FOUNDATIONAL COURSE

Satellite Foundational Course for JPSS (SatFC-J)

MICROWAVE

FOUNDATIONAL COURSE

Influence of Clouds and Precipitation

Learning Objectives

1. Understand how microwave sensors provide moisture, cloud properties, and precipitation information against different surface backgrounds (land vs. ocean).

2. Interpret Precipitable Water (TPW, ALPW), Cloud Liquid Water (CLW), Rain Rate (RR), and Snowfall Rate (SFR, mSFR) products from example imagery.

3. Describe how blended microwave and infrared precipitation products are used to improve coverage of significant precipitation events.

MICROWAVE

CONSTELLATION

APPLICATIONS

INITIATIVES

Non-precipitating clouds are transparent

- Microwave detects moisture at all levels
- Infrared can detect moisture at different levels, but only in cloud-free regions

Total Precipitable Water (TPW)

- Definition:

  Liquid water equivalent if all the *water vapor* within a column of the atmosphere were condensed.
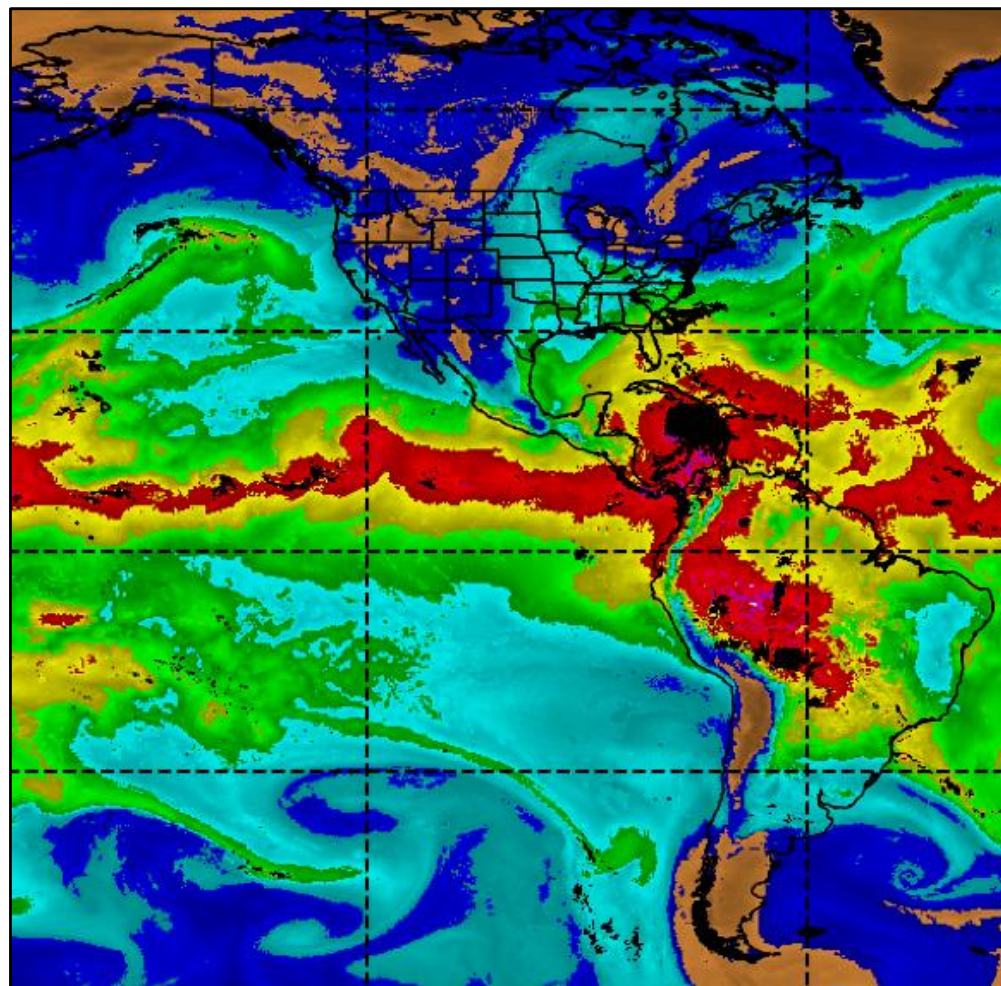
- Observation Region:
  - global, over the oceans
  - excluding areas of precipitation

- Observation Range:

