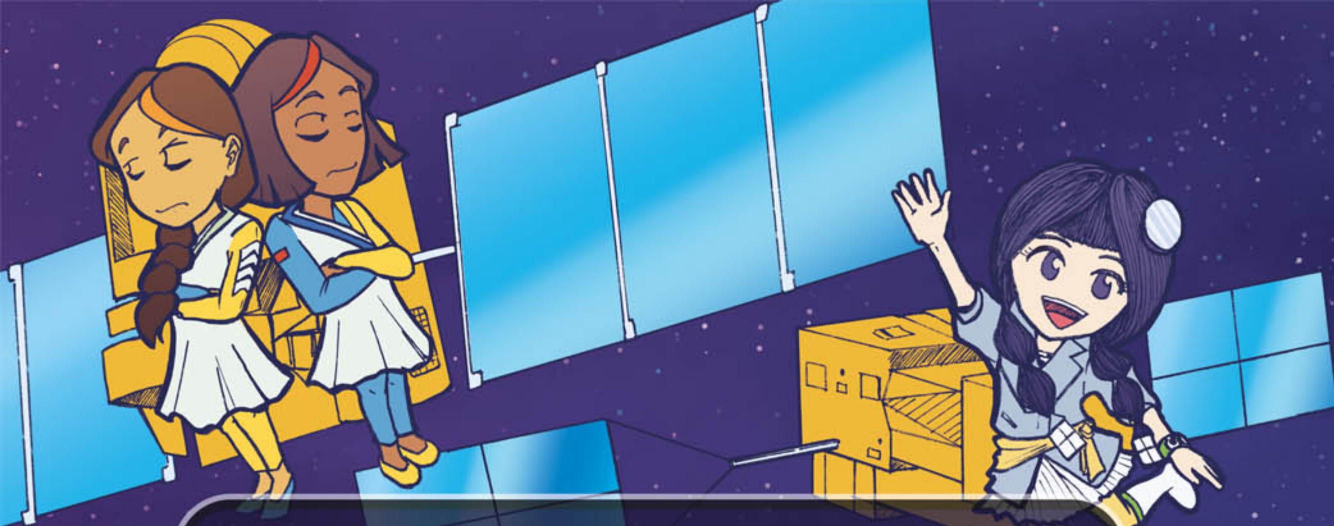
National Aeronautics and
Space Administration

RAINDROP TALES
GPM MEETS MIZU-CHAN



When is it going to rain? How much will it rain? We ask these questions every day to know if we need to wear rain boots or bring an umbrella. We also ask these questions to help us make decisions about bigger issues concerning safety, transportation and our jobs. But have you wondered how scientists measure rain and snow? In this story, you will learn how these measurements are made worldwide with satellites and why they are important. Follow along as a satellite, GPM, begins to observe the world of precipitation and meets some new friends along the way.

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Educational Product	
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Acknowledgements

Global Precipitation Measurement Mission
pmm.nasa.gov
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Precipitation Education
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Supplemental Resources for this Comic Book
pmm.nasa.gov/education/comics

