National Aeronautics and Space Administration

EARTHDATA

Examining Hurricane Milton's Milestones with NASA's GES DISC Datasets

January 29, 2025

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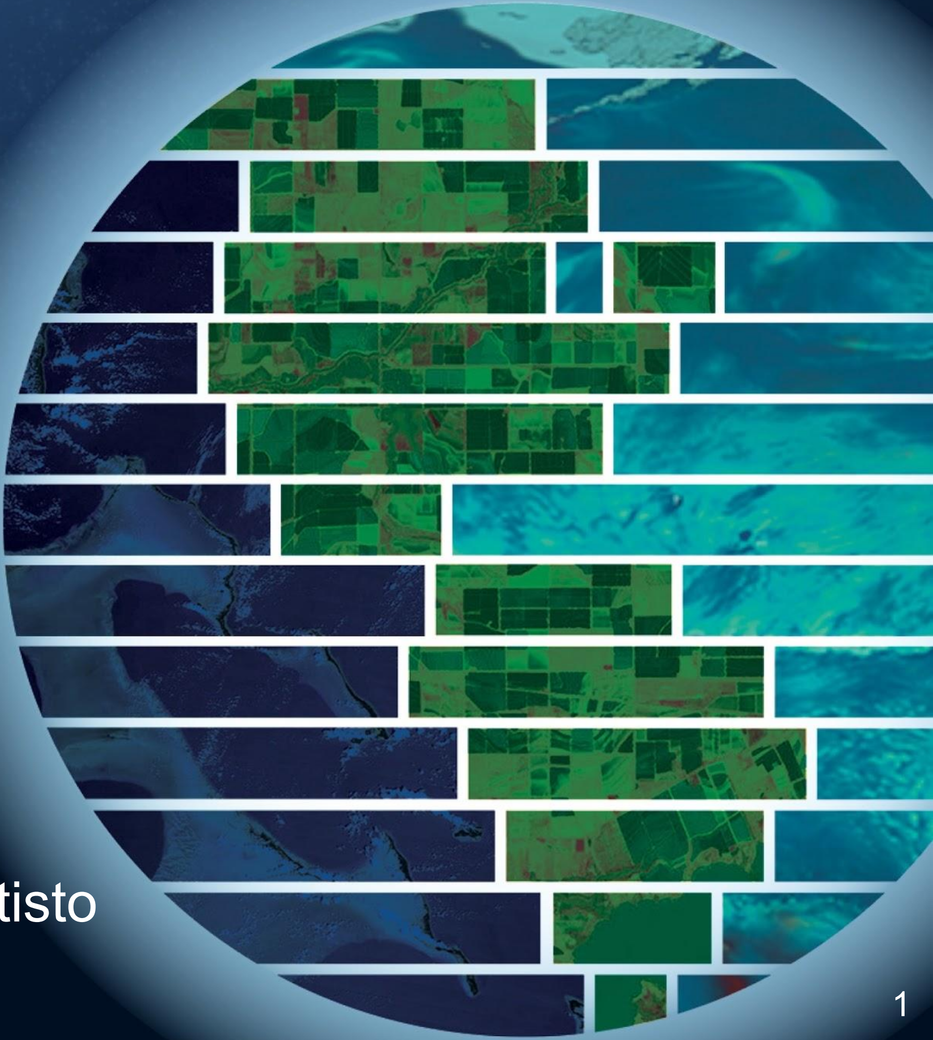
NASA GES DISC



Hurricane Milton’s Milestones

Oct. 5	Oct. 6	Oct. 7	Oct. 8	Oct. 9	Oct. 10	Oct. 11	Oct. 12	Oct. 13
Trop. Depression	Tropical Storm	Category 1-5	Category 5	Landfall as Cat. 3	←	Extratropical Cyclone	→	Dissipated

- **Fastest intensification**

Milton's wind speeds increased from 35 mph to 160 mph in just 49 hours, the fastest recorded increase for a hurricane.

- **Lowest pressure**

Milton's central pressure of 897 millibars made it the fifth most intense Atlantic hurricane on record.

