National Aeronautics and Space Administration

ARSET

Applied Remote Sensing Training

http://arset.gsfc.nasa.gov

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NASA Satellites and Earth System Models for Water Resources Management

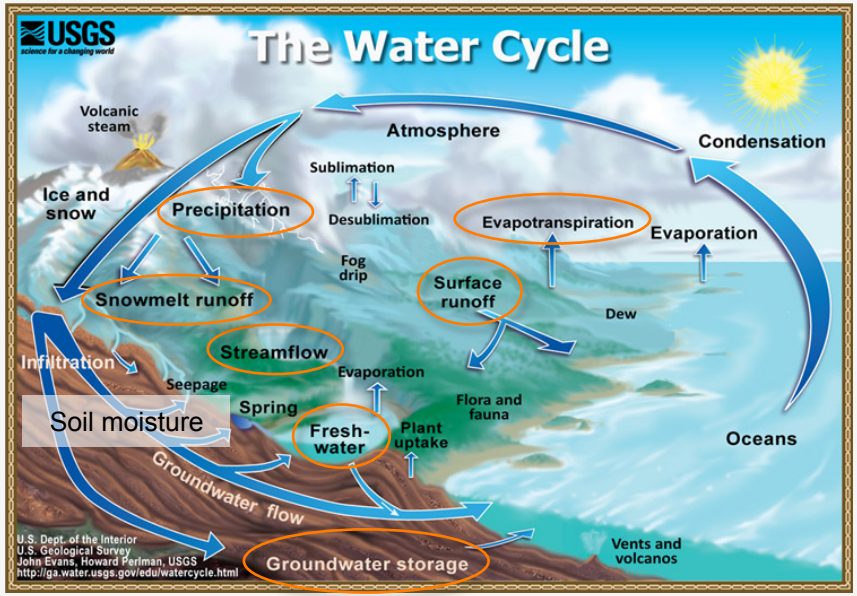
Outline

- Water Resources Management
- Overview of Satellites & Earth Science Models for Water Resources Management
- Satellites & Sensors
- Earth System Models
- Data Applications

Water Resources Management

Water Resources Management

- For sustainable water management, it is critical to have accurate estimates of water cycle components



USGS

Water Resources Management

Freshwater Components

Over a watershed, river basin, or region:

- Precipitation (rain, snow) is the main source of fresh water
  - Other regional contributions: runoff/streamflow, lakes, soil moisture, and ground water
- Evaporation and evapotranspiration through loss of water to atmosphere and runoff outflow contribute to depletion of fresh water
- Surface fresh water availability (W) is largely controlled as follows:

W = (precipitation + runoff in the region) – (evaporation/ evapotranspiration + runoff outflow + infiltration)

Freshwater Information

- Not all water cycle components can easily be measured directly, such as:
  - Evapotranspiration
  - Runoff
  - Water vapor transport

- NASA satellites and Earth system models measure and calculate all water cycle components

Overview of Satellites & Earth Science Models for Water Resources Management

NASA Satellites & Earth System Models

Hourly, Daily, Seasonal, and Multi-Year Time Scales

Useful for water resources management & for hydrology model inputs

- Rain
- Temperature
- Humidity
- Winds
- Soil Moisture
- Snow/Ice
- Clouds
- Terrain

- Ground Water
- Vegetation Index
- Evapotranspiration
- Runoff

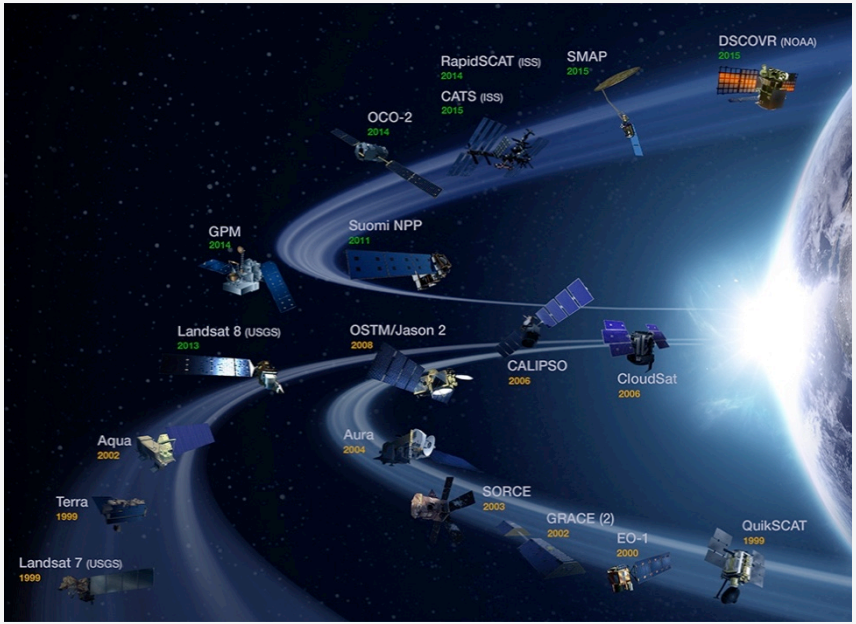
From satellites and models

From satellite observations

From atmosphere-land models that assimilate satellite observations

Satellites & Sensors

NASA Satellites for Water Resources Monitoring



- Landsat: 07/1972-present
- Tropical Rainfall Measuring Mission (TRMM): 11/1997-4/2015
- Global Precipitation Measurements (GPM): 2/2014-present
- Terra: 12/1999-present
- Aqua: 5/2002-present
- Soil Moisture Active Passive (SMAP): 1/2015-present
- Gravity Recovery and Climate Experiment (GRACE): 3/2002-present

