Guiding Questions

- Why do we need to measure rain and snow globally?
- What do we have now?
- What is the Global Precipitation Measurement (GPM) Mission?
- How do we connect the dots between satellite observations and what we measure at the surface?
- How can we use the data?
- Resources available to you!

Educational Themes

- Water Cycle: The continuous movement of water on, above and below Earth’s surface.
- Weather & Climate: The atmospheric conditions that lead to our daily weather and global climate.
- Technology: The spacecraft, instruments and people that study Earth systems.
- Societal Applications: How studying our planet’s rain and snowfall makes the world a better place.
The Freshwater Connection

Why measure GLOBAL precipitation (rain, snow, ice)?

Precipitation is a key component of the water cycle and an important contributor of freshwater around the planet. We need to quantify all inputs to the water cycle in order to better understand how water is moving through the earth system and model how it may behave in the future.

The most noticeable impacts of climate change will be changes in the water cycle.

Global mean water fluxes (1,000 km³/yr) at the start of the 21st century, based on satellite and ground-based observations and data integrating models.
Precipitation is felt locally, but interacts with large-scale circulation patterns. Precipitation links the Earth’s **ENERGY** and **WATER** cycles. 70% of the earth is covered by water where radar and gauges are very sparse. Even the coverage of gauges on land is quite small!
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Space-borne remote sensing can provide both the **space** and **time** coverage needed for measuring and evaluating precipitation across the globe, particularly in areas without ground-based instruments (e.g. rain gauges, radar).
What do we have now?

- Traditional infrared weather satellites orbit the Earth ~20,000 miles above the surface, providing a continuous picture of one slice of the earth
- Polar orbiting satellites cross at the same time of day
- Non-sun-synchronous satellites can view the earth at the same point at different times of a day
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GOES Image
(Geostationary orbit)
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Suomi NPP composite image (Polar orbit)
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**Images:**

- TRMM pass over Southeast US (non-sun-synchronous orbit)
- GOES Image (Geostationary orbit)
- SuomiNPP composite image (Polar orbit)
- TRMM Precipitation mm/hr (PR & TRMM over VHS)

**Dates:**

- 1/30/2013 16:22Z Tornadic Thunderstorms
- Tornado Report
Tropical Rainfall Measuring Mission

- Launched in 1997 to measure tropical rainfall
- Currently has a 15-year record of precipitation from ~35° North to 35° South
- Partnership between NASA and the Japan Aerospace Exploration Agency (JAXA)
- Data at http://trmm.gsfc.nasa.gov

Hot Towers observed in Hurricane Wilma

Rainfall Accumulation from Tropical Cyclone Giovanna, triggering deadly floods in Madagascar
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We need better instruments and improved models to identify light rainfall and snow in higher latitudes.
GPM is an international mission which will use inputs from an international constellation of satellites to provide improved space and time coverage of precipitation (rain, snow) over the globe.
The GPM Core Observatory will carry two advanced instruments that allow us to view precipitation (rain, snow, ice) in new ways and serve as a connector between the GPM Core and measurements taken on other partner satellites.

Non-Sun-Synchronous orbit at 65° inclination (Arctic to the Antarctic Circle) at 407 km
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**Dual-frequency Precipitation Radar (DPR): Ku-Ka bands**
Two different radar frequencies that can look at precipitation in 3-D throughout the atmospheric column.

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**GPM Microwave Imager (GMI): 10-183 GHz**
- 13 channels which provide an integrated picture of the energy emitted by precipitation, including light rain to heavy rain to falling snow.

Non-Sun-Synchronous orbit at 65° inclination (Arctic to the Antarctic Circle) at 407 km
Testing at NASA Goddard!

- Core Observatory satellite is being built and tested at GSFC.
  - May 2011 – Centrifuge testing
  - May 2012 – Completed instrument integration
  - August 2012 – Solar array vibration and acoustic testing
  - December 2012 – Thermal Vacuum Testing
  - March 2013 – Electromagnetic Interference Testing
  - June 2013 – Solar Array Deployment testing
- Early November, 2013 - GPM Core shipped to Tanegashima Island, Japan
- February, 2014 – GPM Launch!

GPM at the clean room at NASA GSFC
Accurate and timely precipitation measurements

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• Partner satellites will come from:
  - NOAA
  - DOD
  - EUMETSAT
  - ISRO/CNES (India/France)

Active Joint Projects (19 PI’s from 13 countries)
• Connecting the dots between what the satellite “sees” from space and what we observe on the ground
Ground Validation and Field Campaigns

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  - Flooding and hydrologic modeling: Iowa (2013)

iFLOODS (2013)
MC3E (2011)
Pre-CHUVA (2010)
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  – Falling snow: Canada (2012)
  – Flooding and hydrologic modeling: Iowa (2013)
• There is also a permanent ground validation effort at Wallops Flight Facility, Maryland
Defining what satellites are “seeing”

Example from 5/20/2013
NPOL – Diagnosed Cross-Sections of the Precipitation Process

