JAXA (Mission Operations System) in Tsukuba, Japan (ref. 99). March 6, 2014: GPM is running as normal. Initial inspections of the GMI and spacecraft showed that both were working as expected, and the GMI instrument continues to collect scientific data on rain and snowfall (Ref. 99). March 5, 2014: The GPM Core Observatory operates as normal. GMI continues in scientific mode, and GMI data is now sent to PPS (Precipitation Processing System) at NASA/GSFC in Greenbelt, Md. Using initial data, the instrument team confirmed that GMI works well in orbit. The GPM spacecraft will have a 60-day orbital period (commissioning phase) to ensure the healthy operation of spacecraft and instruments. Precipitation data will be PPS no later than 6 months after launch, after the scientific teams have checked Accuracy. 99) March 4, 2014: GMI Electronics was switched on, and all seven launch restrictions are released by deploying the device. GMI (GPM Microwave Imager) began spinning today collecting the first scientific data of the mission. GMI will complete several additional departure procedures during the commissioning process. 100) March 1, 2014: After GMI electronic systems were activated and warmed up, nasa's Goddard Space Flight Center team in Greenbelt, Maryland, deployed the main reflector of the U.S. scientific instrument for the GPM Observatory (Ref. 99). - A significant step was also taken today in activating a scientific tool provided by JAXA with the inclusion of a controller for THE DNR (Two-frequency precipitation radar). - NASA/GSFC air traffic controllers have begun using the High Gain Antenna satellite system to transmit high-speed data through NASA's TDRS (Tracking Data Relay Satellites) orbital fleet. February 28, 2014: The GPM Core Observatory operates as normal. The GPS system is on. This tells the satellite the time and its location against the Earth's surface. The team is preparing the spacecraft to use its High Gain Antenna antenna for high-speed data transmission through the satellite data tracking and transmission system. After the release of the main GPM satellite, the second stage performed relationship maneuvers and slightly changed its orbit to deploy seven secondary payloads, which include small spacecraft and CubeSats, designed for scientific missions, technical demonstrations and outreach projects (Ref. 101). Launch Event Time (minutes:seconds) Altitude (km) Inertial speed (km/s) Liftoff 0:00 0 0.4 Solid Burnout launch vehicle 1:39 47 1.5 Solid booster discarded (cutting thrust rack) 1:48 55 1.5 Useful load 4:05 140 discarded Engine 5st Stage (Engine 1.5 main engine) cut (MECO) 6:36 230 5.0 1st and 2nd stages of separation 6:44 236 5.0 2nd ignition stage (SEIG) 6:50 239 5.0 2-engine 2-2 engine cut off (SECO) 15:4 390 7.7 GPM-Core15:49 398 7.7 ShindaiSat cubesat division 24:09 400 7.7 STARS-2 CubeSat division 28:19 403 7.7k TeyoSat-3 micro-satellite division 32:29 406 7.7 ITF-1 CubeSat Division 36:39 408 7.7 OPUSAT CubeSat Division 37:59 408 7.7 INVADER CubeSat Division 39:19 408 7.7 KSat-2 CubeSat Division 40:39 408 7.7 Table 3 : The launch sequence of the GPM mission and secondary payloads - GPM spacecraft is separated from the rocket 16 minutes after launch, at an altitude of 398 km. After the separation of the spacecraft, GPM initiated a pre-programmed sequence to establish a stable three-axis orientation in a safe mode of communication and to obtain communication with ground stations. The GPM signal was received - confirming that the spacecraft was alive and well after it was put into orbit. batteries deployed 10 minutes after division, to power the spaceship. 101) Core Sensor Complement: (DPR, GMI) GPM Core Observatory measurement capabilities are provided by two main INSTRUMENTS of the DPR active microwave and passive microwave GMI. 102) 103) 104) 105) DNR, consists of Ka and Koo range radar subsystems, will provide: - Increased sensitivity (No 12 dB) for light rain and snow detection in relation to TRMM - Improving the accuracy of precipitation measurement with differential time correction, and - Detailed microphysical information of precipitation DSD (distribution of drop size), average mass diameter, particle density) and identification of fluid, ice and mixed-phase regions. Multi-frequency (10-183 GHz) GMI conical microwave radiometer scan will provide: Higher spatial resolution (IFOV: 6-26 km) than in TRMM microwave imager (TMI) predecessor - Improved light rain - snow detection - Improved solid precipitation signals over the ground (especially over snow-covered surfaces), and four-point calibration to serve as a radiometric reference for radiometers. The resulting combined radar-radiometer precipitation extracts using data from these two instruments will combine to provide more severe limitations on possible solutions to improve search accuracy. A cloud-based database based on observations will be used to search for the constellation's radiometer. DPR (Two-frequency precipitation radar): THE DPR, PR heritage aircraft flown by TRMM, is currently being developed and developed as part of a joint effort between JAXA (Japan Aerospace Exploration Agency) and NICT (National Institute of Information and Communication Technology), Tokyo. (industrial partner is NEC Toshiba Ltd., Tokyo). The aim is to enhance TRMM's instrument capabilities in