NASA Satellites for Water Resources Monitoring

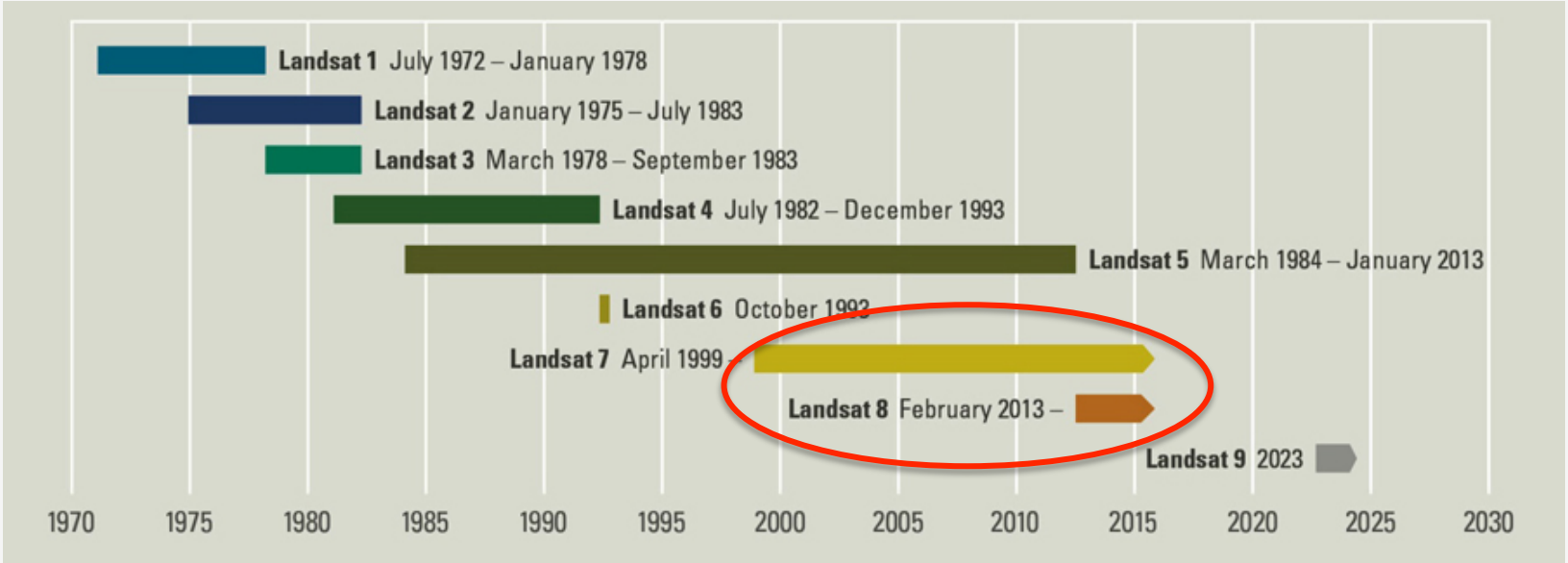
- Each satellite carries one or more sensors or instruments with specific spectral channels to observe geophysical quantities

- This presentation will describe sensors most useful for water resources data

- Landsat: 07/1972-present
- TRMM: 11/1997-4/2015
- GPM: 2/2014-present
- Terra: 12/1999-present
- Aqua: 5/2002-present
- SMAP: 1/2015-present
- GRACE: 3/2002-present

Landsat Satellites and Sensors

http://landsat.gsfc.nasa.gov



From: http://landsat.usgs.gov//about_mission_history.php

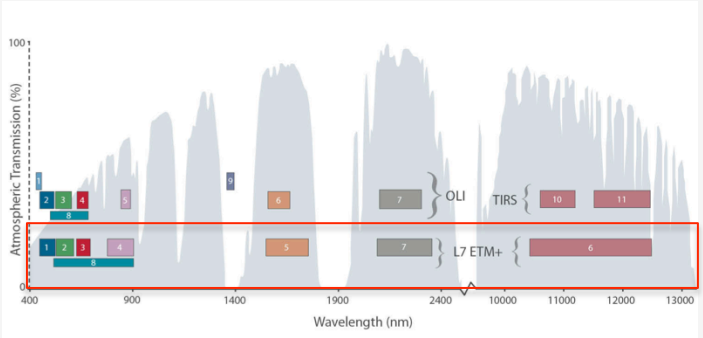
Enhanced Thematic Mapper (ETM+)

http://geo.arc.nasa.gov/sge/landsat/l7.html

- Onboard Landsat-7
- Polar orbiting satellite
- Spatial Coverage and Resolution:
  - Global, Swath: 185km
  - Spatial Resolution: 15m, **30m**, 60m
- Temporal Coverage and Resolution:
  - April 15, 1999-present
  - 16-day revisit time

Spectral Bands

- 8 bands (blue-green, green, red, reflected & thermal IR, panchromatic)
  - Bands 1-5, 7: 30m
  - Band 6: 60m
  - Band 8:15m



NASA

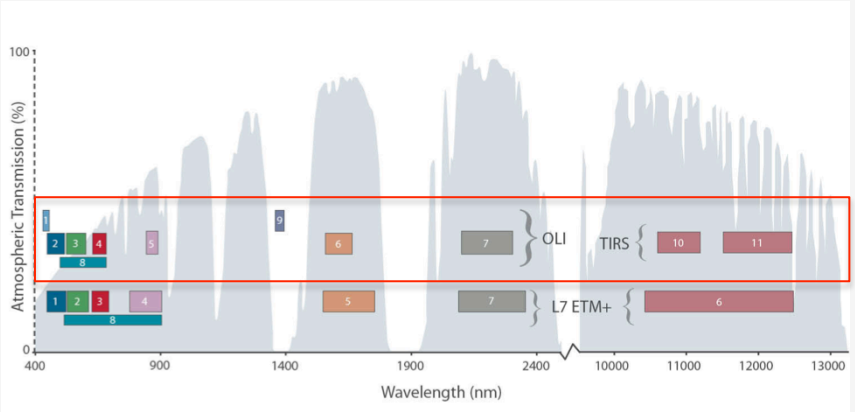
Operational Land Imager (OLI)

http://landsat.usgs.gov/landsat8.php ; http://landsat.gsfc.nasa.gov/?p=5779

- Onboard Landsat-8
- Polar orbiting satellite
- Spatial Coverage and Resolution:
  - Global, Swath: 185km
  - Spatial resolution: 15m, **30m**
- Temporal Coverage and Resolution:
  - Feb 11, 2013 – present
  - 16-day revisit time

Spectral Bands

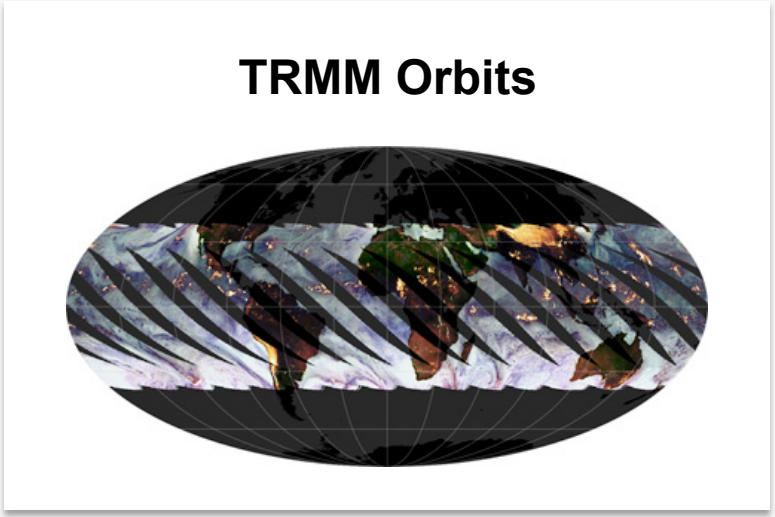
- 9 bands (blue-green, green, red, near IR, shortwave and thermal IR)
  - Bands 1-7, 9: 30m
  - Band 8:15m