- **Most tornadoes in Florida**

Milton spawned at least 45 tornadoes in Florida, the most of any modern Florida tornado outbreak.

- **Most rain in Tampa**

Tampa International Airport recorded 11.73 inches of rain, and St. Petersburg saw nearly 19 inches, a monthly record.

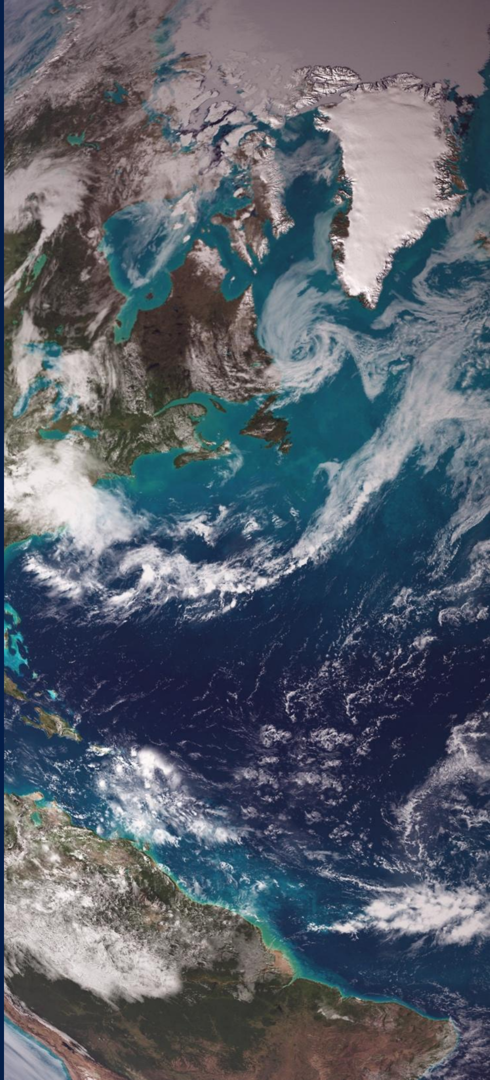
- **Most tornado warnings in Florida in a day**

Milton triggered more than 100 tornado warnings across the state in a single day.

Hurricane Milton Use Case

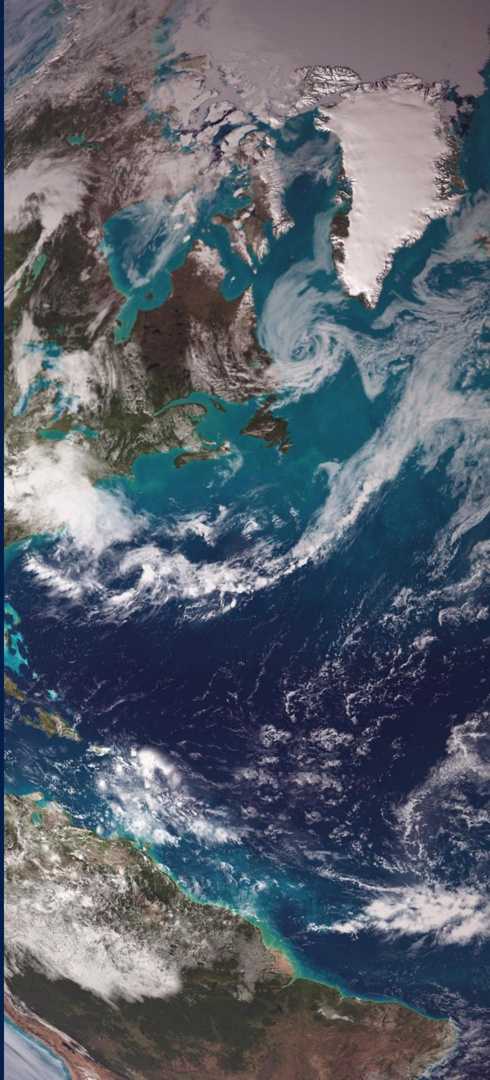
In early October 2024, a tropical low-pressure system originating west of the Yucatan Peninsula intensified very rapidly into a Category 5 hurricane, named “Milton”. Milton was immediately recognized as a dangerous threat to the state of Florida.