a way that fully address key scientific issues from microphysical to climatic time scales. THE DNR will provide accurate rainfall, including snowfall over the ocean and land. THE DNA data will also be used to calibrate MVR (microwave radiometers) in the constellation GPC. The DNR package will provide a global database of precipitation characteristics such as storm heights, freezing levels, DSD (drop size distribution), average rainfall profile structure, and so on. 106) 107) 108) 109) 110) 111) 112) 113) 114) 115) 116) 117) 118) 119) 119) 11 20) Figure 57: The goals and objectives of the GPM/DPR JAXA project (image: JAXA) 121) Figure 58: GPM Core spacecraft with DNR configuration in orbit (image credit: JAXA) The DNR instrument consists of two essentially independent radars. One radar runs in the Ku-band at 13.6 GHz, it is called PR-U, also known as KuPR (Ku-band Precipitation Radar). Another radar runs in the Ka-band at 35.55 it's called PR-A (also known as KaPR (Ka-band Precipitation By measuring the reflectivity of the rain on two strongly different radar frequencies, we can draw a conclusion about the speed of rain, the type of cloud and its three-dimensional structure, as well as the distribution of the size of the droplets. Both radars have almost the same design as the PR tool on TRMM. The specific objectives of the DNR are to: - to provide a three-dimensional structure of precipitation, including snowfall over the ocean and land - to increase the sensitivity and accuracy of precipitation measurement - to calibrate the estimated amount of precipitation on MVR (microwave radiometers) and MVRS (microwave probes) - to classify the type of precipitation. Each radar has 128 game antennas, transmitters (solid power amplifier: SSPA), receivers (low noise amplifier: LNA), Phase Shifts (PHS) and so on. FCIF (Frequency Converter Intermediate Frequency) and SCDP (System Control Data Processing) of both instruments, KuPR and KaPR, have almost identical designs. To make the designs lighter, one SCDP installed on KuPR is used to control both KuPR and KaPR. Another SCDP, which is installed on KaPR, is only for redundancy. There are two main differences from TRMM/PR: 122) - One of the main differences is that that the T/R module brings together one SSPA, LNA and PHS together, and one T/R unit consists of 8 T/R modules. The results of the analysis using subsystems and components of the design and parameters examined in the critical design of the DNR achieved the required technical performance of frequency, resolution of range, spatial resolution, band width, minimum detectable precipitation speed, accuracy of beam comparison, observed range, dynamic range, received power accuracy, and so on. Figure 59 illustrates the concept of two-frequency precipitation measurement in different detectable dynamic ranges. Predominantly, KaPR will detect snow and light rain, while KuPR will detect strong rain more. Both tools share a common effective dynamic range for providing information about DSD (drop size distribution) and more accurate rainfall estimates implemented using a two-frequency algorithm. The double-frequency algorithm uses the difference in rain intensity from the lusped ray data observed by KuPR and KaPR. The data obtained from the DNR will contribute to the creation of a global database of precipitation characteristics, obtaining parameters such as precipitation height, freezing levels, DDD, average rainfall profile structure, and so on. This database should also serve to improve MWR and MWS algorithms. Figure 59: DNR CONCEPT on two-frequency precipitation measurement (image credit: JAXA, NICT) 123) Legend in Figure 59: Vertical precipitation structure; Right: between radar reflectivity and altitude for KuPR and KaPR. Figure 60: THE concept of scanning the DPR antenna (image credit: JAXA) Each radar uses a phased array, slotting the antenna guide wave. Both DNR radars can be operated electronically up to ±17o on either side of the nadir spacecraft, providing a 245-kilometer measuring strip. KaPR also has a high-sensitivity mode that allows scanning to be 120 km wide; This high-sensitivity mode will help in measuring light rain and snow. The two phase antennas of the array will be aligned so that the same size of the same-size measurements with a diameter of 4.5 km can be used. This PF variable method improves signal-to-noise ratio due to the large pulse numbers it offers. KuPR has a strip width of about 245 km (composed of 49 tracks each 5 km wide), which is the same as TRMM PR, while KaPR is observed a band of about 120 km wide. While KuPR monitors the outer area of the band, KaPR can measure snow and light rain in the scanning area in high-sensitivity mode with dual pulse width. Another reason for the narrow width of the KaPR strip is that sidelobe pollution disorder in large scanning angles will prevent the measurement of small snow clouds. Параметр GPM DPR-KaPR (Ка-диапазон) на 407 км GPM DPR-KuPR (Ku-band) на 407 км TRMM KuPR на 350 км Антенна типа Активный фазный массив Нет элементов антенны 128 (планарный массив, прорези волны) 128 Частота 35,547 и 35,553 ГГц 13,597 и 13,603 ГГц 13,796 и 13,802 ГГц Сам ширина 120 км (24 следа на 5 км) 245 км (24 км) 49 следов на 5 км) 215 км Горизонтальная разрешение на надир 5 км 5 км 4,3 км Ширина импульса передатчика (ял.) 