TRMM Satellite & Sensors

http://trmm.gsfc.nasa.gov

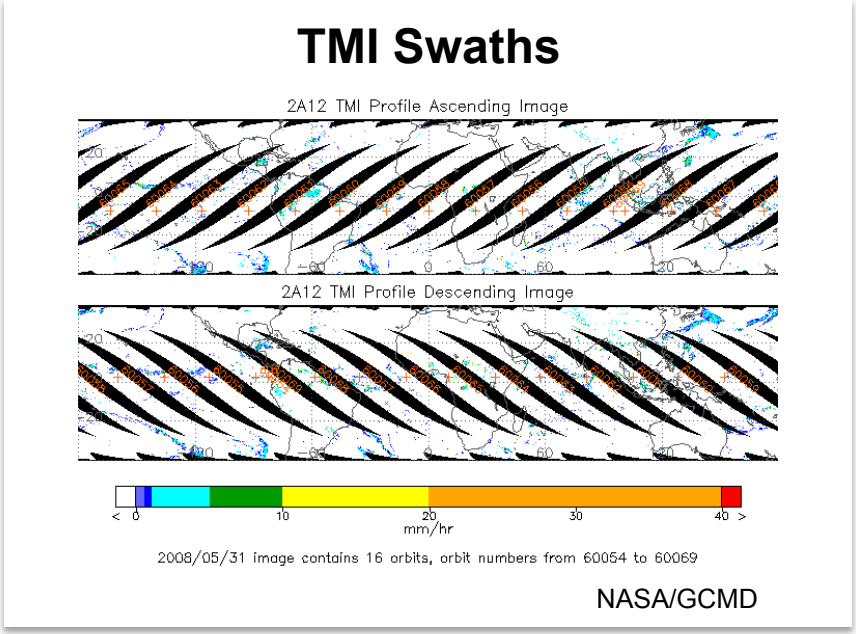
- In a non-polar, low-inclination orbit
- Altitude of approximately 350km, raised to 403km after Aug 23, 2001
- Spatial Coverage
  - 16 TRMM orbits a day covering global tropics between 35°S – 35°N latitude
- Revisit Time: 11-12 hrs
  - Time of observation changes daily
- Sensors:
  - TMI
  - PR
  - VIIRS
  - LIS
  - CERES



TRMM Microwave Imager (TMI)

http://pmm.nasa.gov/TRMM/TMI

- Spatial Coverage and Resolution:
  - Coverage: -180°-180°, 35°S-35°N
  - Swath: 760km (878km after 8/2001)
  - Vertical Resolution:
    - 0.5 km from surface – 4 km
    - 1.0 km from 4-6 km
    - 2.0 km from 6-10 km
    - 4.0 km from 10-18 km
- Temporal Coverage and Resolution:
  - Nov 27, 1988 – Oct 7, 2014
  - 16 orbits per day



Channel Frequencies

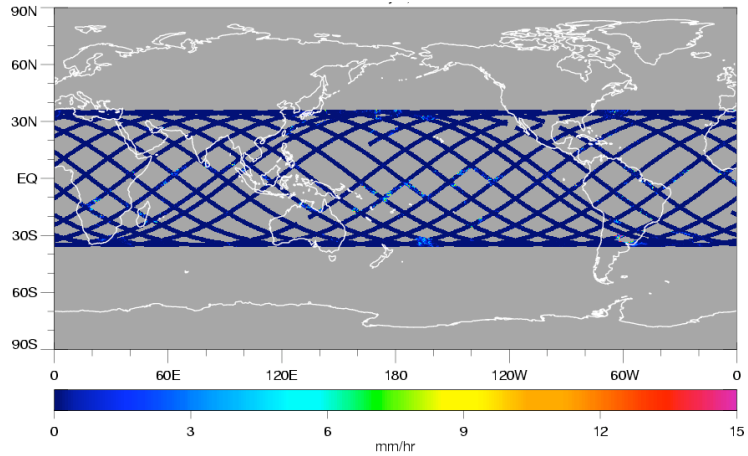
- 10.7, 19.4, 21.3, 37, 85.5 GHz

Precipitation Radar (PR)

http://pmm.nasa.gov/TRMM/PR

- Spatial Coverage and Resolution:
  - Coverage: 35°S-35°N
  - Swath: 215km (247 after 8/2001)
  - Spatial Resolution: 4.3km (5km)
  - Vertical Resolution: 250m (from 0-20km)
- Temporal Coverage and Resolution:
  - Nov 27, 1998 – Oct 7, 2014
  - ~16 orbits per day
- Frequency:
  - 13.6 GHz

PR Swaths



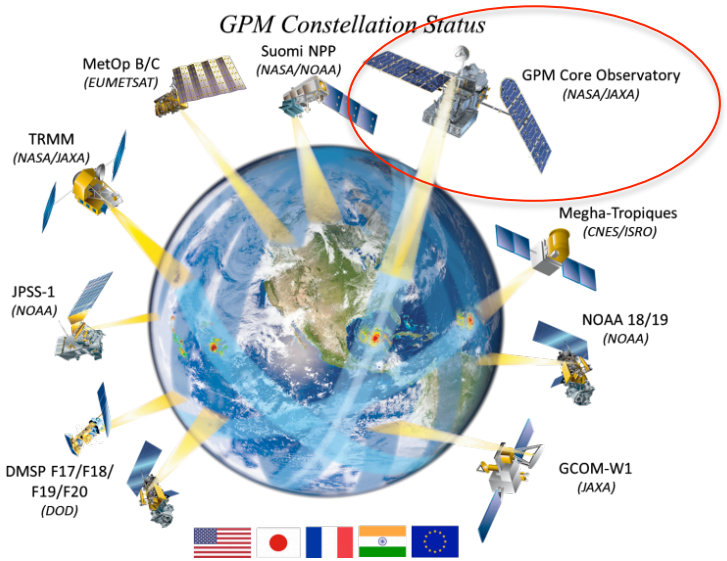
Kummerow, C., et. al, 1998: The tropical rainfall measuring mission (TRMM) sensor package, J. Atmos. Oceanic Technol., 15, 809-817.