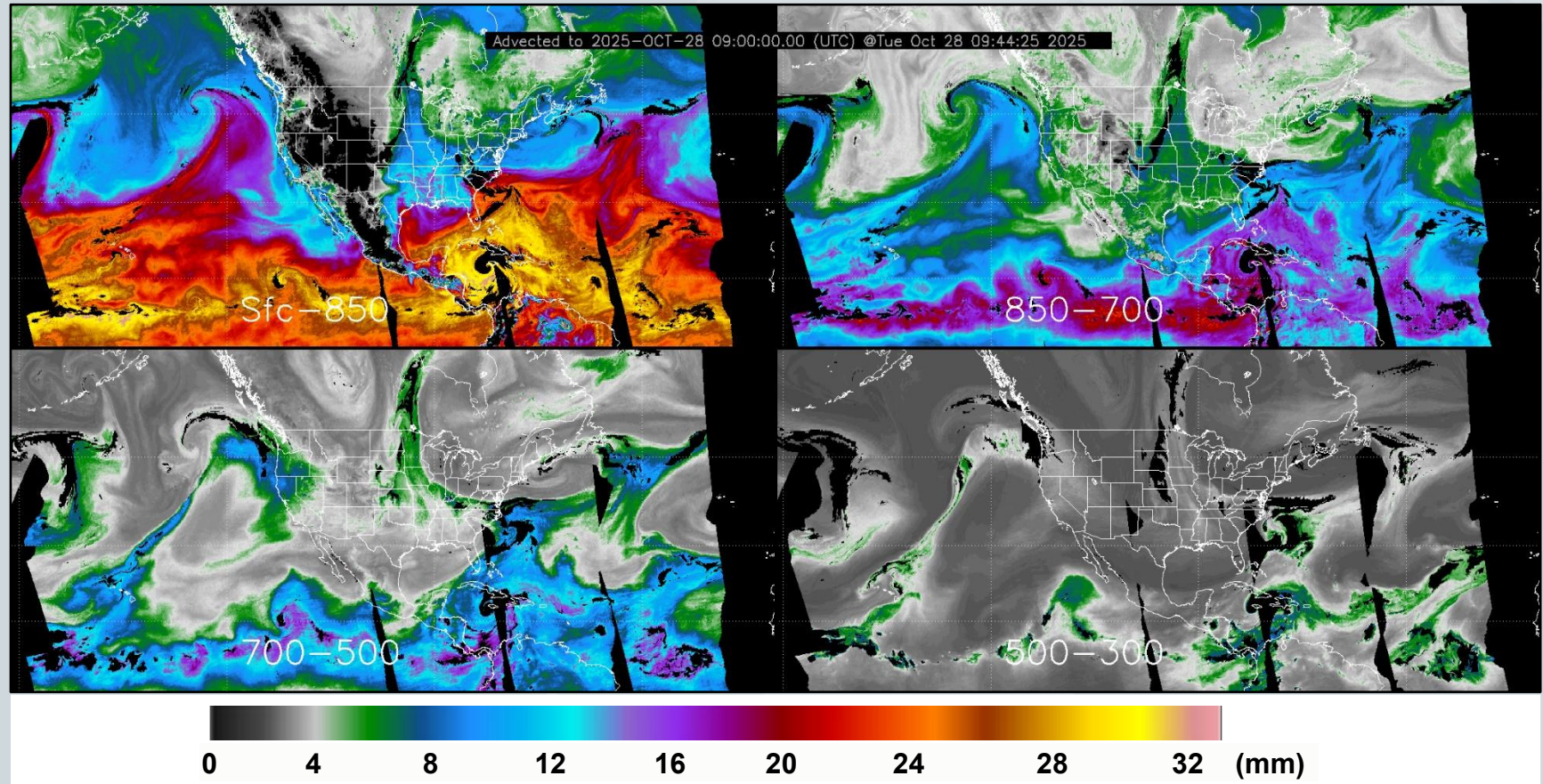 0-75 mm

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Blended TPW

- POES microwave data, GOES data, and GPS data (land)

- Observation Region:
  - global, excluding areas of precipitation

Blended Total Precipitable Water: 2025/10/27

| 0 | 15 | 30 | 45 | 60 | 75 (mm) |

AMSR-2 Product Maps: https://www.ospo.noaa.gov/products/suites/gaasp/maps.html?GPLCT#gpdsMaps
Blended TPW: https://www.ospo.noaa.gov/products/bTPW/Overview.html

Advected Layered Precipitable Water (ALPW)