1.6 / 3.34 (x2) 1.6 (x2) разрешение диапазона (m) 250 / 500 250 Диапазон наблюдений (км) (зеркальное изображение на надир) от 18 до -3 18 до -5 15 до -5 PRF (Частота повторения пульса) Переменный PRF (4275±100 Гц) Переменный PRF (4206 ± 170 Гц) Фиксированная (2776 Гц) Выборка номер 1008 No112 104 - 112 64 Tx: пиковая мощность: 146 W >1013 W >500 W Средний номер выборки >1 >5 Минимальное обнаруживаемое скорость дождя 5e н 12 дБ3 (500 W. Res.) (0.2 mm h-1) 18 dBh (0.5 mm h-1) 18 dBh (0.7 mm h-1) Precision measurements of the ±1 dBz qlt;±1 dBz qlt; 78 kbps qlt; 112 kbps qlt; 93.5 kbps. 365kg qlt; 465kg qlt; 297 w qlt; 383 W qlt; (50 W Tool Size (antenna) 1.44 m x 1.07 m x 0.7 m x 2.4 m x 2.4 m x 0.6 m x 2.2 m x 2.2 m x 0.6 m Table 4: Comparison of GPM instrument parameters with TRMM PR 124) Two radars are designed to provide temporarily appropriate traces with the same same size and scan pattern. Both radar antennas are carefully aligned to ensure the beams are aligned together. Figure 61: Illustration em (engineering model) of the KaPR tool (image credit: JAXA, NICT, Ref. 106) Figure 62: BBM (Bread Model) KuPR (left) and KaPR (right) at the DNR (image credit: NICT) STATUS 2010 (Ref. 106) JAXA Two-frequency precipitation radar (DPR) in phase-C development - JAXA DPR CDR (Critical Design Review) completed in August 2009 - engineering test models to test the design completed - NASA /JAXA DPR Interface Design Review completed in October 2009 and GMI-DPR interference testing completed in December 2009 in Japan. - Currently (2010) production and testing of all components of PFM DNR (proto-flight model) - Delivery of the DPR simulator to NASA GSFC in the fall of 2010. - The proto-flight test of the DNR continues and will be completed in the summer of 2011. 125) DNR Operating Modes: DNR has 7 modes of operation (Ref. 123): 1) Surveillance mode is a normal mode of operation where KuPR and KaPR perform normal measurements of rain echo with ±17o scan for KuPR and with ±8.5o scan for KaPR. System noise, surface return and mirror image data are also collected. In the case of unforeseen circumstances, when the signal between KuPR and KaPR is lost, THE SCDP (System Control Data Processing) in KuPR and SCDP in KaPR work simultaneously, so that both radars perform observation on their own. But a bundle of matching is not possible in this case. 2) Internal calibration mode - used to calibrate FCIF (medium frequency converter frequency) and SCDP. During this regime, Russian radiation does not occur. 3) External calibration mode - Used for the ultimate and final calibration of the DNR using ARC (Active Radar Calibration) on the ground. 4) Analysis mode - provides data on the condition of LNAs (low noise amplifiers) and SSPAs (solid power amplifier). There are no scientific observations during this regime. 5) Health check mode is for checking OM (Accidental Access Memory) and OM (Read Only Memory) used in SCDP. During this regime of scientific observations and broadcasts of the Russian Federation does not occur. 6) Standby mode - is used to reload phase code and VPRF (Variable Pulse Repetition Frequency) data, changes in time for which are KuPR and KaPR, and SCDP on-board census. There will be no scientific observations and broadcasts of the Russian Federation in this mode. This mode is also used when the GPM observatory is in solar point mode due to a minor spacecraft failure. In this case, only SCDP continues to feed and all other components are off. 7) Security mode is a mode that DPR is off, except for the survival heater. This mode is used when the GPM observatory from the launch to the early stages of the stages period of departure and when the GPM observatory is in solar point mode due to a power load malfunction. Calibration and verification on board THE DPR: there are two types of calibration: external and internal calibration. 126) - External calibration in the initial verification period: the coordination of the volume of observation of the two radars (KuPR and KaPR) must be confirmed by external calibration; that is, the direction of the radar beam is corresponding to the form of comparison of the antenna models. It is necessary to make an assumption about where RC (Radar Calibrator) existed on the trail. To tread the force of the transmitting and receiving signal, it is assumed by repeating the smaller direction of the beam (from five directions in about ten directions) scanning two or more times. But in observation, as a rule, 49 beams are scanned in one scanning sweep (0.7 seconds). External calibration for orbital transmission: RxRC (Receiving a calibration radar) measures the transmitting power of the DNR form, and assumes in which position the RxRC is set to trace when the DPRK's transmission of the beam formation is altered. A change in the shape of the scan beam is available. TxRC (Calibration Radar Transmission) transmits a continuous wave (CW) to the DNR on f1 and f2. DNR receives the CPC TKS; therefore, the characteristics of DNR reception can be verified. Figure 63: Illustration of the external and internal calibration circuit (image credit: NICT) Prototype RC antenna was developed that combines the two frequencies ku- and Ka-band. Figure 64: Photo of DPR KuPR (left) and KaPR (right) at GSFC (image credit: NASA, Ref. 28) GMI (GPM Microwave Imager): NASA's GMI Instrument, SSM/I, TMI, and SSMIS Legacy, is a conical scan, polarizing sensitive, multi-frequency passive radiometer to measure precipitation. GMI will be used to calibrate radiometric measurements from space at multiple microwave frequencies and polarization. In addition, SMG radiometric measurements and radar measurements from THER will be used jointly to develop a extraction transfer standard to calibrate precipitation extraction algorithms. This calibration standard will establish a link that will be used to compare to other search algorithms that use only microwave radiometers (and without the benefit of DNR) on other satellites in the GPM constellation. 