GPM Satellite & Sensors

http://pmm.nasa.gov/GPM

- GPM core satellite is in a non-polar, low inclination orbit
  - Altitude: 407km
- Spatial Coverage:
  - 16 T orbits a day covering global tropics, between 65°S-65°N
- Along with constellation of satellites, GPM has revisit time of 1-2 hrs over land
- Sensors:
  - GMI
  - DPR

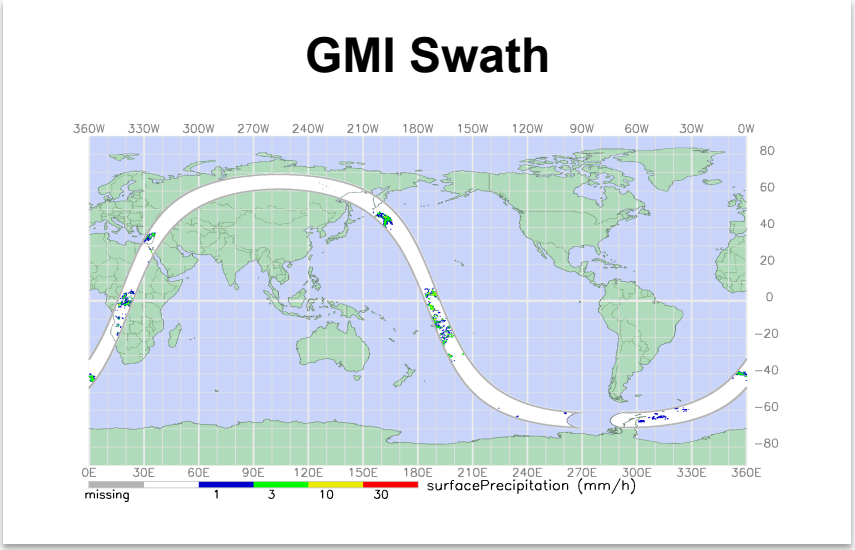
GPM Core Satellite
Launched Feb 27, 2014



GPM Microwave Imager (GMI)

http://pmm.nasa.gov/GPM/flight-project/GMI

- Spatial Coverage and Resolution:
  - Coverage: -180°-180°, 65°S-65°N
  - Swath: 885km
  - Spatial Resolution: 4.4-32km
  - Vertical Resolution:
    - 0.5 km from surface – 4 km
    - 1.0 km from 4-6 km
    - 2.0 km from 6-10 km
    - 4.0 km from 10-18 km
- Temporal Coverage and Resolution:
  - Feb 2014 – present
  - ~2-4 hr observations



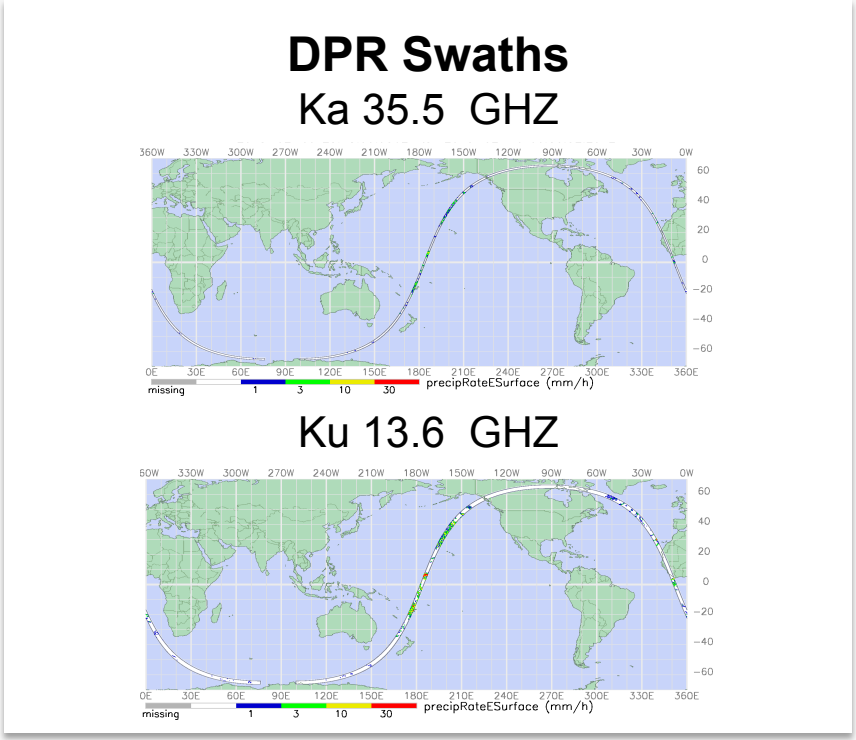
Channel Frequencies:

- 10.6, 18.7, 23.8, 36.5, 89, 166, 183 GHz

Dual Precipitation Radar (DPR)

http://pmm.nasa.gov/GPM/flight-project/DPR

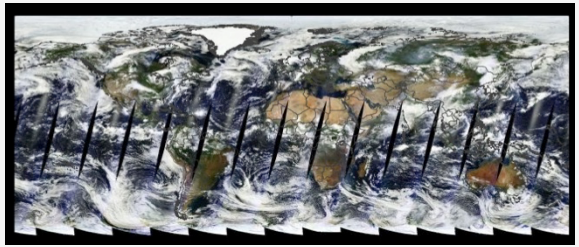
- Spatial Coverage and Resolution:
  - Coverage: -180°-180°, 65°S-65°N
  - Swath: 120km (Ka) and 245km (Ku)
  - Spatial Resolution: 5.2km
  - Vertical Resolution: 250m (from 0-20km)
- Temporal Coverage and Resolution:
  - Feb 27, 2014 – present
  - ~2-4 hr observations
- Frequency:
  - 13.6 and 35.5 GHz



Terra and Aqua

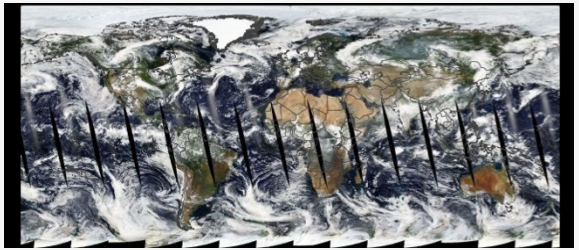
Terra

- Polar orbit, 10:30 a.m. equator crossing time
- Global coverage
- Dec 18, 1999 – present
- 1-2 observations per day
- Sensors:
  - ASTER, CERES, MISR, MODIS, MOPITT



Aqua

- Polar orbit, 1:30 p.m. equator crossing time
- Global coverage
- May 4, 2002 – present
- 1-2 observations per day
- Sensors:
  - AIRS, AMSU, CERES, MODIS, AMSR-E