- Vertical Layers: surface-850 mb, 850-700 mb, 700-500 mb, 500-300 mb
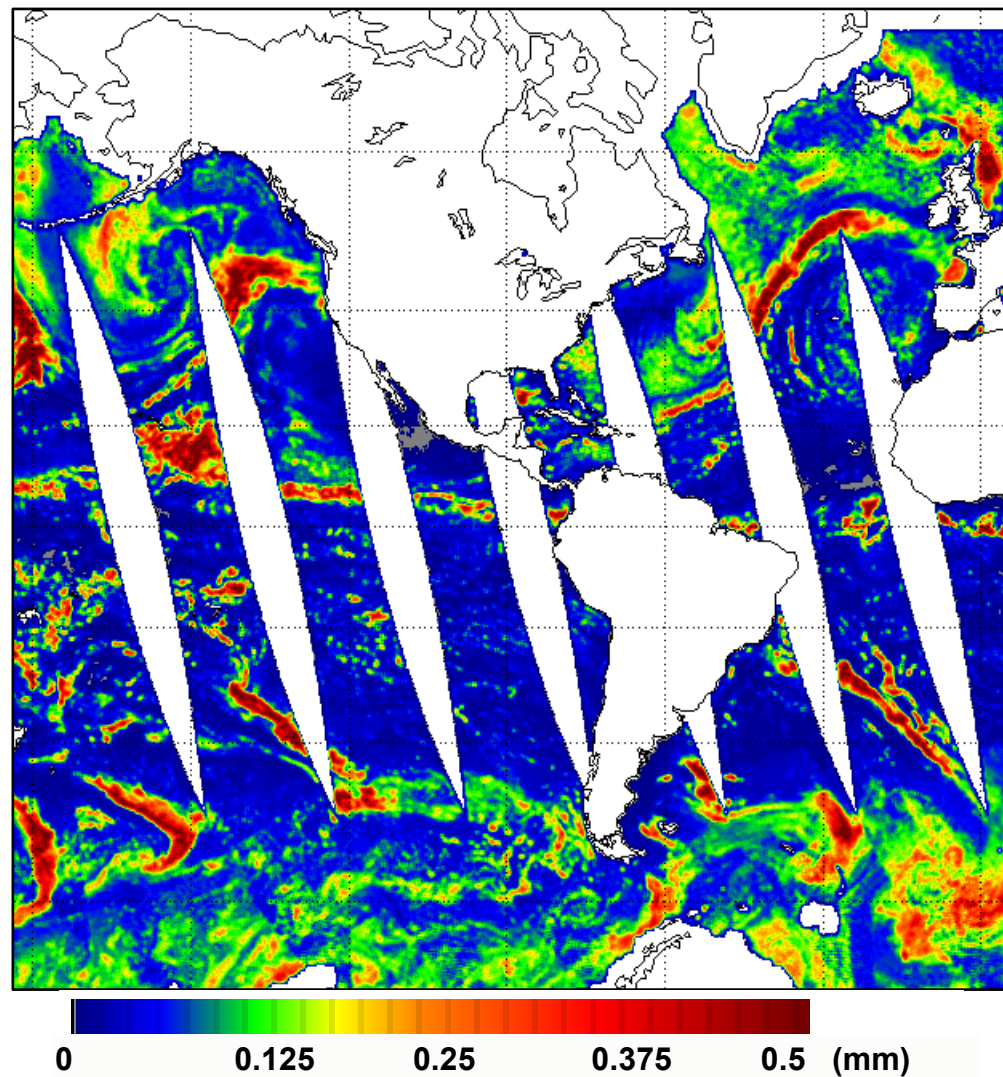- Observation Region: global, excluding areas of precipitation

CIRA: https://cat.cira.colostate.edu/SPoRT/Layered/Advected/ALPW_Hourly.htm
NOAA OSPO: https://www.ospo.noaa.gov/products/atmosphere/alpw/

Cloud Liquid Water (CLW)

▪ Definition:

Depth of water if all the **cloud droplets** were accumulated within a column of the atmosphere

▪ Observation Region:

– global, over the oceans
– excluding areas of sea ice and precipitation
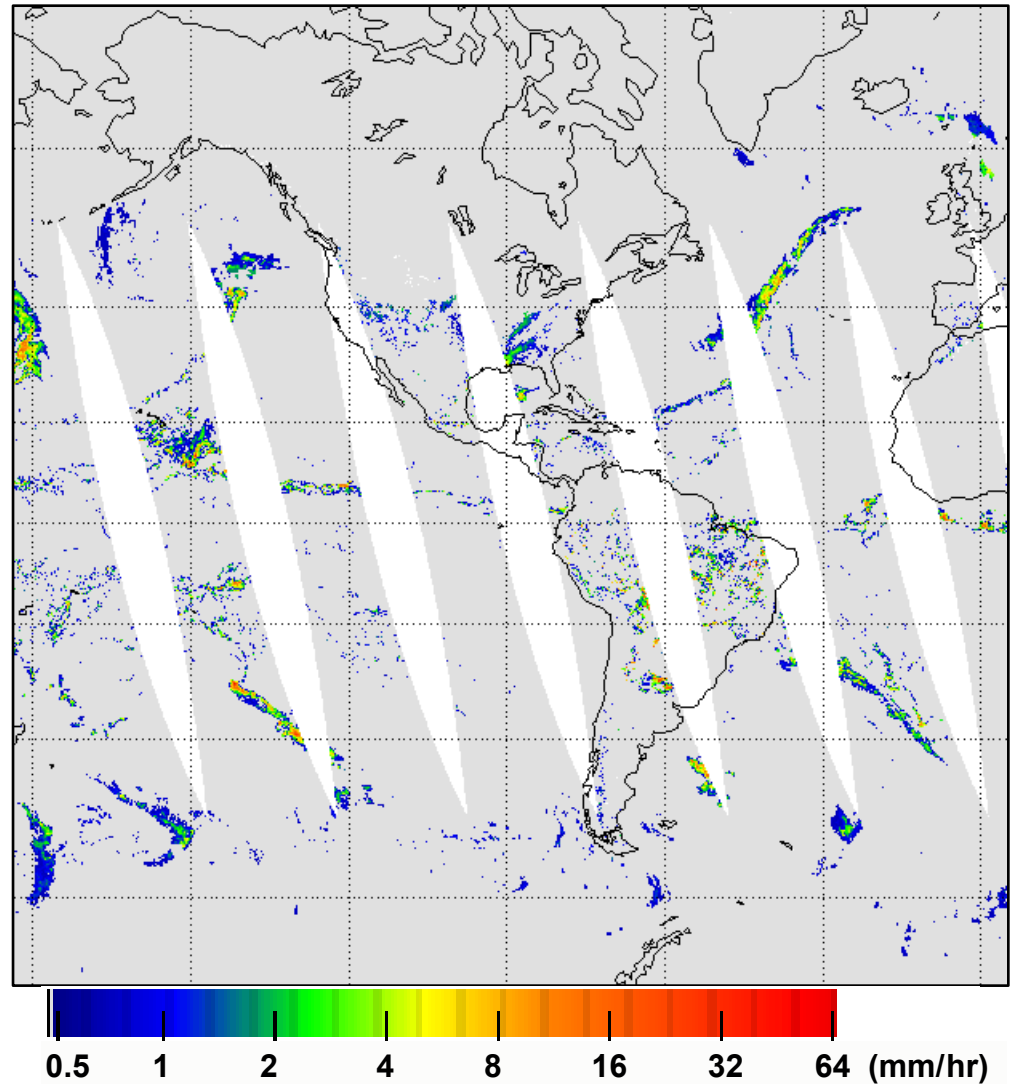
▪ Observation Range:

0-1.0 mm

NOAA Operational GCOM-W1 AMSR-2 Product Maps
https://www.ospo.noaa.gov/products/suites/gaasp/maps.html?GPLCT#gpdsMaps

AMSR-2 Cloud Liquid Water: 2018/01/27

| 0 | 0.125 | 0.25 | 0.375 | 0.5 (mm) |

Rain Rate (RR)

- Definition:
  Depth of hourly rainfall at the ground surface

- Observation Region:
  - tropical to mid-latitude
  - higher accuracy over ocean than over land

- Observation Range:
  0-50 mm/hr

AMSR-2 Rain Rate: 2018/01/27

0.5   1   2   4   8   16   32   64   (mm/hr)

NOAA Operational GCOM-W1 AMSR-2 Product Maps
https://www.ospo.noaa.gov/products/suites/gaasp/maps.html?GPLCT#gpdsMaps
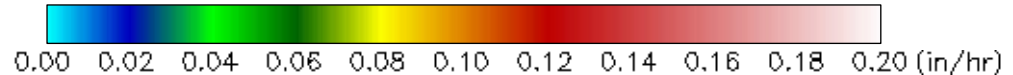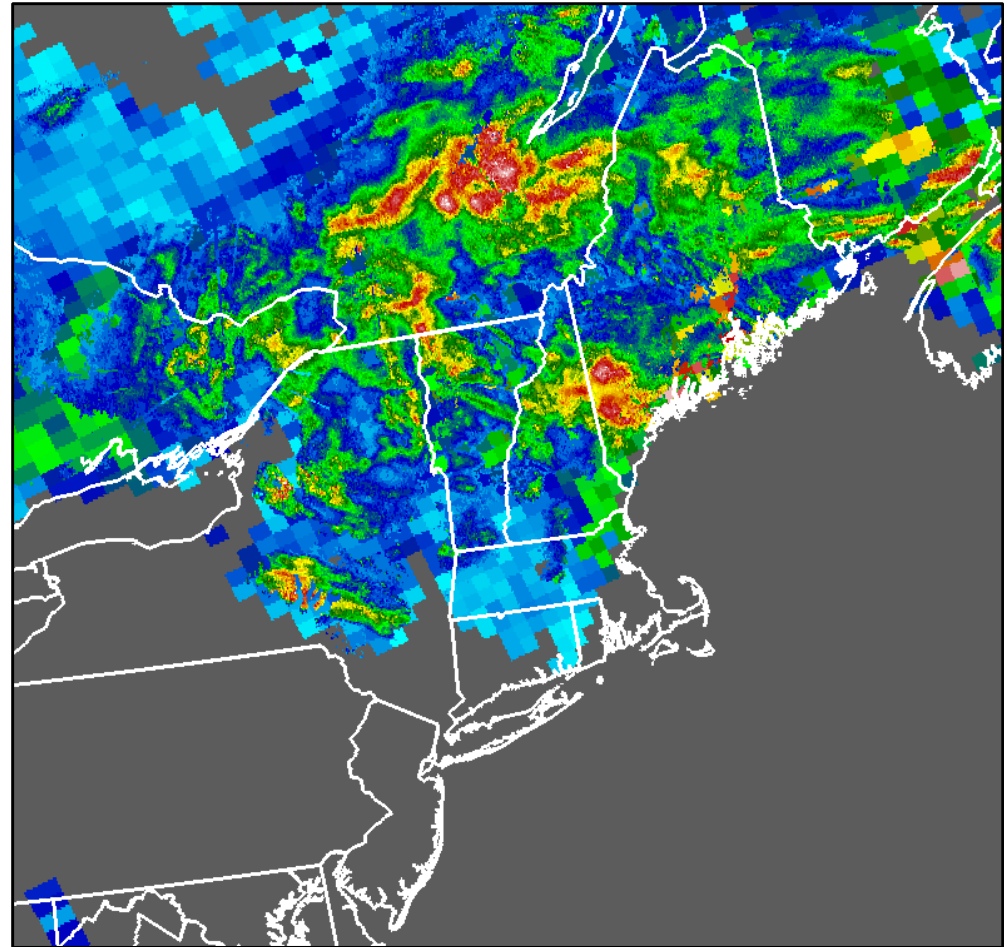
Snowfall Rate (SFR)