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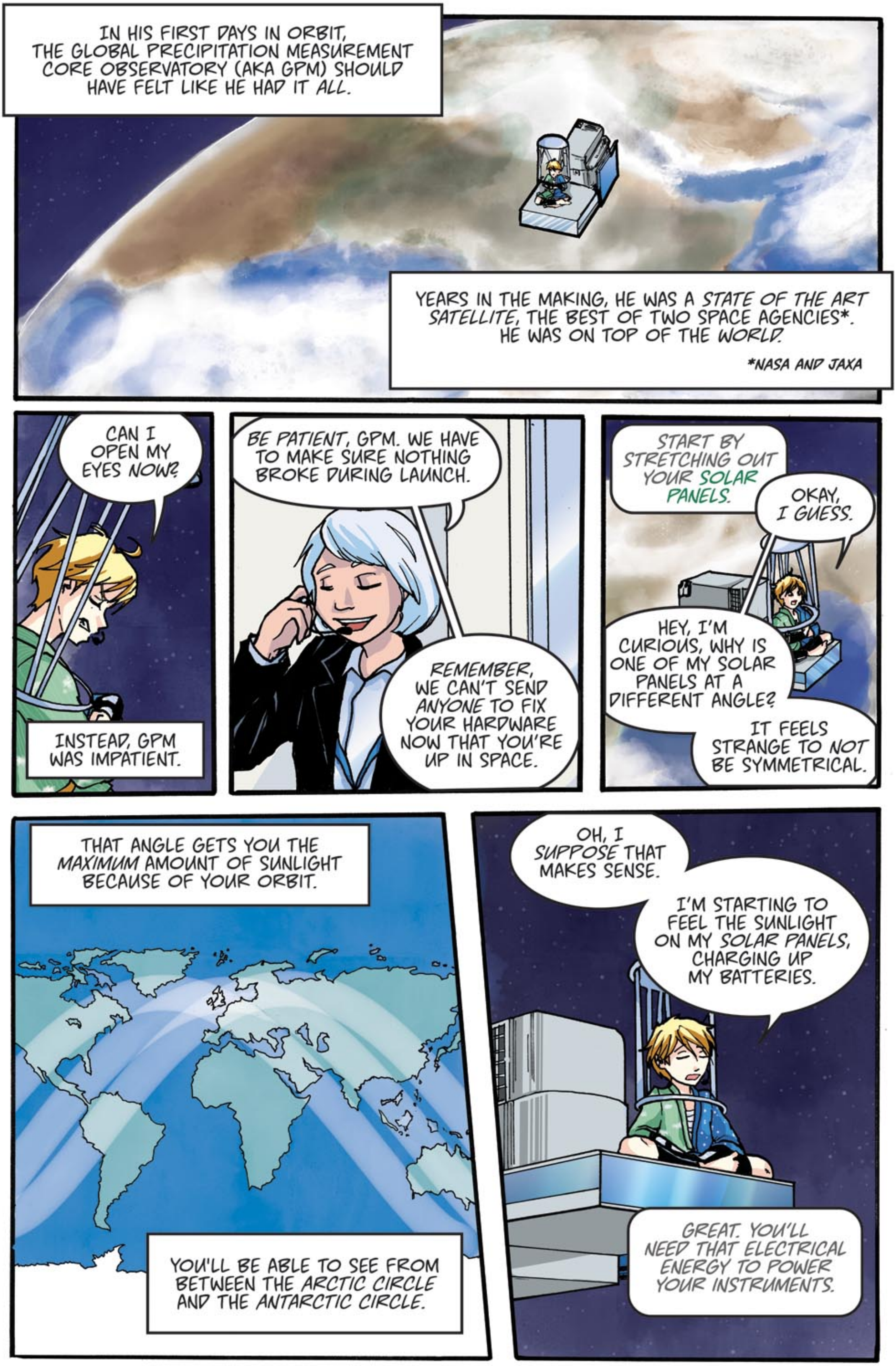
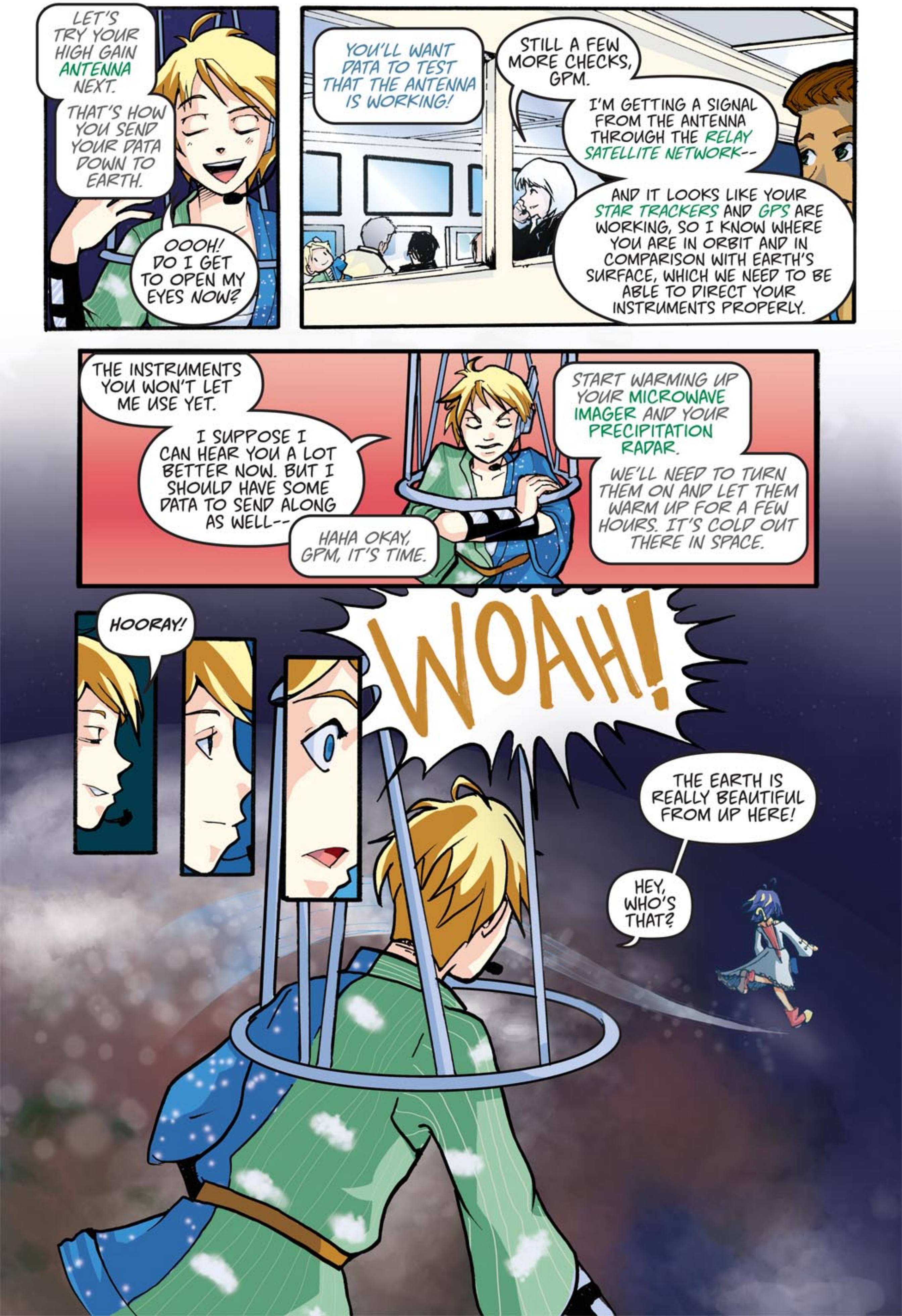
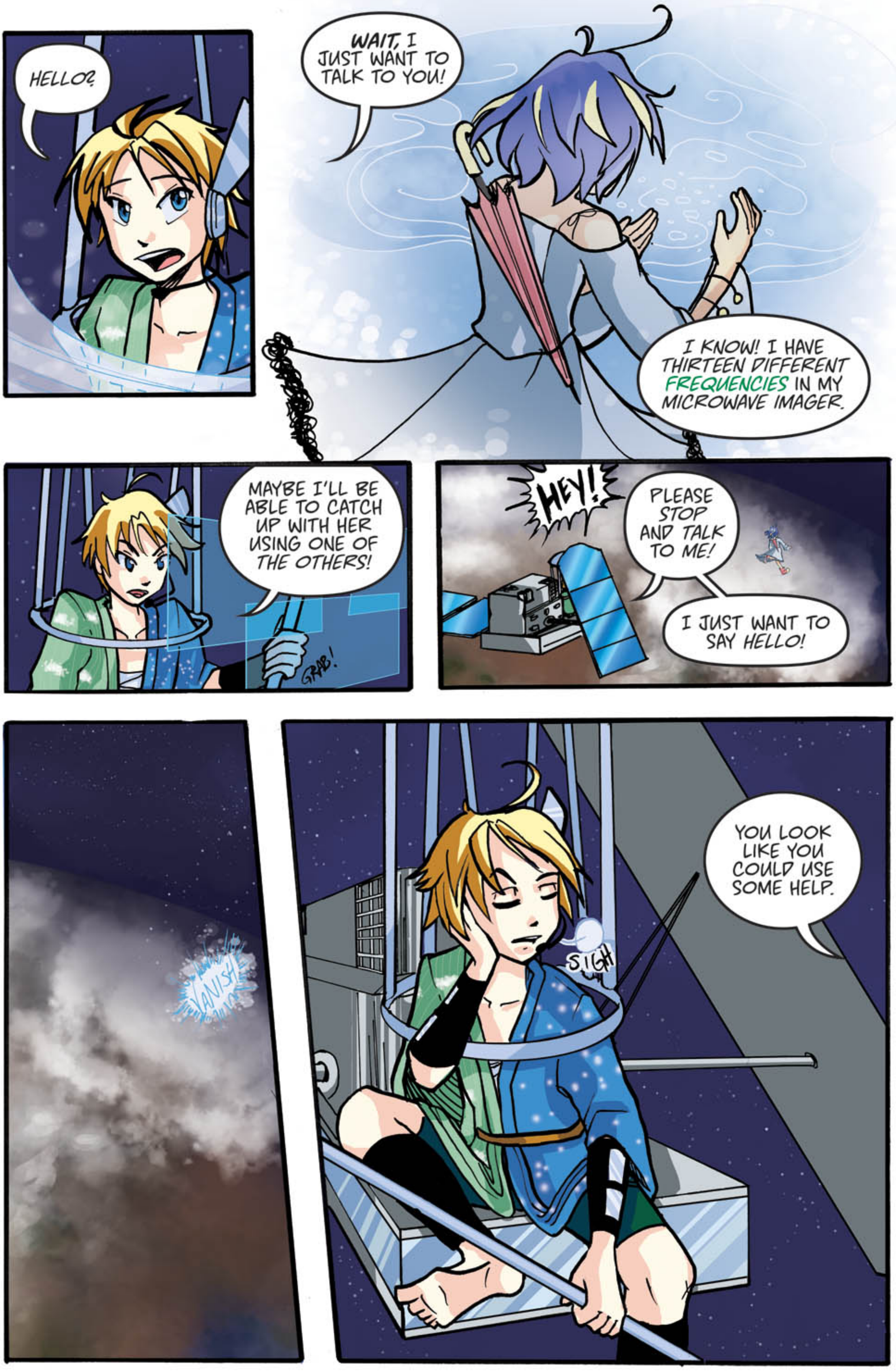
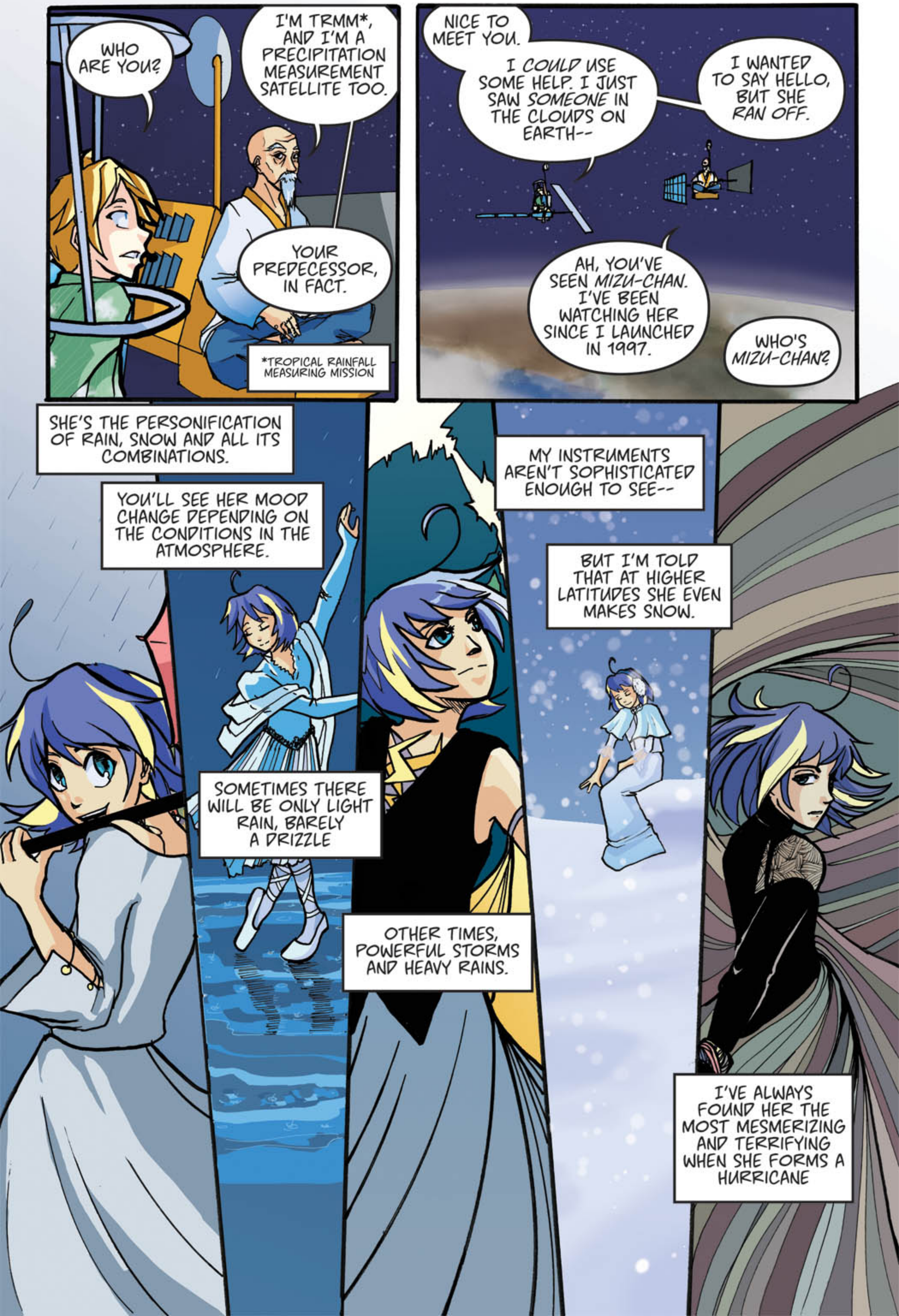