127) In March 2005, NASA signed a contract with BATC (Ball Aerospace and Technologies Corporation) to design and build GMI. A successful pre-testing of the design took place in November 2006. In June 2009, the document completed a critical review of the program's design. The delivery of two flight units is planned for 2012 and 2013 respectively. The geometry of the GMI tape is shown in Figure 66. Outside the nadir-corner definition of the cone swept away by GMI set at 48.5o, which is an angle of 52.8o (identical to tMI on TRMM). The displaced parabolic reflector rotates around the vertical axis of the instrument at a speed of 32 rpm; During each revolution the Earth scanning sector is about 140o centered along the S/C speed vector. The remaining 260o of each scan (revolution) is used to calibrate appliances and household functions. The GMI (140o) band is an 885 km arc on the Earth's surface. 128) 129) 130) 131) 132) SMA (Spin Mechanism Assembly) is a high-precision electromechanical bearing and power transmission assembly mechanism that supports and rotates the GMI at a constant speed of 32 rpm continuously for 3 years plus mission life. The SMA design must meet a complex set of requirements and is based on the legacy of BATC space mechanisms and the lessons learned from the WindSat BAPTA mechanism, which is currently in orbit and has recently surpassed eight years of successful flight operations. 133) SMA provides 0.1% rotation accuracy with a pair of angular contact bearings, separated axially into a shaft controlled by a 3-phase direct current engine with a 2-speed decoder for communication and position feedback. High-precision electro-electro-bearing hosts power and transmit disk data. This document has its own compensation impulse. Control equipment and software if the tool of spinning and pulse compensation are in the assembly of the device controller. This assembly consists of the controller itself and the pulse wheel to compensate for the pulse installed under the design that supports the GMI sensor. Figure 65: SMA Vision Scheme (image credit: NASA, BATC) Figure 66: GMI Geometry Scan (image credit: NASA) The device has 13 microwave channels (similar to TMI) in the frequency range of 10-190 GHz as indicated in Table 5. The equivalent noise delta (NEDT) values are valid for relevant integration periods, when integration time is a scan motion through the width of a single antenna beam. The efficiency of the GMI beam for all channels will exceed 90%, where the beam efficiency is defined as the percentage of energy collected from the isotropic scene within a solid angle, defined by 2.5 times the width of the channel semi-axt and the approximation of the main share of the antenna between the first invalid. Figure 67: Illustration of the GMI instrument (image credit: NASA, BATC) GMI instrument design uses a common power type radiometer with through hot and cold calibration feed. with an offset parabolic antenna with a diaphragm size of 1.2 m. The antenna subsystem includes four stern horns serving nine channels. Each frequency is allocated to an independent stern horn, total feedhorn for 18.7 GHz and 23.8 GHz channels. The antenna subsystem and electronics receiver rotate from 32 rpm. GMI has its own compensation impulse. The control scheme and logic that regulates tool rotation and pulse compensation are contained in the assembly of the device controller. The instrument controller assembly and pulse wheel, which compensates for the pulse, are installed under the shelf supporting the GMI sensor. The 1.22 m GMI aperture provides excellent spatial resolution (IFOVs) for channels 1 to 5, channels for which the entire diaphragm is used in beam formation. These GMI channels offer a subtle spatial resolution compared to other conical scanning radiometers (they are 50-60% better than TMI on TRMM). Figure 68: View in 183 GHz mixer design (image credit: Millitech Inc.) GMI uses a set of frequencies that have been optimized over the past two decades to produce heavy, moderate and light precipitation using the polarization difference on each channel as an indicator of optical thickness and water content. GMI has the following selection channels (Ref. 102): Channel 10 GHz to measure the heaviest precipitation found in the tropics, 9 and 37 GHz channels to measure moderate and light precipitation over the ocean - 21 GHz channel to correct water vapor absorption in other channels - 89 GHz channel to detect the presence of large particles of cloud ice, which is used to distinguish convective from stratiform precipitation over the ocean and to measure heavy rainfall over land - 166 GHz channel to measure light