- Definition:

    Instantaneous liquid equivalent snowfall rate

- Observation Region:

    Global coverage

- Observation Range:

    0.00079 - 0.39 in/hr (liquid)

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merged Snowfall Rate (mSFR)

- Merges SFR and MRMS instantaneous snowfall rate
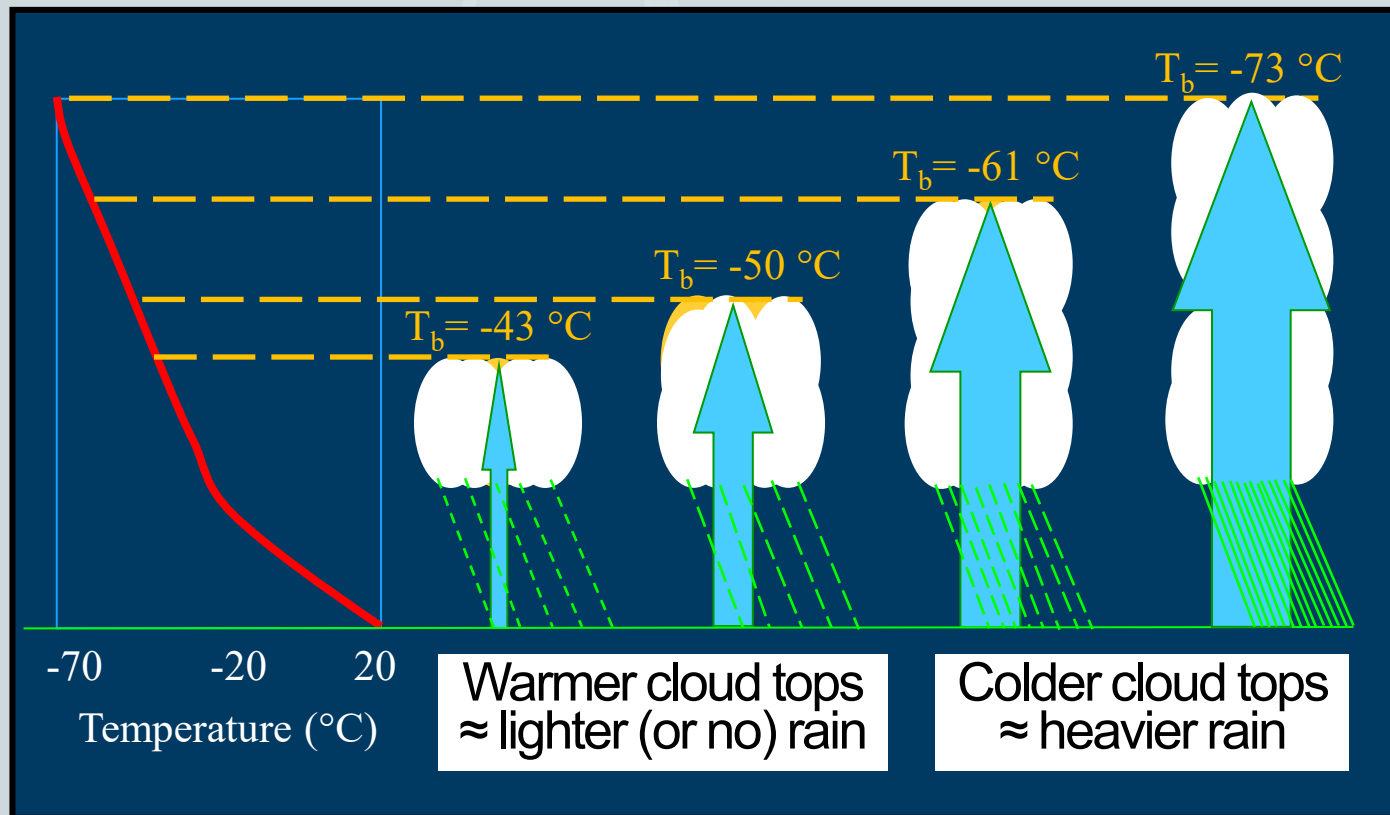
- Observation Region:

    CONUS

POES Snowfall Rate: 2024/04/04 17:55Z

0.00 0.02 0.04 0.06 0.08 0.10 0.12 0.14 0.16 0.18 0.20 (in/hr)

https://sfr.umd.edu/
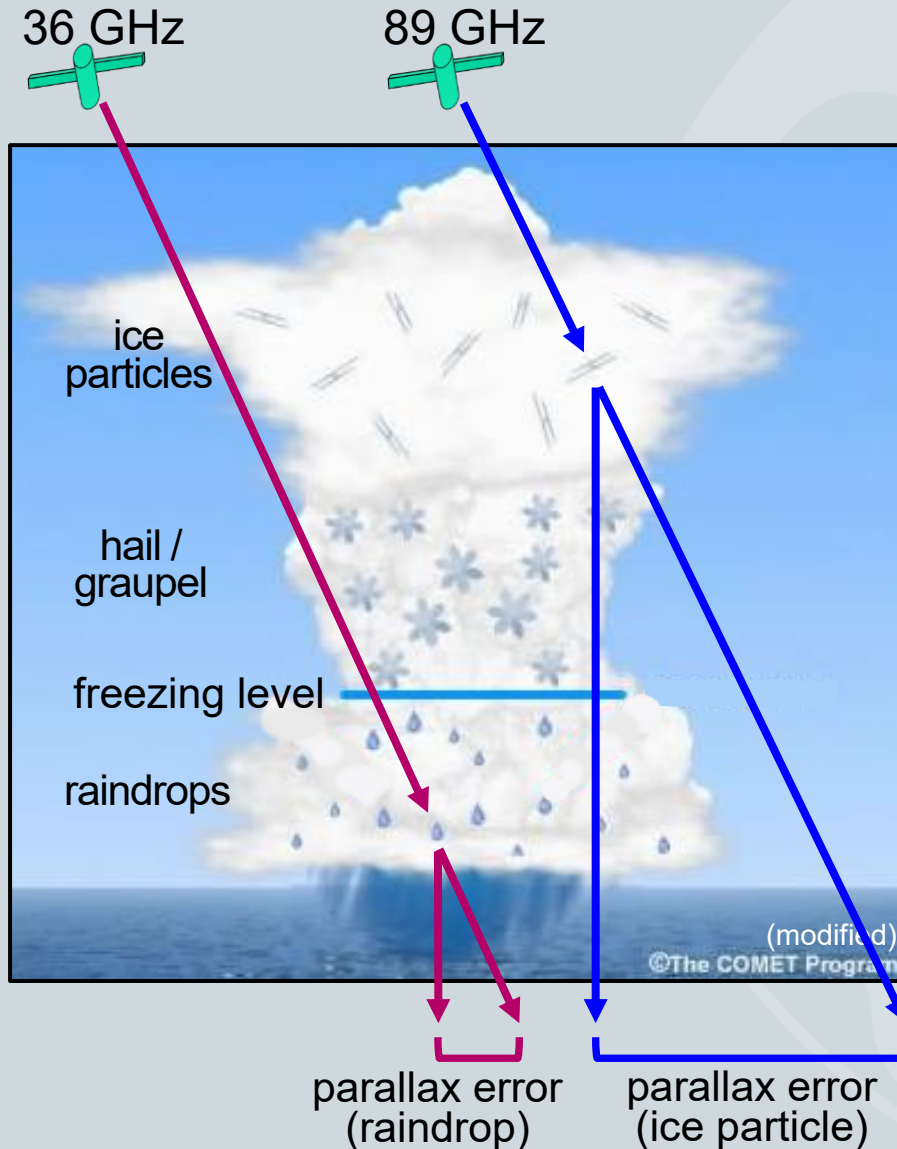
Rain Rate from Infrared

Basic assumptions for opaque mid-latitude clouds:

- Cloud-top temperature (IR) is related to cloud-top height
- Cloud-top height is related to the strength of the updraft and rain rate

T_b= -73 °C

T_b= -61 °C

T_b= -50 °C

T_b= -43 °C

-70   -20   20

Temperature (°C)

Warmer cloud tops ≈ lighter (or no) rain

Colder cloud tops ≈ heavier rain

SatFC-G: GOES-R Rainfall Rate product (modified)

Microwave Interaction with Rain Cloud

36 GHz 89 GHz

ice particles

hail / graupel

freezing level

raindrops

(modified)
©The COMET Program

parallax error (raindrop)   parallax error (ice particle)

Ice particles

- Scattering
- Higher frequencies (> 60 GHz)

Liquid raindrops

- Absorption / emission
- Lower frequencies (< 22 GHz)