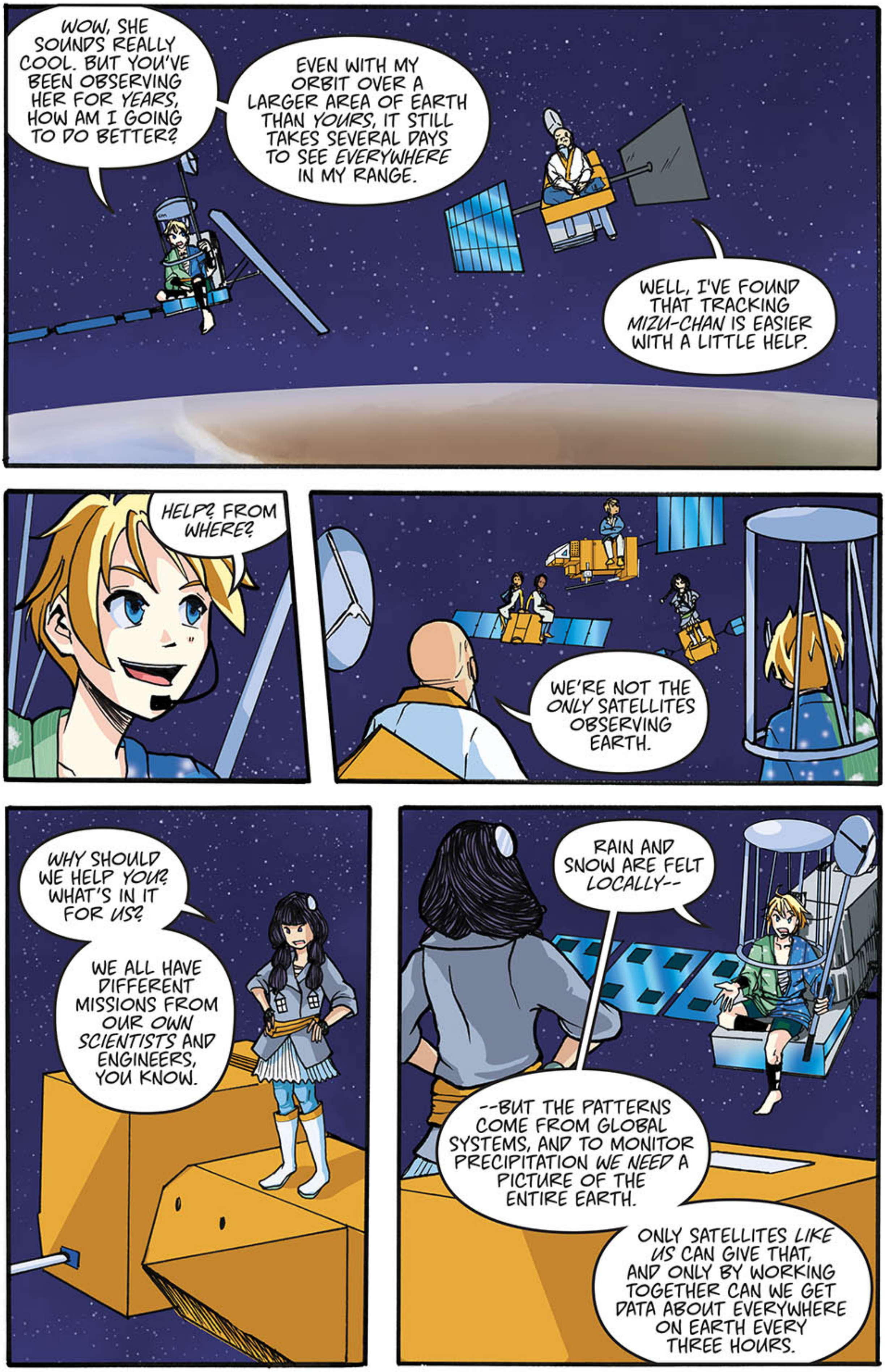
NOTE: *IN THE STORY, THE SATELLITES HAVE CHARACTERS TO REPRESENT THEM. HOWEVER, THE REAL SATELLITES ARE REMOTELY OPERATED AND DO NOT HAVE PEOPLE ABOARD.*