precipitation in frontal structures outside the tropics - two 183 GHz water-para probing channels to detect scattering signals from fine ice particles and protecting surface in regions with high water vapor to estimate the rate of light rain and snowfall over snow. Channel Center Frequency (GHz) Ctr. freq. Stabilization (±MHz) Bandwidth (MHz) Time of polarization integration (ms) NEDT (K) max. Antenna beamwidth @ 3 dB (º) 1 10.65 10 100 V 9.7 0.96 1.732 2 10.65 10 100 H 9.7 0.96 1.732 3 18.70 20 200 V 5.3 0.84 0.977 4 18.70 20 200 H 5.3 0.84 0.977 5 23.80 20 400 V 5.0 1.05 0.862 6 36.50 50 1000 V 5.0 0.65 0.843 7 36.50 50 1000 H 5.0 0.65 0.843 8 89.00 200 6000 V 2.2 0.57 0.390 9 89.00 200 6000 H 2.2 0.57 0.390 10 165.5 200 4000 V 3.6 1.5 0.396 11 165.5 200 4000 H 3.6 1.5 0.396 12 183.31±3 200 2000 V 3.6 1.5 0.361 13 183.31±7 200 2000 V 3.6 1.5 0.361 Table 5: Performance requirements of the GMI instrument Figure 69: Channel footprint scheme of GMI in successive along-sans (image credit : NASA) The timing of GMI sampling is governed by a desire to reach Nyquist spatial sampling along the scanning direction of the band. In the samples from individual channels must be jointly recorded on the Earth's surface. Sampling time is little more than integration time because of the bars inherent in digital electronics sampling. To meet the Nyquist criterion, all channels are now sampling at least twice as GMI scans through one IFOV. To guarantee co-registration, sampling time for each channel is made by integral multiples to each other. Tool weight, power, design life 153 kg, 141 watt, 3 years Data speed, antenna size (offset parabolic reflector) 25 kbps, 1.22 m. No GMI 2 (one at the S/C core, one on the constellation) Table 6: Some GMI Options Figure 70: View of the deployed GMI device configuration (NASA, BATC) Instrument calibration: The primary calibration of the GMI instrument is provided through hot load and cold sky reflector. The hot load design minimizes thermal gradients and provides thermal stability. The hot load has a shroud, which limits the impact of hot load on solar radiation. In addition 14 thermistors are provided in hot load to allow spatial and temporal changes to be tracked accurately. The size of the cold sky reflector has been maximised within mechanical limitations to ensure the high efficiency of the beam into the cold space. The calibration is carried out with the help of the goal of cold skies and precisely controlled hot load. The purpose of the cold sky is a reflector aimed at space to provide the coldest possible target for the calibration target. The sky reflector was the size to ensure the high efficiency of the beam in the cold space. In addition to the hot load and reflector of the cold sky, GMI has internal noise diodes that provide additional information to track the calibration. Noise diodes will be used to track the stability of non-linear receivers during the entire 1 year of the device's service. Noise diodes will also be used to test the short-term stability of hot and cold sky calibration points and can be used to ensure short-term replacement of these loads. Figure 71: Illustration of a cold load reflector and a hot load device on the GMI platform (image credit: NASA, BATC) GMI radiometer will serve as a standard of transmission in two contexts: 1) as a radiometric transmission standard for other radiometers of the constellation GPM and 2) as a constellation. Both transmission standards represent areas of research. 134) In the context of paragraph 1, the GMI radiometric calibration will serve as a benchmark for other radiometers. In this method, the temperature calibration of the brightness of the constellation's radiometers will be adjusted to achieve a common base with GMI. This method will allow differences in the search for precipitation between sensors due to bias from intersensory calibration. The context of paragraph 2 refers to the precipitation transfer standard. Precipitation. this applies to the synergy of measurements created by GMI and DPR instruments aboard the Core spacecraft. Mutual overlap is actively about semantic, vertically profiled radar data at two frequencies combined with multi-channel passive GMI data is a unique capability of the Core Observatory. The GPM project has developed the concept of products that contain inter-calibrated brightness temperatures (Tb), which are a mission consistent through the constellation of radiometers. These products will be the main temperature brightness of the products distributed both in production and almost in real time. The process of inter-calibration is developed, based on a pair comparison of the brightness of the constellation radiometers. This process is the result of early prototype work using TMI as a surrogate for GMI and additionally honed extensive comparisons conducted by the X-cal (cross-calibration) team. In addition, this process has led to the detection of time-dependent biases in TMI brightness temperatures, as well as the development of consistent TMI products. This helps to justify that the developed process can lead to a consistent, well-calibrated Tb for GPM radiometers, leading to significant improvements in extraction. 