Displacement due to viewing geometry (parallax error) is greater for ice than for raindrops.
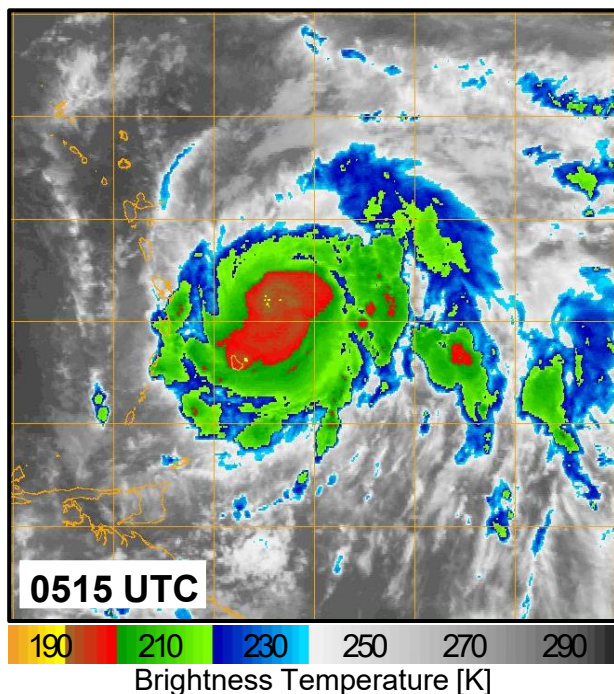
Tropical Cyclone Analysis

- The low-level center and convective rain bands directly related to tropical cyclone intensity are often obscured by high clouds in visible, infrared, and water vapor imagery

- ~36 GHz able to sense clouds and moisture close to the surface
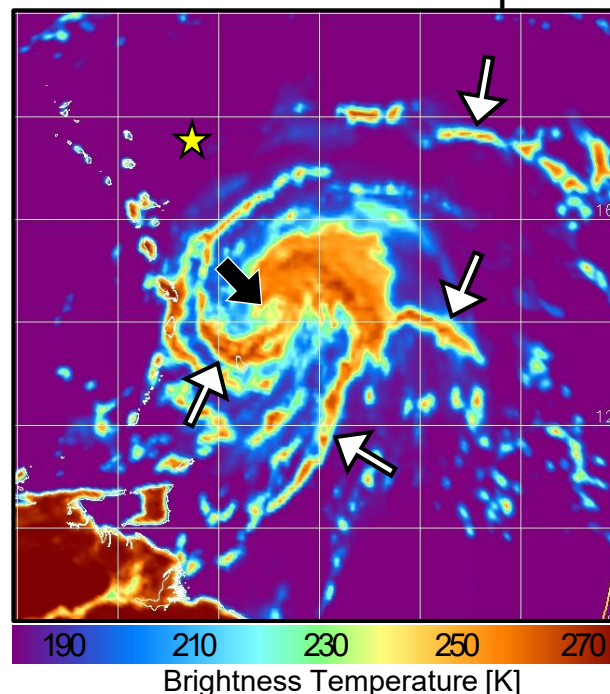
- ~89 GHz sensitive to both rain and ice rates

https://science.nrlmry.navy.mil/geoips/tcweb4/
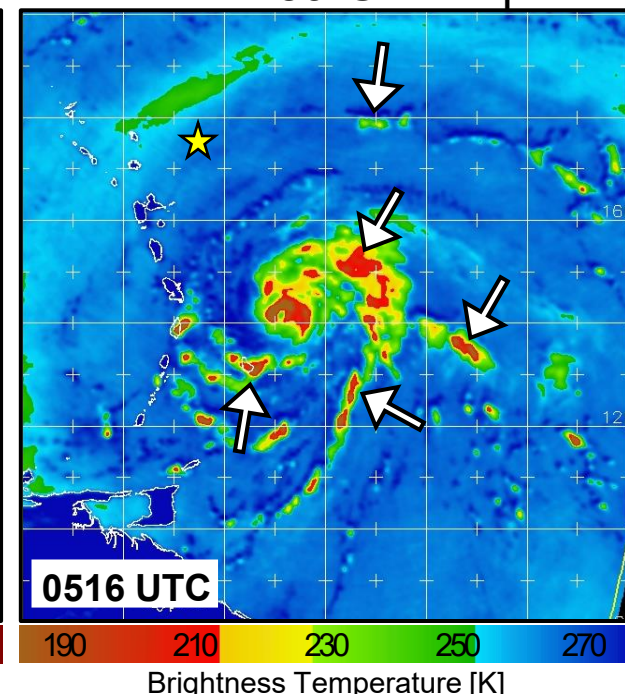
Hurricane Maria: 18 September 2017

GOES-13 Infrared

AMSR-2 36 GHz H-pol

AMSR-2 89 GHz H-pol

0515 UTC

0516 UTC

190 210 230 250 270 290
Brightness Temperature [K]

190 210 230 250 270
Brightness Temperature [K]

190 210 230 250 270
Brightness Temperature [K]

Thunderstorms

- Precipitating clouds are not transparent

What makes brightness temperatures cooler over land surfaces?