Radar Reflectivity (returned power)

A Thunderstorm “Core”

The “process”: Ice to Rain

Snow rimes

Graupel is formed

Graupel becomes hail and/or rain freezes and rimes to become hail

Rain drops (melting snow, hail, graupel)
Defining what satellites are “seeing”

Example from 5/20/2013
NPOL – Diagnosed Cross-Sections of the Precipitation Process

**Radar Reflectivity (returned power)**

**Diagnosed Precipitation Types**

A Thunderstorm “Core”

Snow
Graupel
Hail
Large Rain Drops
Rain

The “process”: Ice to Rain

**Snow rimes**
**Graupel is formed**

Graupel becomes *hail* and/or rain freezes and rimes to become hail

Rain drops (melting snow, hail, graupel)
On Wednesday afternoon, June 12th there was a severe storm outbreak that developed and moved across central and eastern Iowa, spawning several tornadoes and huge thunderstorms.

The NPOL radar was able to observe a Hook echo in a supercell only 40 km north of the radar. Images show convective Boundary Layer Development over NPOL and D3R on 6/12/2013 at ~1700 UTC. NPOL capturing line of multiple supercells, some tornadic moving across Iowa on June 12th at 21:57 UTC.
• Meteorological Phenomena Identification Near the Ground (mPING) – Partnership with University of Oklahoma, NOAA and NASA
• Report precipitation in your area with a click of a button!
• Going international by September
• Meteorological Phenomena Identification Near the Ground (mPING) – Partnership with University of Oklahoma, NOAA and NASA

• Report precipitation in your area with a click of a button!

CoCoRaHS - Community Collaborative Rain, Hail and Snow Network; www.cocorahs.org

• Network of individuals that take daily measurements of precipitation from rain gauges at their houses or other facilities
What can we do with the data?

- Flooding
- Landslides
- Land surface and climate modeling
- Freshwater Availability
- Agriculture/Famine Early Warning
- Extreme Events
- World Health

The rain and snow data gathered from the TRMM and GPM missions already provide and will extend our capabilities to study a wide range of applications for scientific research and societal benefit.
TRMM data are used by many tropical cyclone forecasting centers worldwide to detect the location and intensity of tropical cyclones. In 2004, more than 600 tropical cyclone fixes were made using TRMM.
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GPM’s orbit will enable observation of tropical cyclones as they progress from tropical to mid-latitude systems.

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Landslides and flooding

GPM will provide rain accumulation and distribution data at high resolution to advance predictions of high-impact natural hazard events.
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Landslide Hazard Forecasting

Over 500 people killed in Shiao Lin, triggered numerous and massive landslides throughout Southern and Central Taiwan.

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Global Flood Modeling

Real-time estimates of flood areas using satellite rainfall and a hydrological model updated globally, every 3 hrs.

Over 500 people killed in Shiao Lin, triggered numerous and massive landslides throughout Southern and Central Taiwan.

Typhoon Morakot (Etau) August 8th, 2009
Measurements from TRMM revealed elevated rain rates downwind of urban areas in Texas. The heaviest rain (blue) occurred downwind of Houston.

“I started noticing that around some of the cities, there seemed to be these anomalies in rainfall downwind,” Marshall Shepherd, current AMS president, University of Georgia, PMM Science Team Member

GOES imagery: Summer afternoon thunderstorms that sprang up along the border between Texas and Louisiana on September 6, 2006.

http://earthobservatory.nasa.gov/Features/UrbanRain/
Estimating Urban Impacts

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GOES imagery: Summer afternoon thunderstorms that sprang up along the border between Texas and Louisiana on September 6, 2006.

New research by *University of Georgia, University of Oklahoma, and the National Weather Service* has revealed **potentially predictive relationships** between precipitable water (PW) distributions and urban flooding.

Rainfall (Atlanta floods) as acquired by multiple satellites, are calibrated with rainfall measurements from NASA’s TRMM satellite. The highest rainfall amounts—more than 300 millimeters (11.8 inches)—appear in blue. Credit: NASA/Jesse Allen

http://earthobservatory.nasa.gov/Features/UrbanRain/
Modeling short and long-term fluctuations in climate and the water cycle

Precipitation observations are in use at ECMWF, NCEP, JMA, and other NWP centers to improve weather forecasting.
Accurate satellite precipitation estimates are critical to crop forecasts. Famine Earth Warning System (FEWS) relies on TRMM and other satellite estimates for anticipating poor growing seasons.
TRMM data has been used to estimate and trace the source areas of vector and river-borne diseases in Africa and Western Australia. Examples include Schistosomiasis (snail-spread) in Ethiopia.