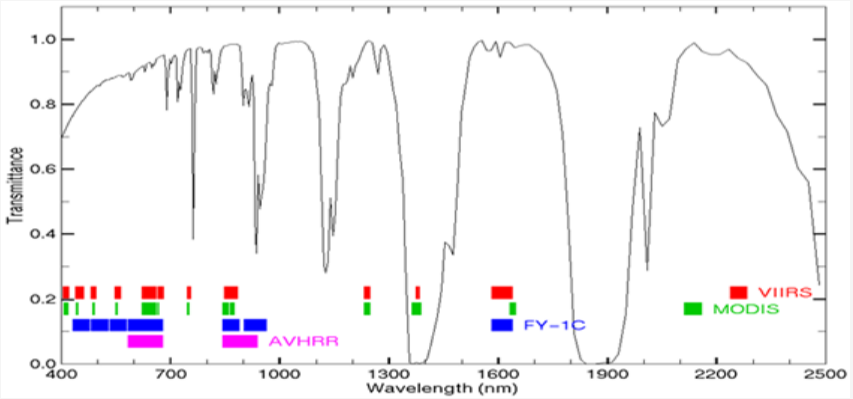
MODerate Resolution Imaging Spectroradiometer (MODIS)

http://modis.gsfc.nasa.gov

- On-board Terra and Aqua
- Designed for land, atmosphere, ocean, and cryosphere observations
- Spatial Coverage and Resolution:
  - Global, Swath: 2,330km
  - Spatial Resolution Varies: 250m, 500m, 1km
- Temporal Coverage and Resolution:
  - 2000-present, 2 times per day

Spectral Bands

- 36 bands (red, blue, IR, NIR, MIR)
  - Bands 1-2: 250m
  - Bands 3-7: 500m
  - Bands 8-16: 1000m

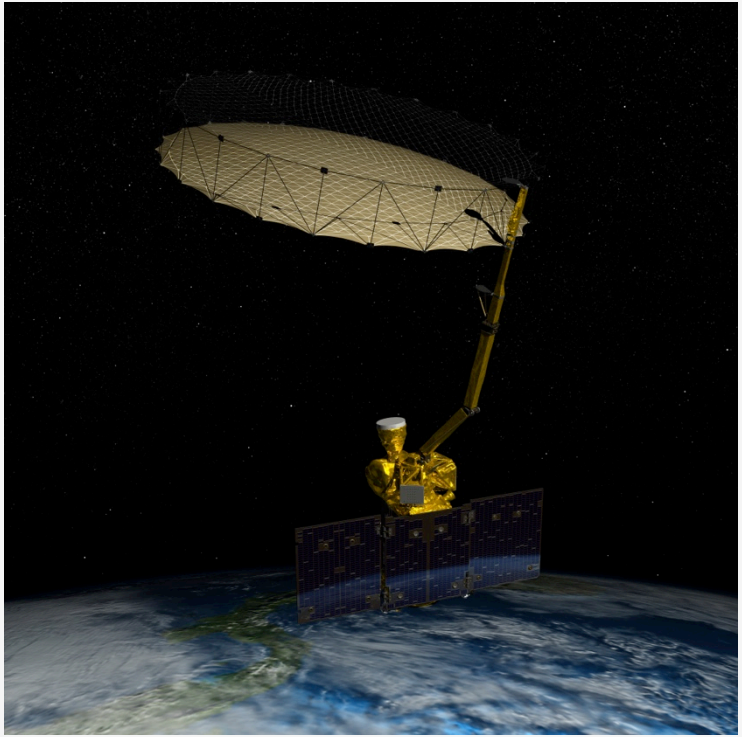


cimss.ssec.wisc.edu

SMAP Satellite & Sensors

http://smap.jpl.nasa.gov

- Polar Orbit
  - Altitude: 685km
- Spatial Coverage:
  - Global
- Temporal Coverage:
  - Jan 31, 2015 – present
- Sensors:
  - Microwave Radiometer
  - Microwave Radar (not currently available)



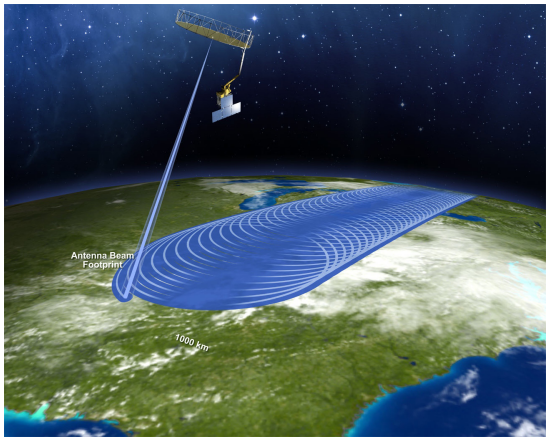
SMAP Microwave Radiometer and Radar

http://smap.jpl.gov/observatory/instrument

- Spatial Coverage and Resolution:
  - Global
  - Radiometer Swath: 1,000km
  - Resolution: 30km
- Temporal Resolution:
  - 8-day revisit time (6 a.m./p.m. observation time)
- Designed to work as Synthetic Aperture Radar (SAR) with 3km spatial resolution
  - Stopped operating after Jul 7, 2015