36 GHz:
- rain and wet ground
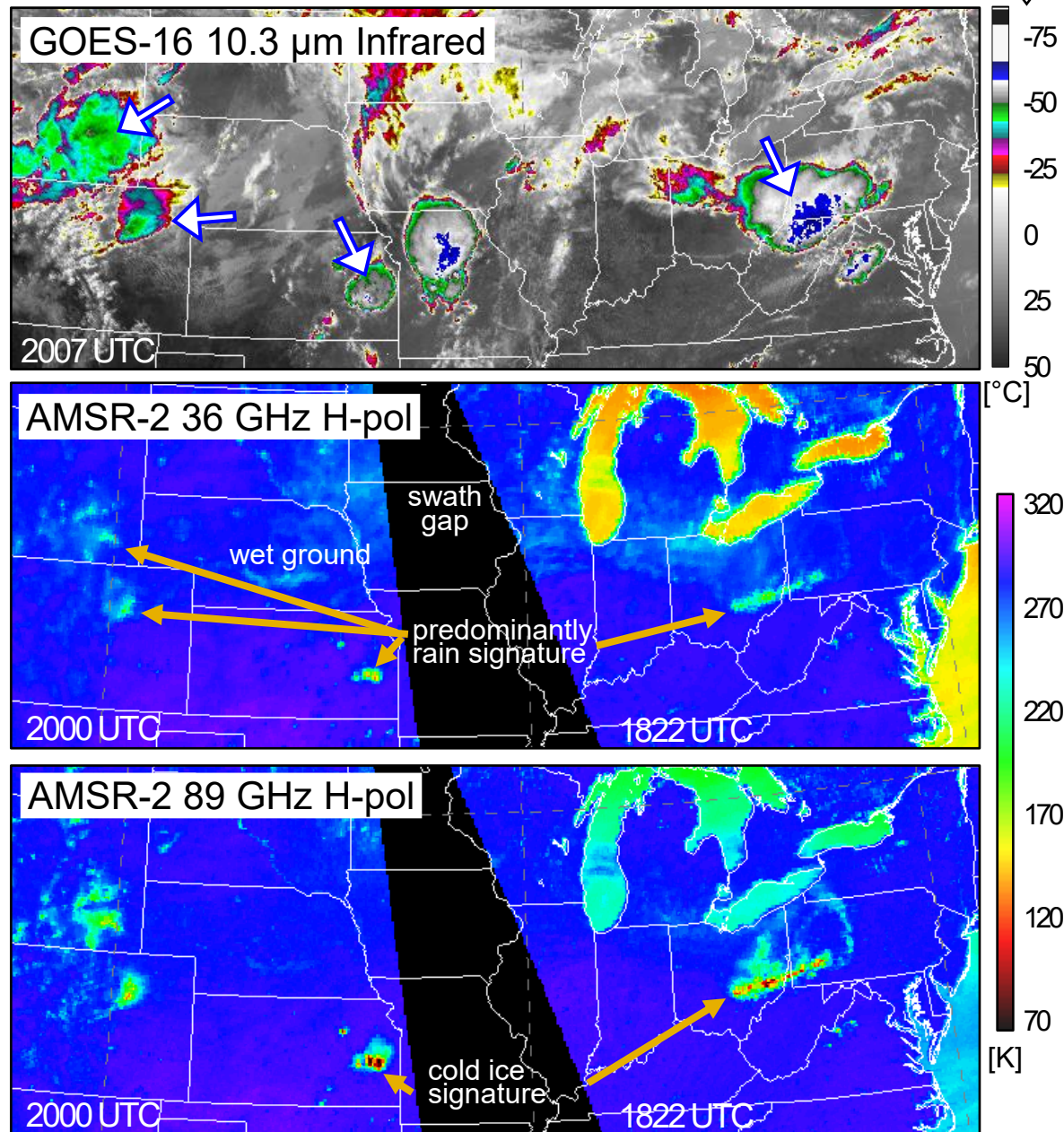
89 GHz:
- rain, ice, and wet ground

14 May 2018

Brightness Temperature

GOES-16 10.3 μm Infrared

2007 UTC

[°C]

AMSR-2 36 GHz H-pol

swath gap

wet ground

predominantly rain signature

2000 UTC

1822 UTC

[K]

AMSR-2 89 GHz H-pol

cold ice signature

2000 UTC

1822 UTC

Summary

- Microwave products related to atmospheric moisture include:
  - Precipitable Water products
  - Cloud Liquid Water
  - Rain Rate
  - Snowfall Rate products

- The best precipitation estimation algorithms use a combination of:
  - infrared data from geostationary satellites (temporal advantage)
  - microwave data from polar-orbiting satellites (higher accuracy)

- Precipitation estimation is more reliable over the ocean, which provides a cold contrasting background.

MICROWAVE

CONSTELLATION

APPLICATIONS

INITIATIVES

Resources

- Microwave Remote Sensing: Applications for Water Vapor, Clouds and Precipitation https://learn.meted.ucar.edu/#/online-courses/6aaf6d26-1b18-4bc9-8834-3627d41ae826

- A First Course in Atmospheric Radiation, 2nd Ed. (Petty 2006)

- SatFC-G: GOES-R Rainfall Rate http://rammb.cira.colostate.edu/training/visit/training_sessions/goes_r_rainfall_rate/

- Product Quick Guides: https://rammb2.cira.colostate.edu/training/visit/quick_reference/

Questions? Email: CIRA_Training@colostate.edu

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