135) GMI RDA (Reflector Deployment Assembly): GMI RDA is an articulation structure that accurately positions and maintains the GMI (Global Microwave Imager) main reflector throughout the mission's 3-year lifespan. In order for the GMI to fit into the launch vehicle's vow, the main reflector must be stowed to the front of the space shuttle bus (Figure 72). 136) Figure 72: GPM Spacecraft Vision Scheme with stacked GMI instrument (credit image: BATC) Restrictions launch to provide a basic reflector and RDA to the basic GMI structure. Once launched, the restrictions deploy and the RDA must maneuver the reflector from its laid location and place it in an accurate orientation over the tool to work. The orbited reflector must correspond to the earth alignment orientation within 0.5 mm in position and 40 arcsec in order to maintain a tight nadir angle pointing requirements. RDA should maintain a stable reflector orientation over the course of 3 years of GMI life. Figure 73 shows the architecture of the GMI tool. The ISS Deck (Instrument Support Structure) consists of a composite panel that contains an interface to the spacecraft, supports the instrument and provides a structure to support the laid main reflector. The IBA (Instrument Bay Assembly) consists of a hexagonal composite structure with a circular upper deck that supports the RF and RDA subsystem. The calibration targets are supported by a calibration support structure that is despun and connected back SMA stator assembly (spin engine assembly), which provides rotational motion provides energy and signal transmission between rotating and stationary elements. 137) The main link between the two composite structures is SMA and IBS Launch Restraints (IBS LR). 3 IBS LR acts as a load bypass mechanism for bearings contained in the SMA, and provides a direct load trajectory for the supported mass in the spacecraft interface. THE activation of IBS LR allows SMA to rotate rotating elements. The main reflector launch restrictions (MR LR) provide a laid interface for the main reflector, providing a load trajectory through a composite structure to the spacecraft's interface. The main reflector is located in its deployed RDA orientation after the launch restrictions are released. The deployed orientation can be seen in Figure 70. The calibration targets are connected to the SMA stator elements through the furs that connect the slide ring on the SMA to the Despin Assembly which supports the calibration assembly and keeps the calibration assembly still. This calibration support structure contains a launch calibration limit (CAL LR), which provides an alternative load path to support the mass of calibration targets without over-loading the Despin assembly. Figure 73: The stacked GMI configuration (image: BATC) GMI RDA is a kinematically defining structure consisting of a two-legged aft structure and a forward and side assembly rack that attaches to four seats on the upper deck of the instrument and three seats on the outer perimeter of the main reflector. The RDA is built from composite tubes associated with titanium fittings that are attached to different joints designed for the structure to fold into a stacked configuration. When stacked, the reflector is located in a specific location where it is limited to run, and the RDA pipes are located in limited available areas in the enclosed envelope. Deployment force is provided by a xercyon spring attached to the build of bipods at a speed controlled by a liquid damper. Deployment reliability is enhanced by eliminating the ability to bind the joints of the rack. This is achieved by a combination of spherical and revolutive loops configured in such a way that the structure is actually limited. To provide control during deployment, the new connection auxiliary synchronization directs the movement of the reflector for most of the operation until the spring is loaded with the side rack of the elbow joints to block the completion of the deployment and the formation of a geometrically defining structure. Figure 74 shows the main elements of the build. Figure 74: Illustration of RDA components (image credit: BATC) The location of the laid reflector is determined by the available volume on the spacecraft and the launch vehicle, thus controlling the geometry of the laid RDA. RDA must reliably deploy 12-kilogram reflector this place is in a repetitive position and maintains its orientation when impacting the environment in orbit throughout the life of the mission. Table 7 lists the basic performance requirements of the RDA. Weight 5.7 kg Maximum deployed rigidity of 11 Hz min Deployment duration of deployment of zlt; 0.5 mm, zlt; 40 arcsec Stability deployment of 0.25 mm, zlt; 20 arcsec Deployment duration of lt; 5 minutes Table 7: Key requirements of THE RDA performance of the tube rack cylindrical smallpox tuber with titanium installation linked to each other. They were made using precisely aligned communication tools. Once bound and cured, they were thermally cyclical, proof of testing, and then the assembly began with a bolted matching hinge setup at each end of the tube rack. Deployment testing: Major performance tests superimposed on the RDA included deployment repetitiveness, deployment duration, rigidity deployment, torque, space deployment, off-par deployment, and kinematic model verification. The GMI RDA development and verification program has successfully demonstrated the ability to accurately deploy