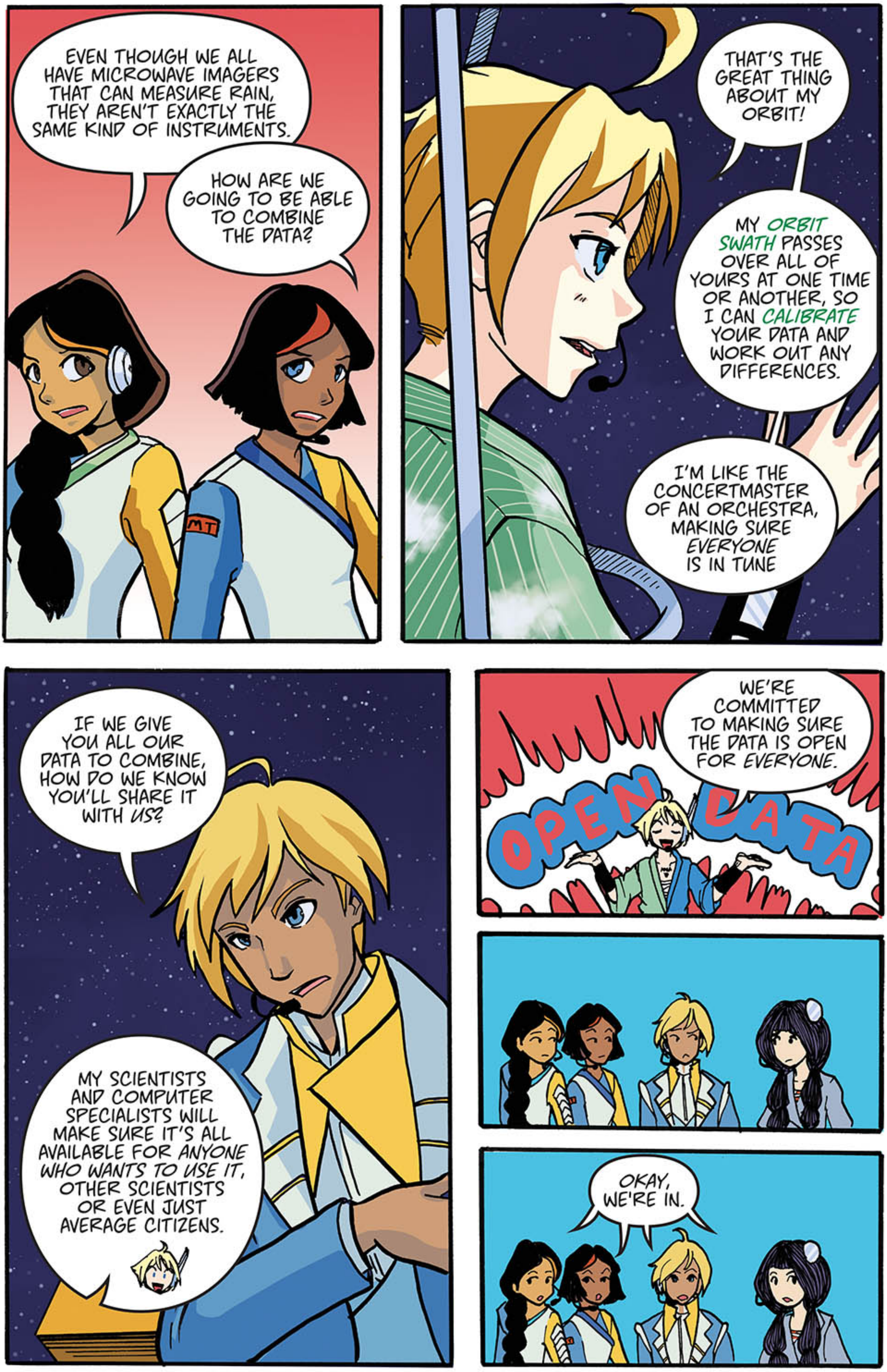

IN HIS FIRST DAYS IN ORBIT, THE GLOBAL PRECIPITATION MEASUREMENT CORE OBSERVATORY (AKA GPM) SHOULD HAVE FELT LIKE HE HAD IT ALL.
YEARS IN THE MAKING, HE WAS A STATE OF THE ART SATELLITE, THE BEST OF TWO SPACE AGENCIES*. HE WAS ON TOP OF THE WORLD.
*NASA AND JAXA
CAN I OPEN MY EYES NOW?
INSTEAD, GPM WAS IMPATIENT.
BE PATIENT, GPM. WE HAVE TO MAKE SURE NOTHING BROKE DURING LAUNCH.
REMEMBER, WE CAN'T SEND ANYONE TO FIX YOUR HARDWARE NOW THAT YOU'RE UP IN SPACE.
START BY STRETCHING OUT YOUR SOLAR PANELS.
OKAY, I GUESS.
HEY, I'M CURIOUS, WHY IS ONE OF MY SOLAR PANELS AT A DIFFERENT ANGLE?
IT FEELS STRANGE TO NOT BE SYMMETRICAL.
THAT ANGLE GETS YOU THE MAXIMUM AMOUNT OF SUNLIGHT BECAUSE OF YOUR ORBIT.
YOU'LL BE ABLE TO SEE FROM BETWEEN THE ARCTIC CIRCLE AND THE ANTARCTIC CIRCLE.
OH, I SUPPOSE THAT MAKES SENSE.
I'M STARTING TO FEEL THE SUNLIGHT ON MY SOLAR PANELS, CHARGING UP MY BATTERIES.
GREAT. YOU'LL NEED THAT ELECTRICAL ENERGY TO POWER YOUR INSTRUMENTS.


LET'S TRY YOUR HIGH GAIN ANTENNA NEXT.
THAT'S HOW YOU SEND YOUR DATA DOWN TO EARTH.
OOOH! DO I GET TO OPEN MY EYES NOW?
YOU'LL WANT DATA TO TEST THAT THE ANTENNA IS WORKING!
STILL A FEW MORE CHECKS, GPM.
I'M GETTING A SIGNAL FROM THE ANTENNA THROUGH THE RELAY SATELLITE NETWORK--
AND IT LOOKS LIKE YOUR STAR TRACKERS AND GPS ARE WORKING, SO I KNOW WHERE YOU ARE IN ORBIT AND IN COMPARISON WITH EARTH'S SURFACE, WHICH WE NEED TO BE ABLE TO DIRECT YOUR INSTRUMENTS PROPERLY.
THE INSTRUMENTS YOU WON'T LET ME USE YET.
I SUPPOSE I CAN HEAR YOU A LOT BETTER NOW. BUT I SHOULD HAVE SOME DATA TO SEND ALONG AS WELL--
HAHA OKAY, GPM, IT'S TIME.
START WARMING UP YOUR MICROWAVE IMAGER AND YOUR PRECIPITATION RADAR.
WE'LL NEED TO TURN THEM ON AND LET THEM WARM UP FOR A FEW HOURS. IT'S COLD OUT THERE IN SPACE.
HOORAY!
WOAH!
THE EARTH IS REALLY BEAUTIFUL FROM UP HERE!
HEY, WHO'S THAT?

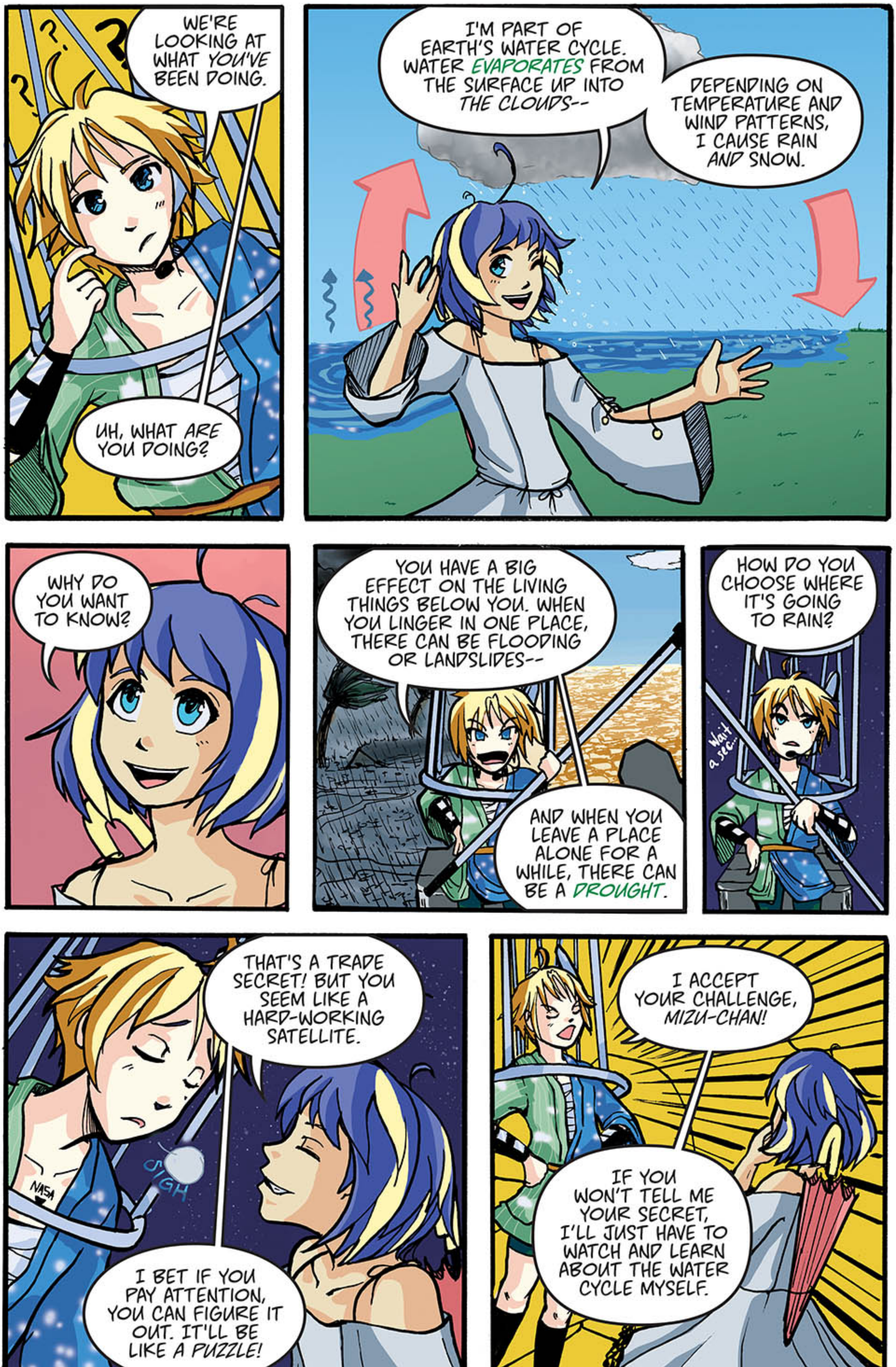

HELLO?
WAIT, I JUST WANT TO TALK TO YOU!
I KNOW! I HAVE THIRTEEN DIFFERENT FREQUENCIES IN MY MICROWAVE IMAGER.
MAYBE I'LL BE ABLE TO CATCH UP WITH HER USING ONE OF THE OTHERS!
GRAB!
HEY!
PLEASE STOP AND TALK TO ME!
I JUST WANT TO SAY HELLO!
VANISH!
SIGH
YOU LOOK LIKE YOU COULD USE SOME HELP.