In this webinar, several datasets available at the NASA Goddard Earth Sciences Data and Information Services Center (GES DISC), including data from the innovative TROPICS mission, will be used to examine what caused Milton to be a remarkable, record-setting hurricane, and some of its effects on the Sunshine State.



Webinar Agenda

- Introduction and Context ♦ The Oceanographic Environment ♦ Milton's Track, Intensification, and Landfall ♦ After effects on the Gulf
- The TROPICS Mission ♦ Uses and Users of TROPICS Data ♦ Why Use TROPICS Data to Observe Milton? ♦ Data Views of Milton
- Water Impacts on Florida from Milton
- Jupyter Notebook Demonstration ♦ Methods for Data Access and Quality Flagging ♦ A Jupyter Notebook Accompanying the Data Shown in the Presentation
- Conclusions and More Information



History of Hurricane Milton

In early October 2024, a disorganized tropical low pressure system formed in the between the Mexican coast and the Yucatan Peninsula.

Weather models quickly indicated this system would be a serious threat to Florida.

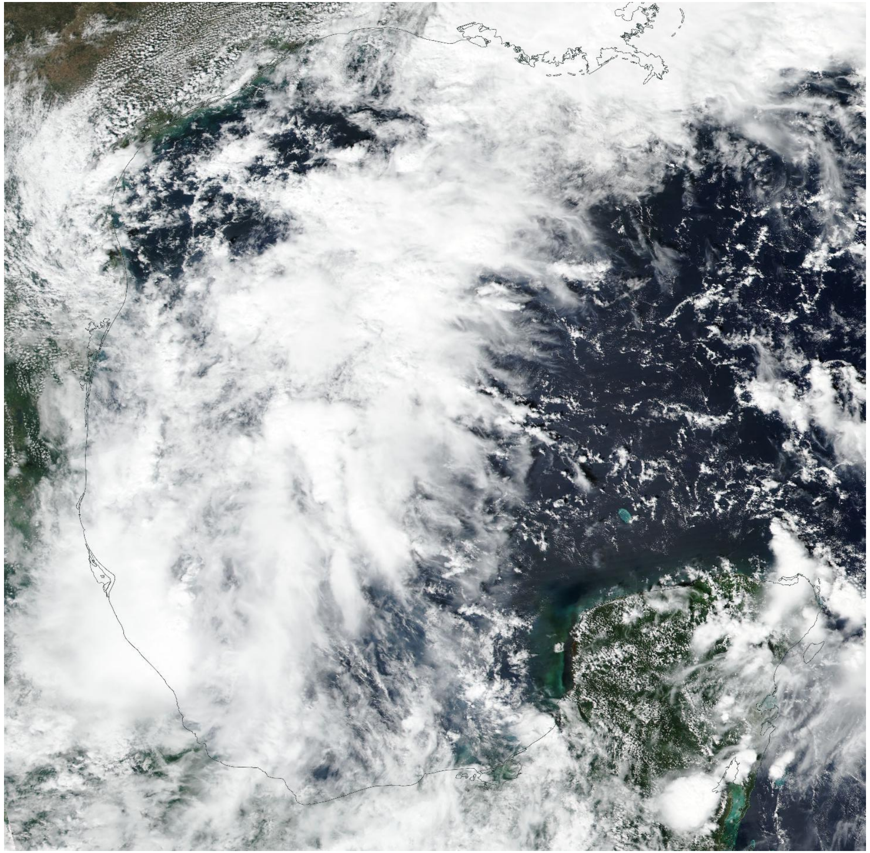


Image courtesy of Worldview, worldview.earthdata.nasa.gov. Remote-sensing data is from the Moderate Resolution Imaging Spectroradiometer (MODIS) and the Visible Infrared Imaging Radiometer Suite (VIIRS), October 4, 2024