- Radiometer frequency: 1.41 GHz
- Radar frequency: 1.26 GHz

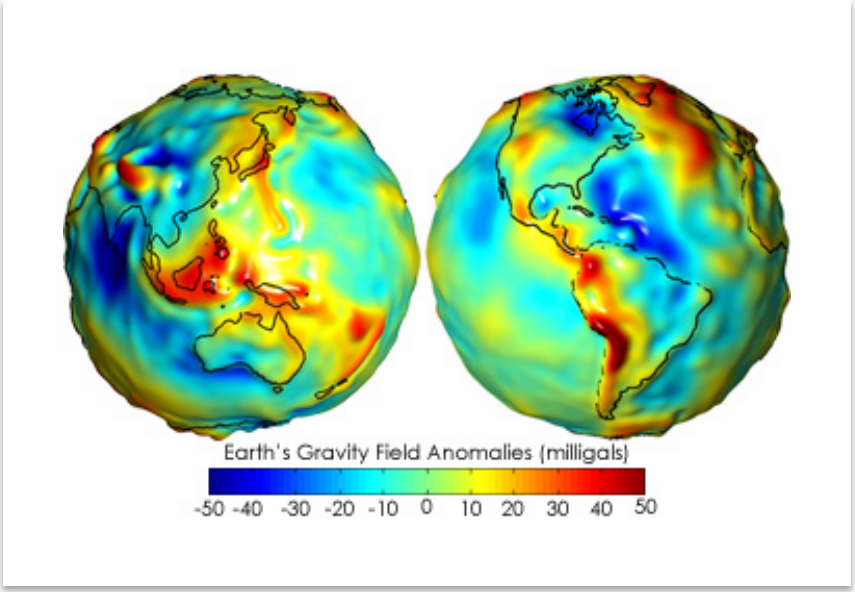
SMAP Swath



GRACE Satellite & Sensors

http://www.jpl.nasa.gov/missions/details.php?id=5882

- Polar, sun-synchronous orbit
- Twin satellite mission
- Spatial Coverage and Resolution:
  - Global
  - Resolution: 150,000 km^2
- Temporal Coverage and Resolution:
  - Mar 17, 2002 – present
  - 250 gravity profiles per day
- Sensors:
  - Microwave k-band ranging instrument
  - Accelerometers
  - Global Positioning System Receivers



Earth System Models

Earth System Models Provide Value-Added Information

Remote Sensing + Surface Observations + Numerical Models

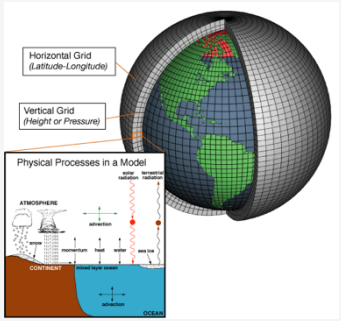
Satellite Data

NASA

Surface Measurements and In-Situ Data

NASA

Numerical Models



NOAA

NASA Models Useful for Water Resources Management

Atmosphere-Ocean-Land Models

- GEOS-5:
  - The Goddard Earth Observing System Version 5
- MERRA:
  - Modern Era Retrospective-Analysis for Research and Application
- GLDAS:
  - Global Land Data Assimilation System

Global & North American Land Data Assimilation Systems

http://ldas.gsfc.nasa.gov

- Integrates ground and satellite observations within numerical models to produce consistent, high resolution fields of land surface states and fluxes
- Uses data from MODIS, TRMM, GOES
- GLDAS and a version of NLDAS use the Land Information System (LIS) with different sources of inputs
  - Meteorological Analysis
  - Surface Solar Radiation
  - Precipitation
  - Soil Texture
  - Vegetation Classification and Leaf Area Index
  - Topography
- Integrated Output for Water Resources
  - Soil Moisture
  - Evapotranspiration
  - Surface/Sub-Surface Runoff
  - Snow Water Equivalent

Satellites and Models

Freshwater Components

- Rain Amount (TRMM, GPM)
- Snow Cover (Terra and Aqua MODIS)
- Soil Moisture (SMAP, GLDAS)
- Evapotranspiration (Terra and Aqua MODIS, Landsat, GLDAS)
- Runoff/Streamflow (TRMM, GPM, GLDAS)

Data Applications

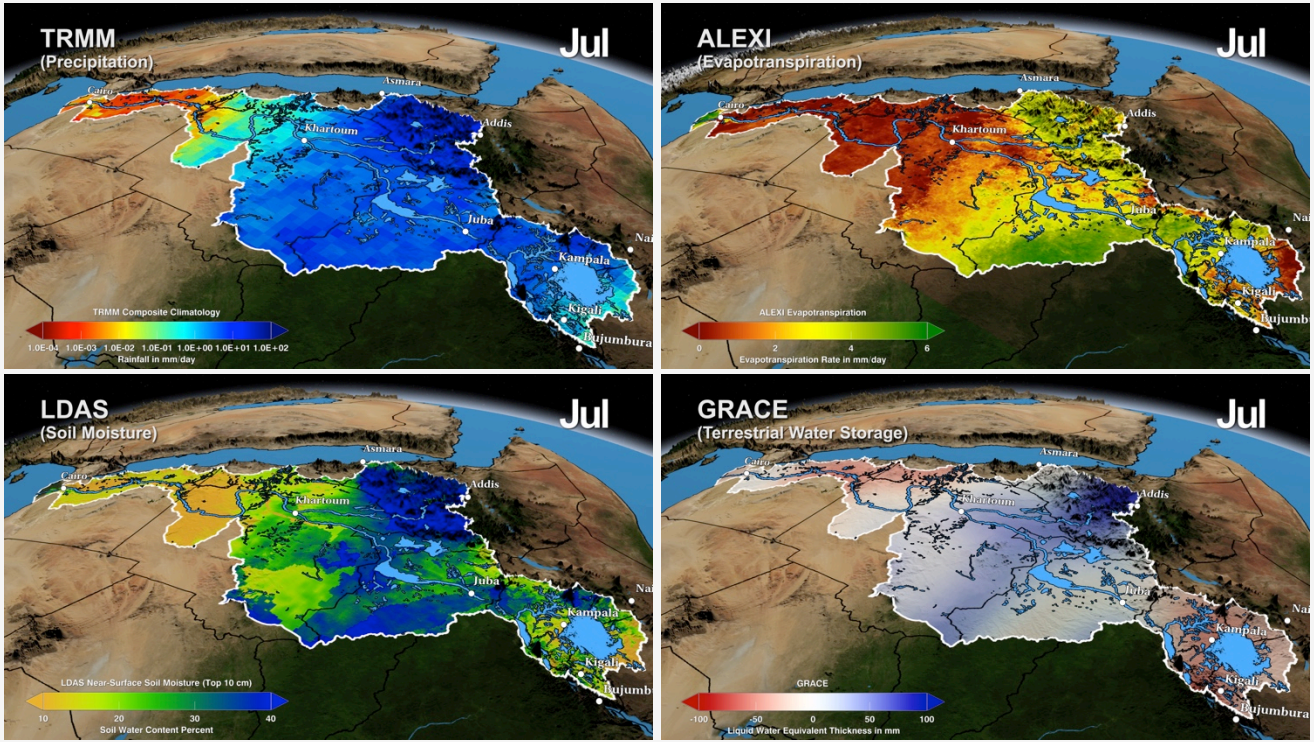
Water Resources Data Applications

Crucial Freshwater Components

Water Allocation	Agricultural & Irrigation Management	Flood & Drought Management	Reservoir & Dam Management
• Water Budget	• Precipitation • Soil Moisture • Evapotranspiration	• Precipitation • Runoff/Streamflow • Soil Moisture • Evapotranspiration • Groundwater	• Reservoir Height • Precipitation • Runoff/Streamflow