WHO ARE YOU?
I'M TRMM*, AND I'M A PRECIPITATION MEASUREMENT SATELLITE TOO.
YOUR PREDECESSOR, IN FACT.
*TROPICAL RAINFALL MEASURING MISSION
NICE TO MEET YOU.
I COULD USE SOME HELP. I JUST SAW SOMEONE IN THE CLOUDS ON EARTH--
I WANTED TO SAY HELLO, BUT SHE RAN OFF.
AH, YOU'VE SEEN MIZU-CHAN. I'VE BEEN WATCHING HER SINCE I LAUNCHED IN 1997.
WHO'S MIZU-CHAN?
SHE'S THE PERSONIFICATION OF RAIN, SNOW AND ALL ITS COMBINATIONS.
YOU'LL SEE HER MOOD CHANGE DEPENDING ON THE CONDITIONS IN THE ATMOSPHERE.
SOMETIMES THERE WILL BE ONLY LIGHT RAIN, BARELY A DRIZZLE
OTHER TIMES, POWERFUL STORMS AND HEAVY RAINS.
MY INSTRUMENTS AREN'T SOPHISTICATED ENOUGH TO SEE--
BUT I'M TOLD THAT AT HIGHER LATITUDES SHE EVEN MAKES SNOW.
I'VE ALWAYS FOUND HER THE MOST MESMERIZING AND TERRIFYING WHEN SHE FORMS A HURRICANE

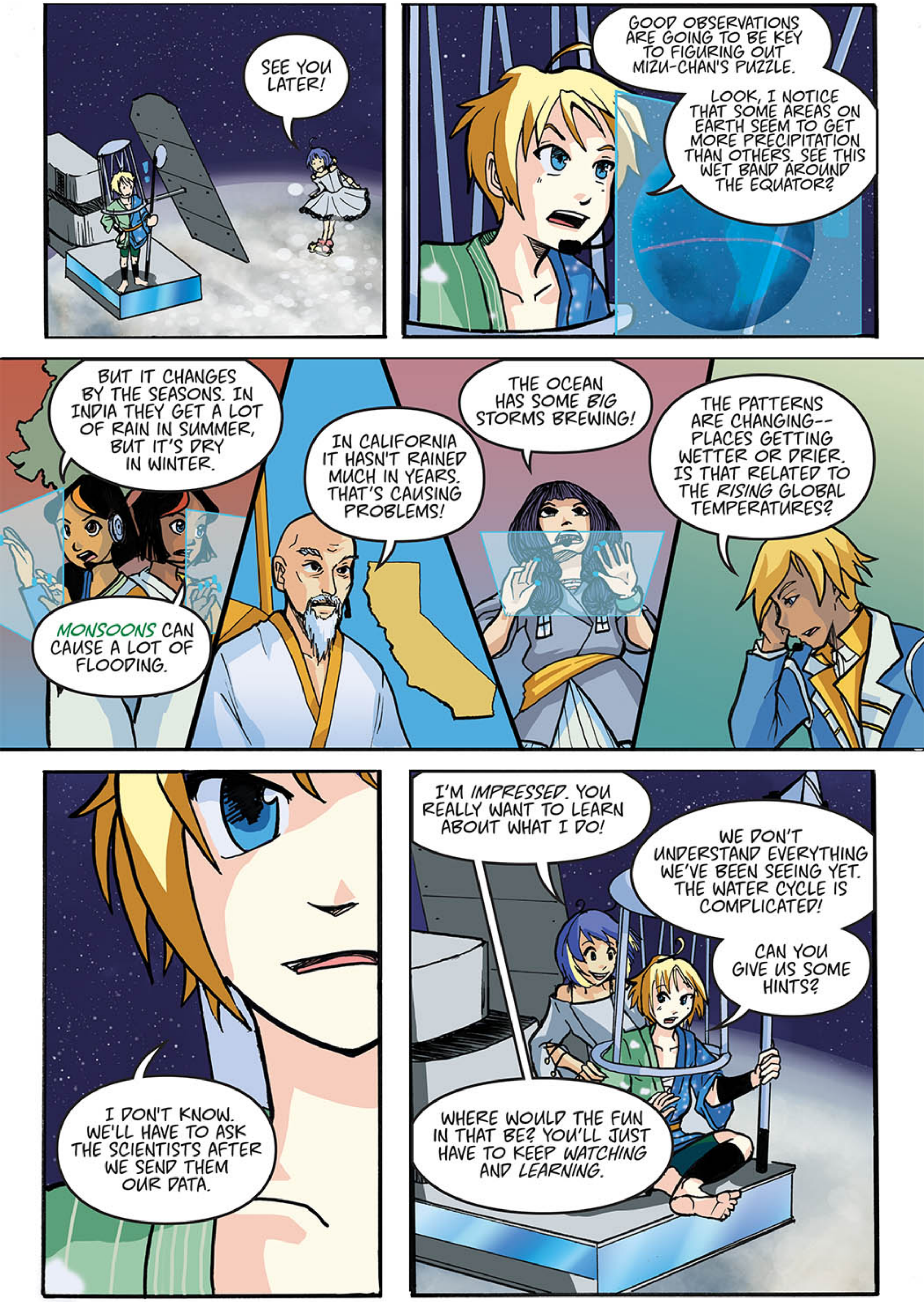

WOW, SHE SOUNDS REALLY COOL. BUT YOU'VE BEEN OBSERVING HER FOR *YEARS*, HOW AM I GOING TO DO BETTER?
EVEN WITH MY ORBIT OVER A LARGER AREA OF EARTH THAN *YOURS*, IT STILL TAKES SEVERAL DAYS TO SEE *EVERYWHERE* IN MY RANGE.
WELL, I'VE FOUND THAT TRACKING *MIZU-CHAN* IS EASIER WITH A LITTLE HELP.
HELP? FROM WHERE?
WE'RE NOT THE *ONLY* SATELLITES OBSERVING EARTH.
WHY SHOULD WE HELP *YOU*? WHAT'S IN IT FOR *US*?
WE ALL HAVE DIFFERENT MISSIONS FROM OUR OWN *SCIENTISTS* AND ENGINEERS, YOU KNOW.
RAIN AND SNOW ARE FELT *LOCALLY*--
--BUT THE PATTERNS COME FROM GLOBAL SYSTEMS, AND TO MONITOR PRECIPITATION *WE NEED* A PICTURE OF THE ENTIRE EARTH.
ONLY SATELLITES *LIKE US* CAN GIVE THAT, AND ONLY BY WORKING TOGETHER CAN WE GET DATA ABOUT EVERYWHERE ON EARTH EVERY THREE HOURS.


EVEN THOUGH WE ALL HAVE MICROWAVE IMAGERS THAT CAN MEASURE RAIN, THEY AREN'T EXACTLY THE SAME KIND OF INSTRUMENTS.
HOW ARE WE GOING TO BE ABLE TO COMBINE THE DATA?
THAT'S THE GREAT THING ABOUT MY ORBIT!
MY ORBIT SWATH PASSES OVER ALL OF YOURS AT ONE TIME OR ANOTHER, SO I CAN CALIBRATE YOUR DATA AND WORK OUT ANY DIFFERENCES.
I'M LIKE THE CONCERTMASTER OF AN ORCHESTRA, MAKING SURE EVERYONE IS IN TUNE
IF WE GIVE YOU ALL OUR DATA TO COMBINE, HOW DO WE KNOW YOU'LL SHARE IT WITH US?
MY SCIENTISTS AND COMPUTER SPECIALISTS WILL MAKE SURE IT'S ALL AVAILABLE FOR ANYONE WHO WANTS TO USE IT, OTHER SCIENTISTS OR EVEN JUST AVERAGE CITIZENS.
WE'RE COMMITTED TO MAKING SURE THE DATA IS OPEN FOR EVERYONE.
OPEN DATA
OKAY, WE'RE IN.