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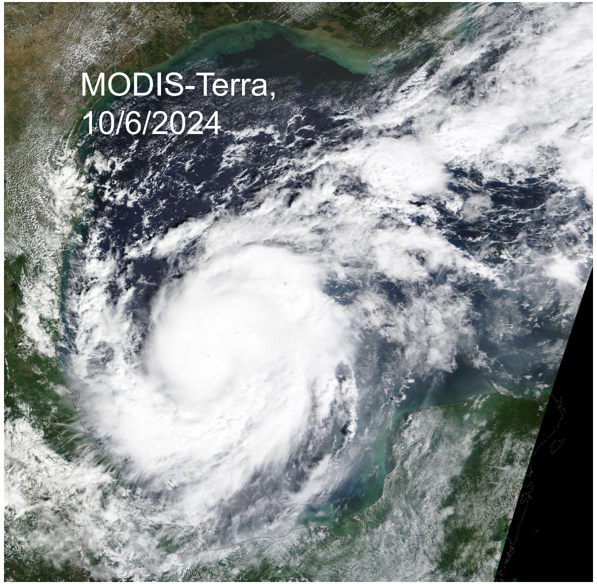
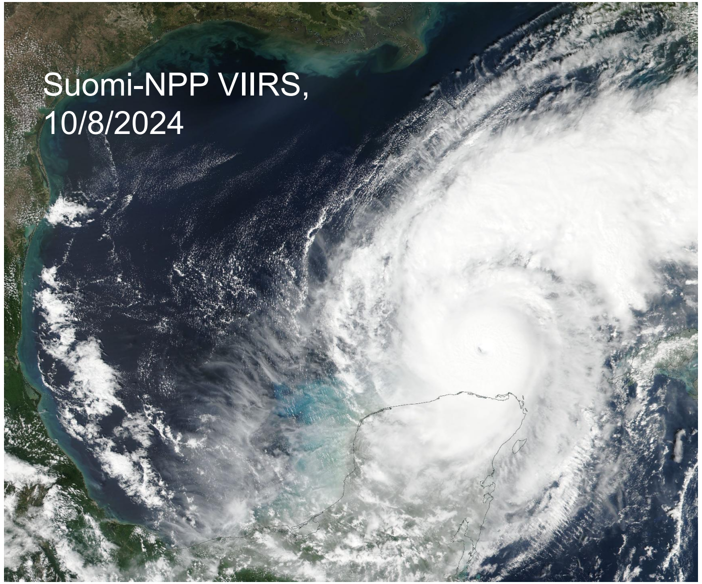
History of Hurricane Milton

Due to favorable conditions, this system became a Category 5 storm, intensifying from a tropical storm to Cat 5 *in 49 hours*.