Monitoring Water Balance in the Nile Basin

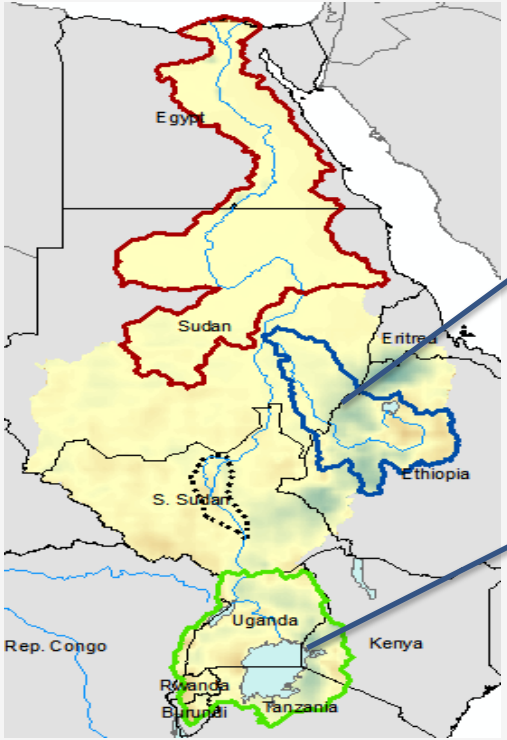
NASA Observations and Modeling Systems Capabilities

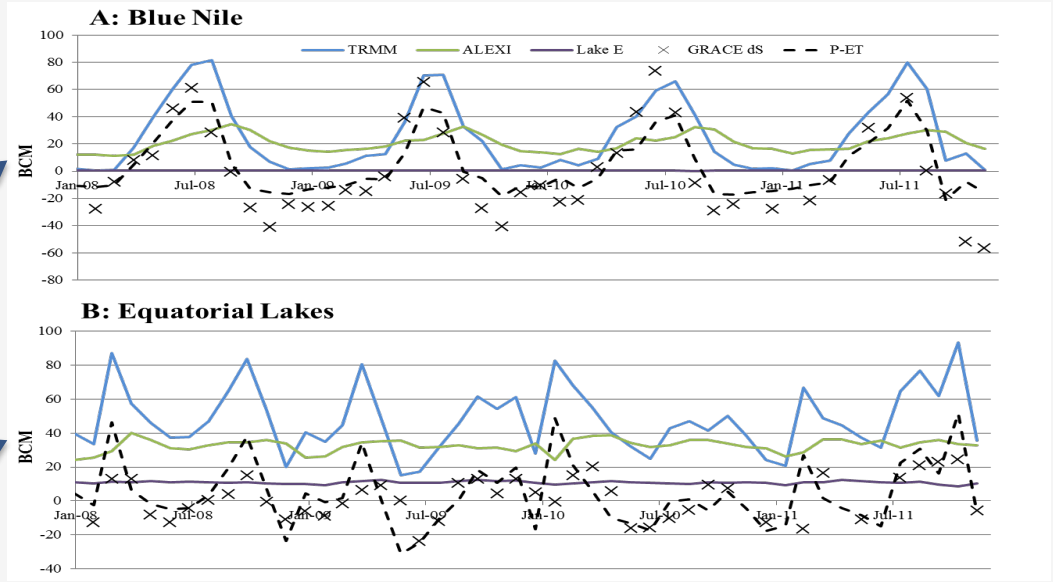


Applied Sciences Project Scientist: Ben Zaitchik (Johns Hopkins University)

Scale Water Balance in the Nile Basin

Based on TRMM, ALEXI, LDAS, and GRACE



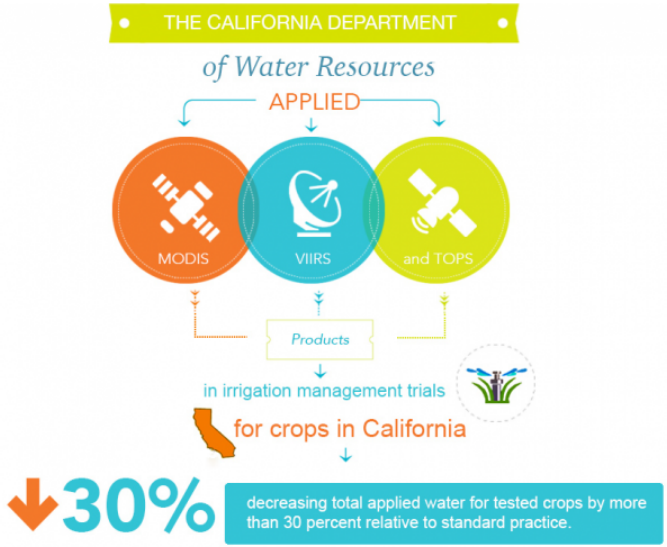


Courtesy of: Ben Zaitchik (Johns Hopkins University)

Irrigation Management Using Satellite-Based ET

Based on the Terrestrial Observation and Prediction System (TOPS)