GREAT! LET'S GET STARTED!
HUH?
MIZU-CHAN! HELLO! PLEASE, CAN WE TALK?
I SEE YOU'VE LEARNED MY NAME, THAT'S A START.
WHAT ARE YOU ALL DOING UP THERE?



WE'RE LOOKING AT WHAT YOU'VE BEEN DOING.
UH, WHAT ARE YOU DOING?
I'M PART OF EARTH'S WATER CYCLE. WATER EVAPORATES FROM THE SURFACE UP INTO THE CLOUDS--
DEPENDING ON TEMPERATURE AND WIND PATTERNS, I CAUSE RAIN AND SNOW.
WHY DO YOU WANT TO KNOW?
YOU HAVE A BIG EFFECT ON THE LIVING THINGS BELOW YOU. WHEN YOU LINGER IN ONE PLACE, THERE CAN BE FLOODING OR LANDSLIDES--
AND WHEN YOU LEAVE A PLACE ALONE FOR A WHILE, THERE CAN BE A DROUGHT.
HOW DO YOU CHOOSE WHERE IT'S GOING TO RAIN?
Wait a sec...
THAT'S A TRADE SECRET! BUT YOU SEEM LIKE A HARD-WORKING SATELLITE.
SIGH
NASA
I BET IF YOU PAY ATTENTION, YOU CAN FIGURE IT OUT. IT'LL BE LIKE A PUZZLE!
I ACCEPT YOUR CHALLENGE, MIZU-CHAN!
IF YOU WON'T TELL ME YOUR SECRET, I'LL JUST HAVE TO WATCH AND LEARN ABOUT THE WATER CYCLE MYSELF.


SEE YOU LATER!
GOOD OBSERVATIONS ARE GOING TO BE KEY TO FIGURING OUT MIZU-CHAN'S PUZZLE.
LOOK, I NOTICE THAT SOME AREAS ON EARTH SEEM TO GET MORE PRECIPITATION THAN OTHERS. SEE THIS WET BAND AROUND THE EQUATOR?
BUT IT CHANGES BY THE SEASONS. IN INDIA THEY GET A LOT OF RAIN IN SUMMER, BUT IT'S DRY IN WINTER.
MONSOONS CAN CAUSE A LOT OF FLOODING.
IN CALIFORNIA IT HASN'T RAINED MUCH IN YEARS. THAT'S CAUSING PROBLEMS!
THE OCEAN HAS SOME *BIG* STORMS BREWING!
THE PATTERNS ARE CHANGING--PLACES GETTING WETTER OR DRIER. IS THAT RELATED TO THE *RISING* GLOBAL TEMPERATURES?
I DON'T KNOW. WE'LL HAVE TO ASK THE SCIENTISTS AFTER WE SEND THEM OUR DATA.
I'M *IMPRESSED*. YOU REALLY WANT TO LEARN ABOUT WHAT I DO!
WE DON'T UNDERSTAND EVERYTHING WE'VE BEEN SEEING YET. THE WATER CYCLE IS COMPLICATED!
CAN YOU GIVE US SOME HINTS?
WHERE WOULD THE FUN IN THAT BE? YOU'LL JUST HAVE TO KEEP WATCHING AND *LEARNING*.


I GUESS WE'LL HAVE TO FIND OUT *TOGETHER*!

Glossary

Antenna
A device used to transmit signals. GPM uses its antenna to send data and get instructions from the ground.

Calibrate
To measure and adjust readings in comparison to a set standard. The GPM Core Observatory is the calibration standard for the other satellites in the constellation to be able to combine all the data together.

Constellation
In this case, the group of international satellites that combine their data to get a global view of precipitation.

Drought
Long periods of low precipitation.

Evaporation
The process by which water molecules in liquid water are heated and escape into the air as water vapor.

Flooding
The submerging or covering of land under water.

Frequency
The number of cycles (up and down) per second of a wave of electromagnetic energy as it moves. GPM measures thirteen different frequencies, each sensitive to different types of precipitation.

GPS - Global Positioning System
A satellite network used to provide information about the position and velocity of an object.

Hurricane
A tropical storm that has winds of 119 kilometers (74 miles) per hour or higher; the scientific term is "tropical cyclone".

Instrument
A tool used to make specific measurements to answer a scientific question.

Landslide
The sliding down of a mass of earth or rock from a mountain, cliff or other slope.

Background Image: Grant Petty

Glossary

Microwave Imager — A GPM science instrument designed to sense the total precipitation within all cloud layers, including light rain, heavy rain and snowfall.

Monsoon — A seasonally reversing wind pattern that brings heavy rains during certain times of the year.

Orbit — The path followed by an object revolving around another object.

Precipitation — Any product of the condensation of atmospheric water vapor that falls quickly out of a cloud. The main forms of precipitation include drizzle, rain, sleet, snow, graupel and hail.

Precipitation Radar — A GPM science instrument that provides detailed three-dimensional measurements of particles of rain and snow, including information about their size, shape and location in the cloud layers.

Relay Satellite Network — The Tracking and Data Relay Satellite System (TDRSS) is a group of communications satellites and ground stations used by NASA for space communications.

Satellite — Anything that orbits or circles something else. Human-made satellites are artificial machines that are put in space in order to collect information or for communication.

Solar Panel — A panel that absorbs the sun's rays to create electricity. In the case of GPM, this energy powers the scientific instruments.

Star Trackers — Devices that measure the positions of stars and use a catalog of star locations to help the satellite know where it is in space.

Swath — The area of Earth observed by a satellite as it revolves around the planet.

Background Image: Jason Weingart

Learn More Glosssary Terms At:
pmm.nasa.gov/resources/glossary

Measuring Rain:
On the Ground and From Space

When is it going to rain? How much will it rain? We want to know about precipitation to plan day-to-day events, but also to help us make decisions about bigger issues related to safety, transportation and our jobs. Precipitation also significantly affects our food and water supply. Therefore, it is important to accurately measure rain and snowfall.

A simple rain gauge. Credit: CoCoRaHS

There are many ways to measure precipitation. Rain gauges collect and measure rainfall in a location over a period of time. However, rain gauges only measure rain in one specific spot. Radars can be set up on land and cover more area. From Earth, radar sends out a signal to the sky and measures how much of the signal is scattered by rain or snow. However, radars are only available in certain locations and do not measure rain over most of the oceans.

More complex scientific rain gauges. Credit: Iowa Flood Center

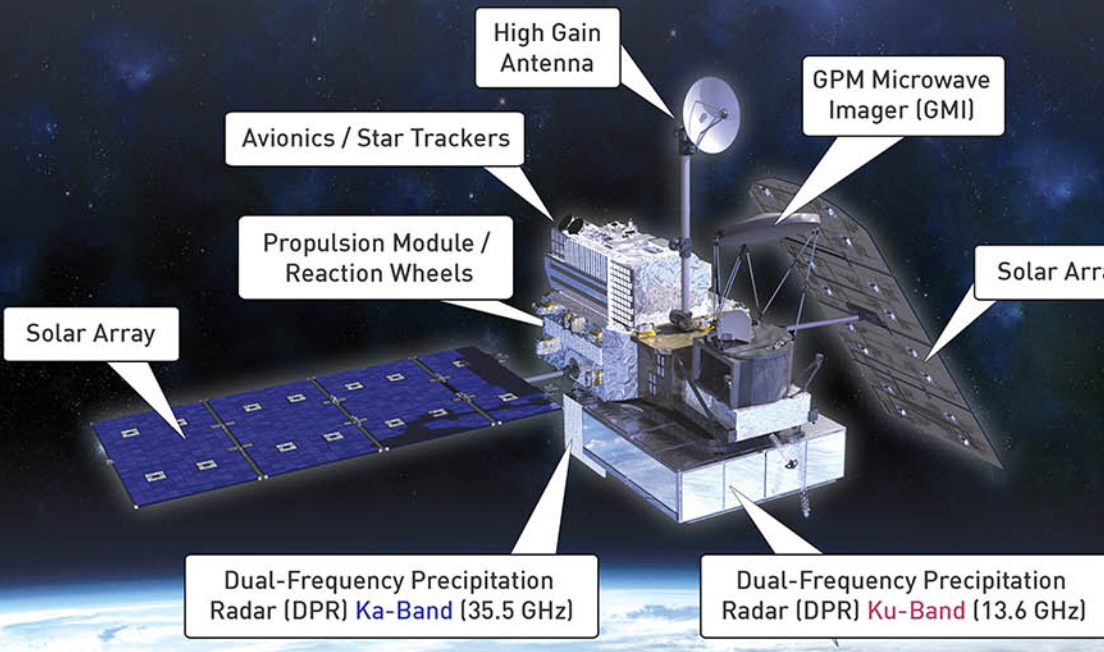
For a truly global picture of precipitation - over land, oceans and in all parts of the world - we use satellites in the sky.