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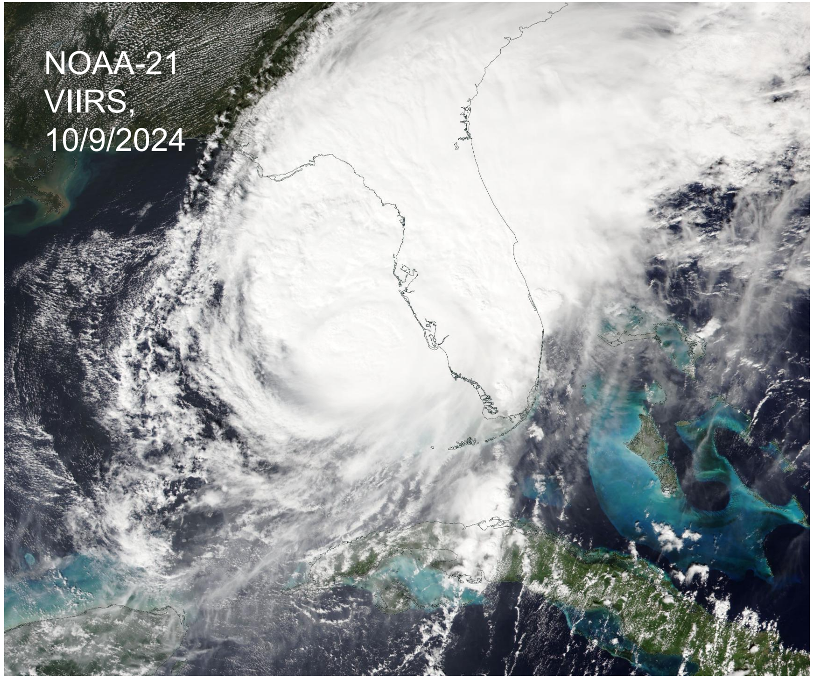
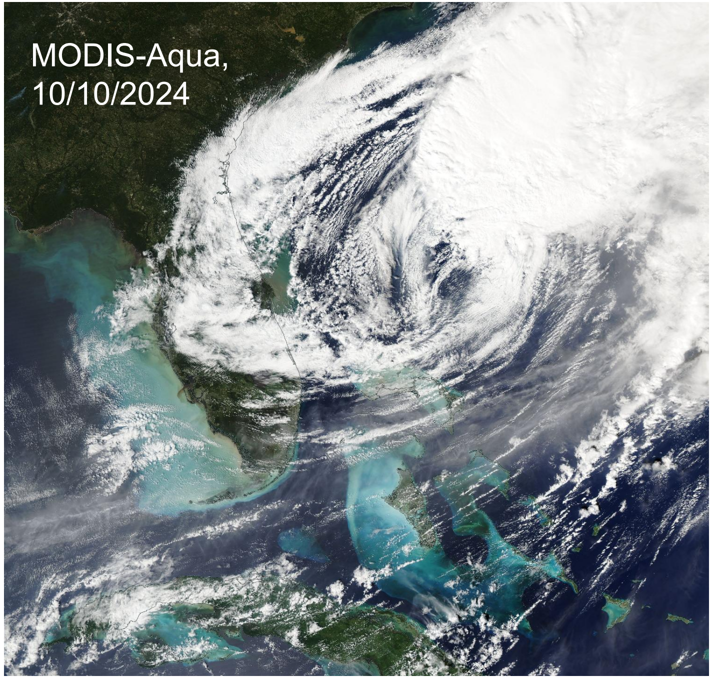
History of Hurricane Milton



On October 9, 2024, Milton struck the west coast of Florida, fortunately as a slightly weaker storm, and just south of the entrance to Tampa Bay, reducing the potential storm surge. Flooding and damage was still significant. The next day, it was gone.