payloads over a large range of motion in a controlled and reliable manner. RDA avoids the complexity and reliability of problems associated with metrology/return loop of a motorized deployment circuit in favor of a passively powered, cinematically defined approach. The RDA manages this with a lightweight rack design that is inherently flexible until fully deployed, where it becomes a rigid structure. This configuration can be adapted for different payload sizes and deployment requirements. The performance demonstrated by RDA is applicable to the requirements for most RF antennas, as well as to a wide range of optical payloads. These other applications will benefit from a deeper understanding and opportunity from the RDA (Ref. 136) program. GPM 1) Climate Diagnostics: Processing and Expanding Precipitation Climatology, Including Snowy Climatology; Identification of statistically significant global and regional precipitation trends 2) GWEC (Global Water and Energy Cycle) / Hydrological Predictability: Global Water and Energy Cycle Analysis and Modelling; Water transport; Closing the water budget; Hydrometeorological modeling; Freshwater Resource Forecast 3) Climate Change / Climate Predictability: Climate-Water-Radiation States; Climate change analysis and forecasting; GWEC Reaction to Climate Change and Feedback 4) Data Assimilation/Weather and Storm Predictability: Assimilation of Rainfall Data; nwP 5) MBL (Marine Processes: Air and sea interface processes and surface flow simulations; the salinity of the mixed ocean layer alters 6) Land processes: interaction processes between the earth and the atmosphere and the simulation of surface flows; Integrated Surface Radiation Energy-Water-Carbon Budget Modeling Process 7) Linked Models: diagnostics of cloud dynamics, macrophysical/microphysical processes, 3D radiation field response; parameterization of microphysics and radiation transfer in non-hydrostatic mesoscale cloud solutions of models 8) extraction/verification/synthesis: physical precipitation extraction and hidden heating; Calibration of the algorithm and the normalization of products; Checking the algorithm and quanting uncertainty Synthesis of verification to improve algorithm 9) Apps/Propaganda: Weather Forecasting; Flood forecasting Media; educational tools. The ground segment of the GPM Core spacecraft: The architecture of the GPM ground system is based on lessons learned from

TRMM's experience and experience. In particular, the ground system supports the production of a radiation meter of precipitation from GMI for one hour after observation and combined radar-radiometer products within three hours of observation. The ground system consists of fully integrated elements that support flight operations, data processing and dissemination, and ground verification. The MOC (Mission Operations Center) is highly automated and staffed by 8x5 (8 hours, five days a week) because GPM devices operate in survey mode and require very little ground command. It interacts with PPS (Precipitation Processing System) to deliver 5-minute files of a scientific duration tool, 5-minute household data files, metadata related to data processing and delivery, and supporting data to support the production of scientific products. The MOC also interacts with PPS to obtain device commands and command requests as needed (Ref. 102). Figure 75: Earth Segment Overview of the GPM Core spacecraft (image credit: NASA) PPS (Precipitation Processing System) is based on the evolution of the TSDIS (TRMM Data Information System) algorithm, which authorizes an algorithm and other prototypes to assist in the development of the GPM data system. Its function is to create a higher level of scientific data products, deliver scientific data products to the user community, provide the interface to device teams, and deliver device commands and device team requests to the MOC. Figure 76: Overview of the Earth segment of the GPM Core spacecraft in JAXA (image credit: JAXA) Figure 77: GPM Core Observatory data stream and constellation satellites into the precipitation processing system in GSFC (image credit: NASA, Ref. 54) Product Level Description Level 1B GMI Level 1C GMI Delay No. 1 h Geolocation of brightness temperature and inter-caliber brightness OF IFOV (produced by NASA) Level 1B DPR Geolocation, calibrated radar powers Swath, IFOV (produced at JAXA) Level 1C, partner radiometers Intercalibrated temperature brightness 1h Radar Extended (RE) Precipitation Search, IFOV Level 2 DPR Delay Delay characteristic, PSD, precipitation with vertical structure Swath, IFOV (Ku, Ka, Combined Ku/Ka) Level 2 Combined GMI/DPR Delay 3 h Swat Precipitation, IFOV (first in DPR Ku swath, and then on the GMI strip) Level 3 hidden heating (GMI, DPR, Combined) Hidden heating and related parameters 0.25 × 0.25 monthly Grid Level 3 GMI Accumulation Device, Partner Radiometers, Combined and DPR 0.25 × 0.25 Monthly Grid Level 3 Merger Product Merger GMI, Partner Radiometer, and IR 0.1 × 0.130-min Grid Level 4 Products Model assimilated precipitation forecast and analysis Model Time and Space Scale Table 8: GPM Product Description (Ref. 18) GPM Ground Validation: Mission GPM supports a vigorous ground validation program (GV) to develop a pre-smoothing algorithm and post-product evaluation. Based on lessons learned from