The **Global Precipitation Measurement** mission (GPM) is an international network of satellites that are all looking down on Earth and measuring precipitation from space. The GPM concept centers on the deployment of the **GPM Core Observatory**, a satellite that helps measure precipitation all over the world every three hours. Not only will this data give us a better picture of global precipitation, it will help advance our understanding of Earth's water and energy cycle and improve forecasting of extreme events like floods, droughts, landslides and hurricanes.

Background Image: Steven Sandner

The GPM Core Observatory

The GPM Core Observatory carries two instruments that measure precipitation from space. The data from these two instruments serves as a reference standard to unify precipitation measurements made by an international network of partner satellites. The design and sampling technique of the Core Observatory builds on the concept of the Tropical Rainfall Measuring Mission (TRMM), which was launched in 1997 and continued collecting data until 2015.



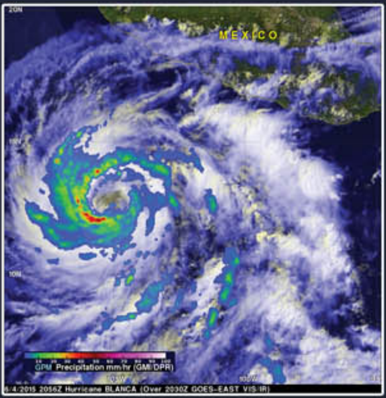
The two main instruments on the Core Observatory are the **Dual-Frequency Precipitation Radar** (DPR) and the **GPM Microwave Imager** (GMI). The DPR provides three-dimensional information about precipitation particles in the different layers of clouds. It sends energy at two frequencies (Ku- and Ka-band) into the cloud and observes the energy that is reflected from different heights. It is an active radar instrument since it actually sends out energy. The GMI is a passive radiometer – it just observes and measures energy that is emitted by precipitation within clouds. Different types of precipitation, like heavy rain and light snow, emit different frequencies of energy. The GMI measures these frequencies to tell us what kind of precipitation is in the cloud.Other components of the satellite include the solar panels to provide power, a high gain data-relay antenna for communication, a star-field finder for navigation and a control system to manage the satellite.

GPM Microwave Imager (GMI) is a passive radiometer with a reflector above to receive the microwave energy reflected from precipitation.

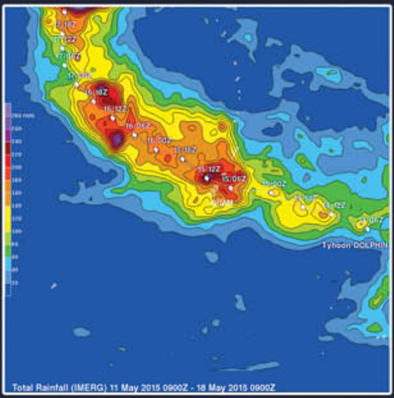
The Dual-Frequency Precipitation Radar (DPR) is the two boxes on the bottom of the Core Observatory – the small one is the Ka frequency radar and the larger flat box is the Ku frequency radar.

The GPM mission is co-led by NASA and the Japan Aerospace Exploration Agency (JAXA). The GPM Core Observatory launched from the Tanegashima Space Center on Tanegashima Island, Japan in February 2014.

Global Precipitation Data

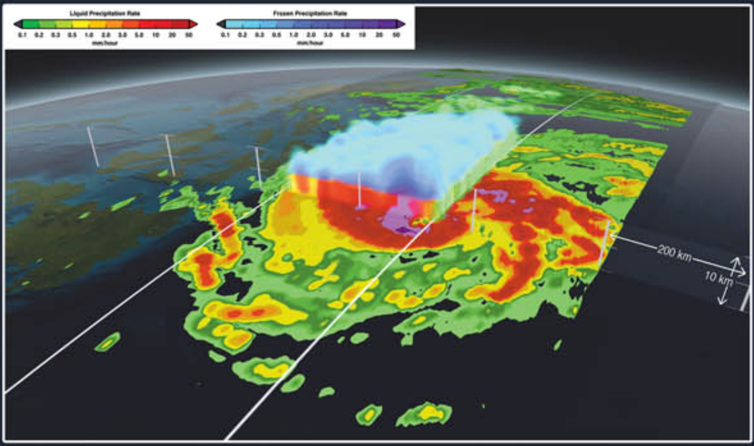


The GPM Microwave Imager (GMI) can generate 2D images of the rainfall and snowfall rates within storms, similar to an x-ray. This data can then be combined with other satellite data and used to calculate the total precipitation that fell over a period of time.

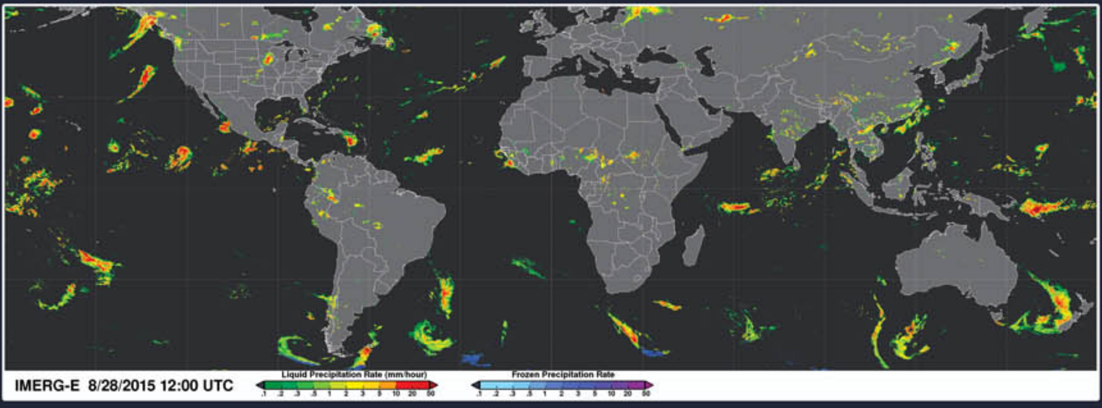


Rainfall rates (mm/hour) from Hurricane Blanca on June 4th, 2014 are shown overlaid on top of a GOES satellite image of visible clouds. The red areas have the highest rainfall rate, while the blue areas are the lowest for the storm.

Rainfall totals (in mm) from Typhoon Dolphin were calculated using GPM IMERG data from May 11th - 18th, 2015. The areas of highest total rain are red/pink, while lower accumulation is in blue.



GPM's Dual-Frequency Precipitation Radar (DPR) can provide 3D images of the intensity of precipitation within storms, similar to a CAT scan. This image shows precipitation within Typhoon Hagupit on December 5th, 2014. You can see a layer of frozen precipitation in blue above the melting layer, shown in red and pink.



Data from all the satellites in the GPM Constellation is combined to create a global image of precipitation known as IMERG (Integrated Multi-satellitE Retrievals for GPM) which scientists use to study the global water cycle.

pmm.nasa.gov/data-access

About the Characters

GPM

Designed by Japanese comic writer and illustrator ***Yuki Kiriga***, the design for the GPM character was selected as one of the winners of the GPM Anime Challenge, a character creation contest held in 2013. His blond hair and kimono (with snow and rain patterns drawn on it to represent the rain and snow he observes) show that he is half American and half Japanese, just like the real satellite.