Schistosomiasis

![Schistosomiasis Diagram](image)

Sporocysts in snail (successive generations)

Cercariae released by snail into water and free-swimming

Penetrate skin

Cercariae lose tails during penetration and become schistosomulae

Circulation

Migrate to portal blood in liver and mature into adults

Eggs hatch releasing miracidia

Mirobadia penetrototo snail tissue

Paired adult worms migrate to mesenteric venules of bowel/rectum (laying eggs that circulate to the liver and shed in stools)

S. mansoni

S. japonicum

S. haematobium

In feces

In urine


Courtesy of Bitew and Gebremichael
Educational resources

- Follow us on Twitter: @NASA_Rain
- “Like” us on Facebook: https://www.facebook.com/NASA.Rain
- Precipitation Education Website: www.pmm.nasa.gov/education

GPM Anime Challenge:
NASA and JAXA challenged people from around the world to design an anime character to help demonstrate GPM educational science themes of the water cycle, weather and climate, and technology. We received over 40 submissions from around the world. We are planning to develop a comic series with our grand prize winning characters.
GPM Education and Public Outreach

• **Formal Education:**
  – Master Teachers: Developing materials with GPM themes to be taught in middle school Earth Science classes
  – Outdoor Education: “Survivor Module” based on measuring water in different environments  
    • GLOBE Protocols: Precipitation and atmospheric measurements – Training sessions Tuesday and Thursday this week (morning/afternoon)

• **Informal Education:**
  – Earth to Sky partnership: stipends to National Parks, Fish and Wildlife Centers, etc. to develop an activity for their park
Lessons introduce students to making hands-on measurements through GLOBE protocols to explore Earth’s Hydrosphere, Biosphere, Geosphere and Atmosphere.
Types of Measurements

- Land Cover
- Water in Biosphere
Types of Measurements

- Land Cover
- Water in Biosphere
- Rainfall
- Air temperature
- pH of rain
- Relative humidity
- Cloud type and cover
Types of Measurements

- pH
- Temperature
- Transparency
- Land Cover
- Water in Biosphere
- Rainfall
- Air temperature
- pH of rain
- Relative humidity
- Cloud type and cover
Types of Measurements

- Land Cover
- Water in Biosphere
- Rainfall
- Air temperature
- pH of rain
- Relative humidity
- Cloud type and cover
- Soil Moisture
- Soil Temperature
- Soil Consistence
- Soil Color
- pH
- Temperature
- Transparency
Freshwater Availability Classroom Activity

Type: Lesson Plan

Audience: Formal, 9 - 12, 6 - 8, K - 5


Keywords: groundwater, glaciers, saline, blue marble

Summary: This classroom activity (originally developed for the GPM Poster) will teach students about the value of Earth's freshwater resources and how important it is to study how water is transferred and stored.

This activity can be used with any age level, from elementary level students to adult groups.

Educational Standards:
Earth and Space Science: Structure of Earth System

- Water, which covers the majority of the Earth's surface, circulates through the crust, oceans, and atmosphere in what is known as the “water cycle”
- Fresh water, limited in supply, is essential for some organisms and industrial processes. 4B/MS*

Classroom Activity

This activity is designed to introduce participants to the concept that although about 70% of Earth's surface is covered by water, only a small fraction of that water is available to humans as an essential resource.

Engage:
Show participants a picture of the Earth taken from space to begin a discussion about water on Earth and how we have learned about water on Earth from satellites in space.

Show students the following image and use the following questions as discussion starters:

Related Topics:
- Water & Life
- Remote Sensing
- Freshwater Resources
- World Health

http://pmm.nasa.gov/education
• Outreach:
  – Science on a Sphere show, “Water Falls” premiering in October!
  – Social Media, websites, Photo contests, Anime Character Challenge
  – Videos, feature stories, Google+ Hangouts, LEGO Model, Launch parties
For more information on the TRMM and GPM Missions:

http://gpm.nasa.gov
www.nasa.gov/gpm

Twitter: NASA_Rain  Facebook: NASA.Rain
http://pmm.nasa.gov/education/videos/for-good-measure
Applications Video

• Special Sensor Microwave Imager/Sounder (SSMIS) instruments on U.S. Defense Meteorological Satellite Program (DMSP) satellites

• The Advanced Microwave Scanning Radiometer-2 (AMSR-2) on JAXA’s Global Change Observation Mission - Water 1 (GCOM-W1) satellite

• The Multi-Frequency Microwave Scanning Radiometer (MADRAS) and the multi-channel microwave humidity sounder (SAPHIR) on the Megha-Tropiques satellite provided by the Centre National D’Etudes Spatiales (CNES) of France and the Indian Space Research Organisation (ISRO)

• The Microwave Humidity Sounder (MHS) instrument on the National Oceanic and Atmospheric Administration (NOAA)-19 satellite

• MHS instruments on the MetOp series of satellites launched by the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)

• The Advanced Technology Microwave Sounder (ATMS) instruments on the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP)

• ATMS instruments on the upcoming NOAA-NASA Joint Polar Satellite System (JPSS) satellites

• A microwave imager planned for the Defense Weather Satellite System (DWSS)

Ou Mi-Lim

Korea Meteorological Administration / National Institute of Meteorological Research (KMA/NIMR)