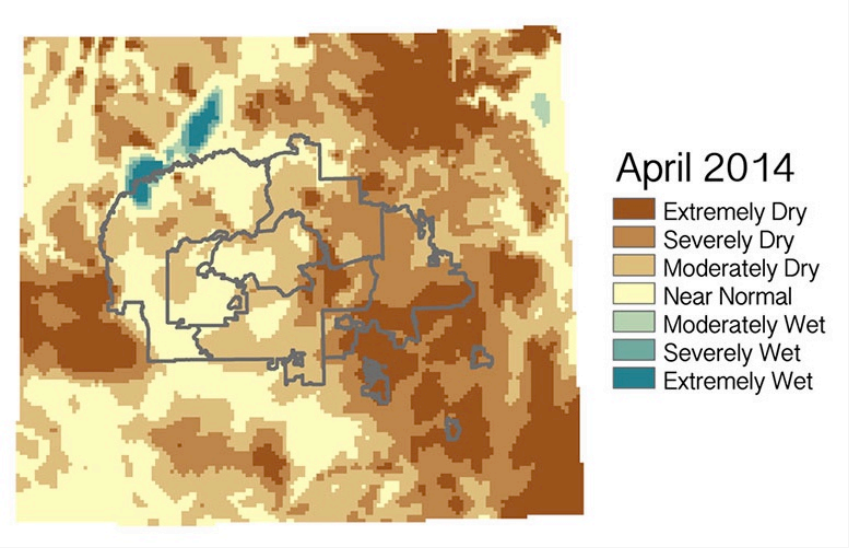
http://ecocast.arc.nasa.gov/dgw/sims



Courtesy of: Forest Melton, NASA ARC-CREST/California State University

Drought Monitoring Decision Support Tool for the Navajo Nation

Based on TRMM and GPM

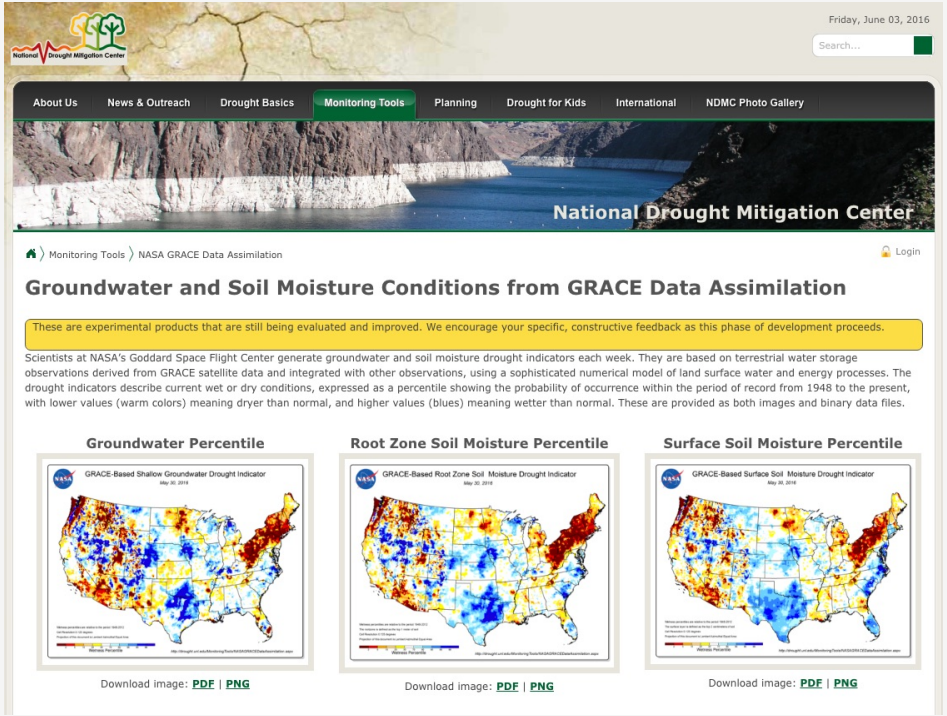


A Drought Monitoring Decision Support Tool for Customized Calculation of a Standardized Precipitation Index Value in the Navajo Nation, 2015 DEVELOP project. Based on precipitation indexes from TRMM and GPM.

- The Navajo Nation has been impacted by
  - Severe droughts
  - Lack of domestic water infrastructure
  - Lack of economic resources
- Roughly 1/3 of population are without access to potable water in their homes
- Created geodatabase of historical climate information specific to the area

National Drought Mitigation Center

Based on GRACE



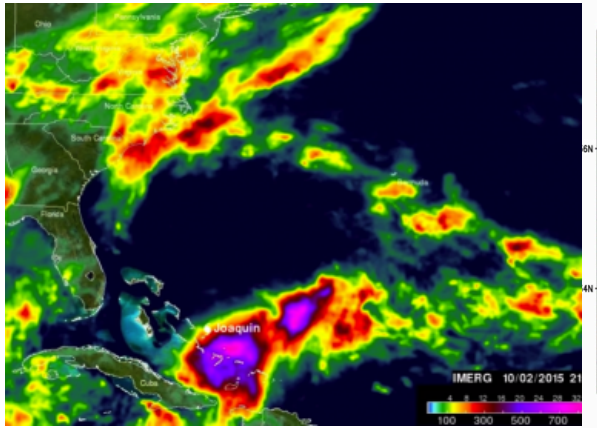
http://drought.unl.edu/MonitoringTools/NASAGRACEDataAssimilation.aspx

- Combines GRACE measurements of water storage with meteorological data
- Generates groundwater and soil moisture percentile maps
- 1948-present

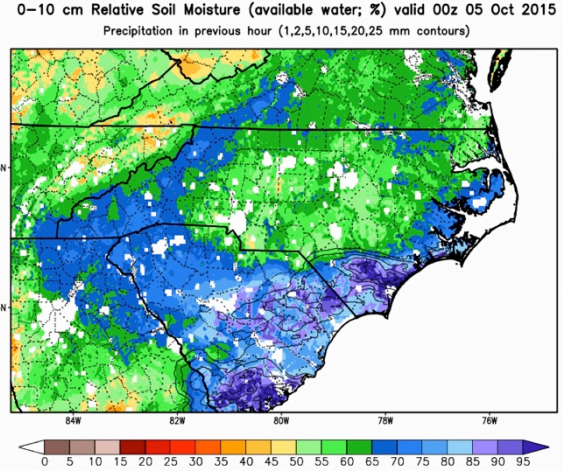
Extreme Precipitation, Relative Soil Moisture, & Flood Detection

Based on GPM and Global Flood Monitoring System (GFMS)

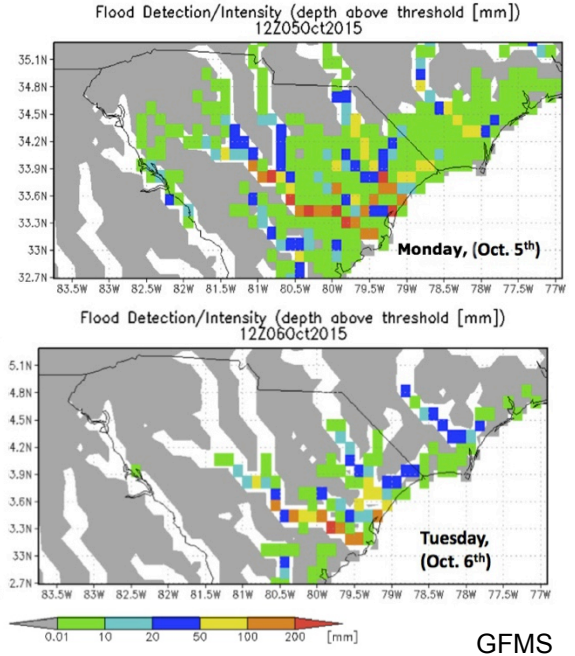
2015 South Carolina Flooding



GPM/IMERG



GFMS



GFMS

Questions

1. What is the different between spatial resolution and spacial coverage?
2. Approximately, what is TRMM’s spatial coverage?
3. What is one benefit of a polar orbiting satellite compared to a geostationary satellite?
4. What is one benefit of a gridded data product compared to an orbital data product?
5. What is one disadvantage of a gridded data product compared to an orbital data product?

Next Presentation:
NASA Web-based Tools for Water Resources Data Access