the traditional approach to soil testing, ground observations can be used to directly assess the quality of satellite products, GPM creates joint GV sites with partner agencies and a series of pre- and post-iron field campaigns for one or more of the following three verification activities (Ref. 102): - Direct verification: These activities facilitate statistical comparison of GPM precipitation products with ground measurements provided by national radar and raincoats networks from GPM partners around the world. The purpose of these activities is to identify potential discrepancies between space and ground precipitation estimates, which may require more in-depth research. Precipitation Physics Testing: These activities are aimed at collecting intensive, focused, on-board and ground measurements of precipitation processes and supporting observations to provide the basis for the development, testing and refinement of satellite search algorithms using both simulated and resulting observations of microphysical databases. The broad purpose of these activities is to gain a further understanding of the physical relationship between clouds/besieging particles and simulated microwave auroras at different frequencies to refine the interpretation of GPM satellite measurements and search algorithms. Comprehensive hydrological validation: These activities follow the GPM multi-track sediment assessment paradigm using hydrological pools as a comprehensive measurement of data quality over time and area in terms of joint hydrological and ground modeling and forecasting. Thus, four field campaigns were conducted or planned in 2010-2012, which will be conducted in different climatic regimes: - Pre-CHUVA - This is GPM-Brazil - NASA Field Campaign Targeted Warm Rains Search Over the Ground and focused on the Alc'ntara Launch Center in northeast Brazil March 3-24, 2010. 138) 139) - Light Light Experiment Verification (LPVEx) - This collaboration between CloudSat-GPM focuses on light rain in the shallow melting of the layer. It covers the Helsinki test site and the Gulf of Finland in September and October 2010. It includes FMI (Finnish Meteorological Institute) and Environment Canada in addition to NASA. 140) - Mid-latitude Continental Convective Cloud Experiment (MC3E) - This is a NASA-DOE (Department of Energy) field campaign at the DoE-ASR Central Facility in Oklahoma. It is scheduled for April 15 - June 1, 2011. 141) - High latitude snowfall campaign in the cold season: This GPM-Environment Canada campaign focused on finding snowfall in Ontario, Canada. The project was held from January 15, 2012 to March 3, 2012. However, most ground-based instruments were installed in November 2011. The GCPEx Cold Season Precipitation Experiment (GPM) was conducted in the winter of 2011/012 in Ontario, Canada. Its purpose was to provide information on precipitation microphysics and cold-season precipitation processes to support GPM snowfall search algorithms that use two-frequency precipitation radar and passive microwave imaging aboard the main GPM satellite, as well as radiometers on constellation satellites. 142) - Japan GV: Japan develops DNR on the basis of excellent legacy of PR development TRMM. Japan's GV focuses on a ground-based experiment related to DNR. Airborne Experiment (Ref. 106) is planned. 143) Figure 78: Illustration of field campaign locations between 2010 and 2012 (image credit: NASA) GV (Ground Check) site in Okinava: NICT (National Institute of Information and Communication Technology) has three sites on the main island of Okinawa. The main office is the Okinawa Electromagnetic Technology Centre (NICT Okinawa), as well as two radar facilities - the OGimi profile (NICT Ogimi) and the Nago Precipitation Radar Center (NICT Nago), as shown in Figure 79. 144) - COBRA (C-band polarimetry radar) is installed on the NICT Nago website. The COBRA system is a ground-based monostatic pulsed Doppler radar using a single wave (5340 MHz) in the C-band. The maximum range of observation is about 300 km, although this depends on the frequency of repetition and the pulse transmitted. The spatial resolution is 37.5-600 m, depending on the pulse width and the frequency of sampling. 400-MHz Wind Maker: 400-MHz Wind Profiler (400-MHz WPR) is installed on the NICT Ogimi website. The 400-MHz WPR is capable of simultaneously observing echoes of atmospheric turbulence and echoes from precipitation. Thus, by analysing the echo spectrum of the energy of the received signal, it is possible to estimate the distribution of the size of the raindrops, for which the effects of wind speed, atmospheric turbulence and background these vertical and terrestrial measurements of the distribution of the size of raindrops, the cross-section of extinction and the cross-section of reverse scattering can be processed by the Mie scattering theory. The specific fading (k) and radar reflectivity (k) for ku-band are then evaluated. You can analyze vertical variations and characteristics (depending on the type of rain) of rain intensity for Ku-band. The GPM/DPR algorithm for the Ku- and Ka-band algorithm can also be evaluated using this ground-based verification surveillance network in Okinawa. Figure 79: Location of the ground inspection site in Okinawa (image: NICT)

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