TRMM

The Tropical Rainfall Measuring Mission was launched in 1997 to study rainfall for weather and climate research. After 17 years of productive data gathering, the instruments on TRMM were turned off in April 2015, and the spacecraft re-entered Earth's atmosphere. In addition to a microwave imager, TRMM carried the first precipitation radar into space, a legacy GPM continues with its improved instruments. The character of TRMM is depicted as an older man, imparting his wisdom to the next generation GPM satellite.

Mizu-Chan

From the Japanese word for water, Mizu-chan is the personification of water and precipitation. Designed by then 14-year-old ***Sabrynne Buchholz*** of Hudson, Colorado, USA, Mizu-chan was selected as one of the winners of the GPM Anime Challenge, a character creation contest held in 2013. As explained by her creator, her flowing dress in many shades of blue signifies the many forms of water found on Earth, although it can change color to be gray during storms, or white in the winter. Her hemline is surrounded by clouds, showing water vapor condensing as part of the water cycle. Depending on her "mood" (which correlates to temperature, pressure and other atmospheric conditions on Earth), the clouds will also form different types of precipitation – rain, sleet or snow. During storms, her hair may be tousled by the wind or strands may stand out straight to look like lightning bolts. She wears boots to avoid getting her feet wet from run-off, although they may also be covered by frost when the conditions are cold.

The Engineer

The Engineer is based on GPM Deputy Project Manager Candice Carlisle, who works at NASA's Goddard Space Flight Center in Greenbelt, Maryland, USA. Prior to working on GPM, she worked on the Space Technology 5 project as well as the Earth Science Data and Information System. Candace holds a B.S. in Computer Science and Physics from the College of William and Mary and M.S. degrees in Technical Management and Computer Science from Johns Hopkins University.

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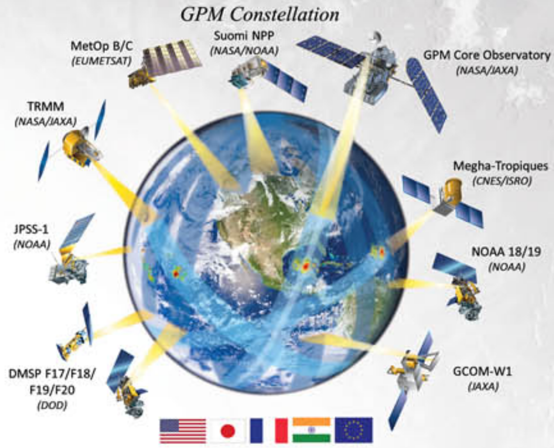
Background Image: Jessi Fife

The GPM Constellation

GCOM-W

The Global Change Observation Mission - Water (GCOM-W) was launched by the Japan Aerospace Exploration Agency on May 18, 2012 from the Tanegashima Space Center on Tanegashima Island, Japan. GCOM-W observes global water and energy circulation using an Advanced Microwave Scanning Radiometer 2 instrument, the world's largest revolving space antenna at time of launch. GCOM-W is one of two satellites in the GCOM mission, along with GCOM-C, which observes climate change with an emphasis on the carbon cycle. The GCOM-W satellite is also known as "Shizuku," and the character in the comic reflects that Japanese heritage.

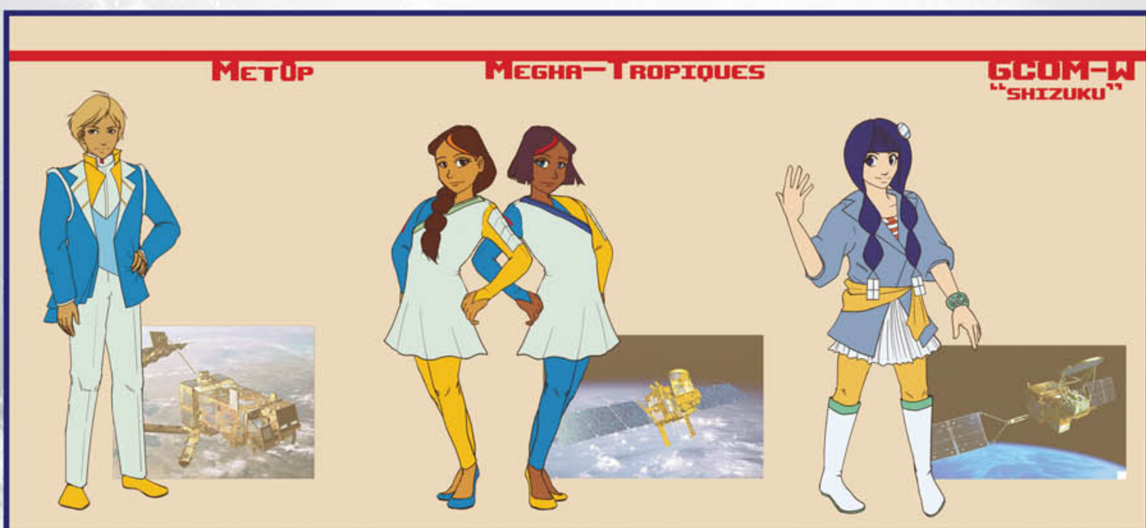


Megha-Tropiques

Megha-Tropiques was launched on October 12, 2011 from the Satish Dhawan Space Centre in Sriharikota, India. A joint mission between the Indian Space Research Organization (ISRO) and the Centre National D'Études Spatiales (CNES), the French government space agency, Megha-Tropiques studies the water cycle and energy exchanges in the tropics. This satellite holds a microwave imager that observes precipitation and cloud properties, a six channel microwave radiometer that observes water vapor distribution, and a radiometer that measures outgoing radiative fluxes. Because of the joint nature of the Megha-Tropiques mission between ISRO and CNES, two characters were used to represent the satellite.

MetOp

The Meteorological Operational Satellite Program is a series of three meteorological satellites developed jointly by the European Organization for the Exploitation of Meteorological Satellites and the European Space Agency (ESA). MetOp-A and MetOp-B were launched in 2006 and 2012, respectively, both from Baikonur Cosmodrome in Kazakhstan, and MetOp-C is scheduled to be launched in 2017. These satellites provide global weather data services and improve weather forecasting. The MetOp satellites carry 13 different instruments and sensors, supplied by both American and European agencies. Many of the instruments measure similar aspects of climate and weather, but use different measuring techniques to develop more accurate models. Although only one character was used to represent the satellite, ESA is an international organization with 22 member states and centers all over Europe.



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View Digital Comic:

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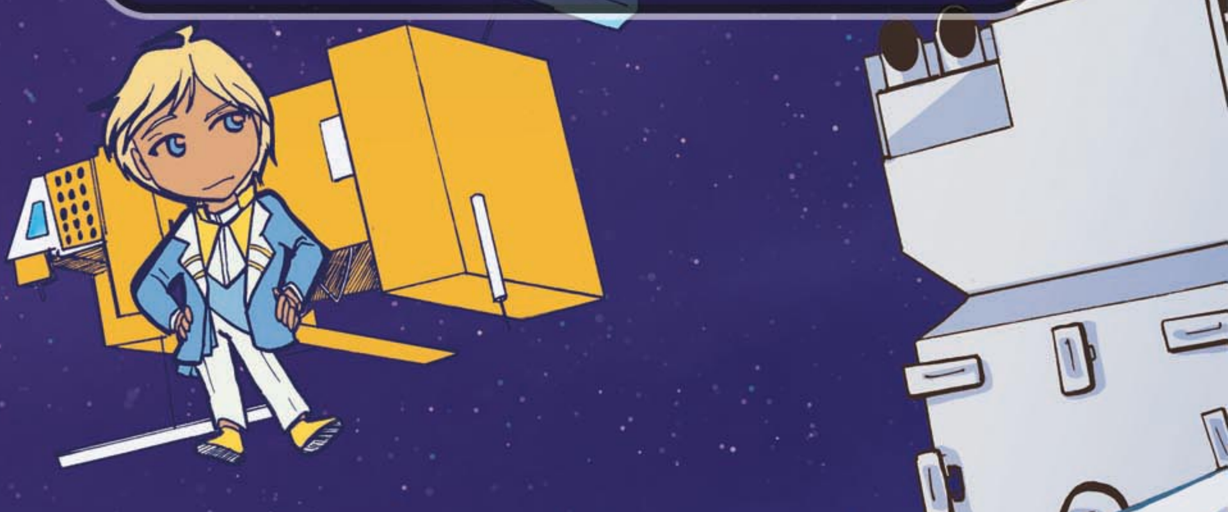

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