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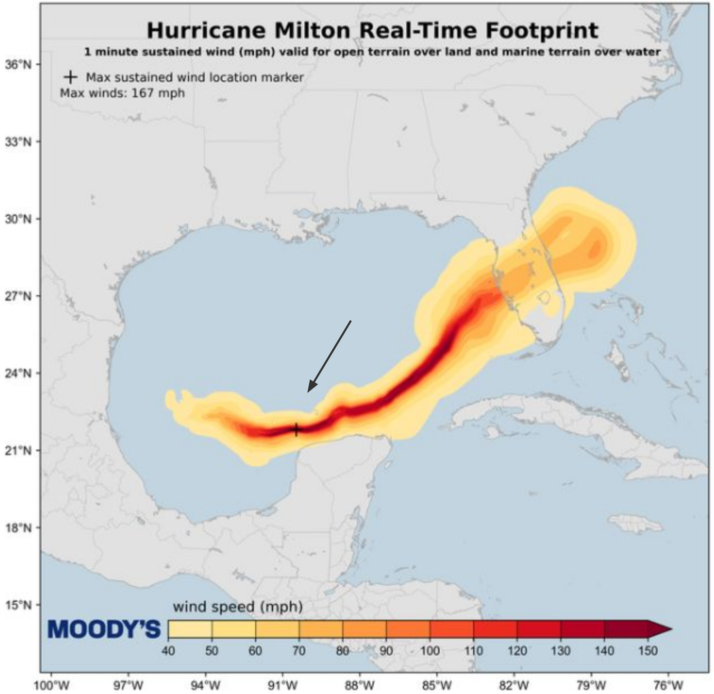
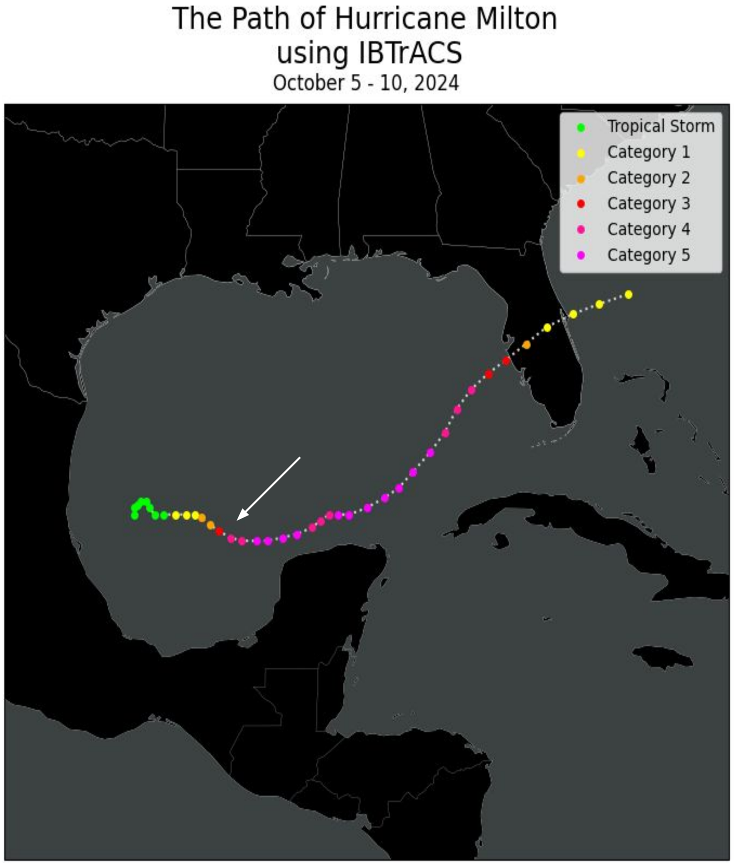
Milton's Wind History



Source: [Moody's Hurricane Milton Live Blog]()



Source: [International Best Track Archive for Climate Stewardship (IBTrACS)]()

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Tropicana Field, Before and After Milton

(Left) MAXAR satellite image (Right) Aerial view, Imagn Imaging from *The Sporting News*

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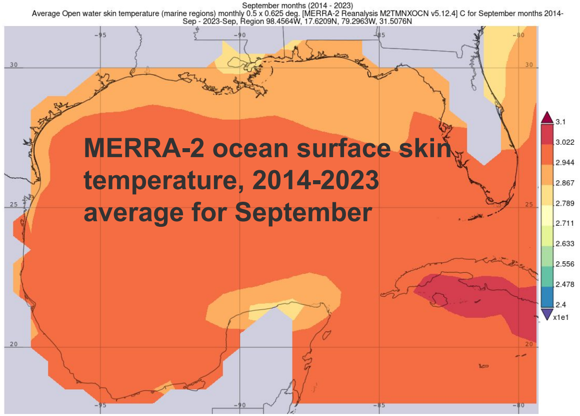
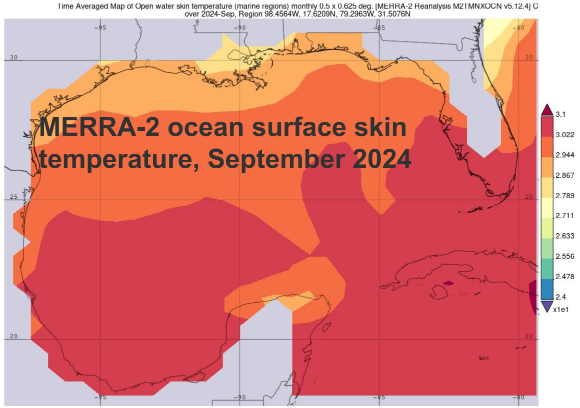
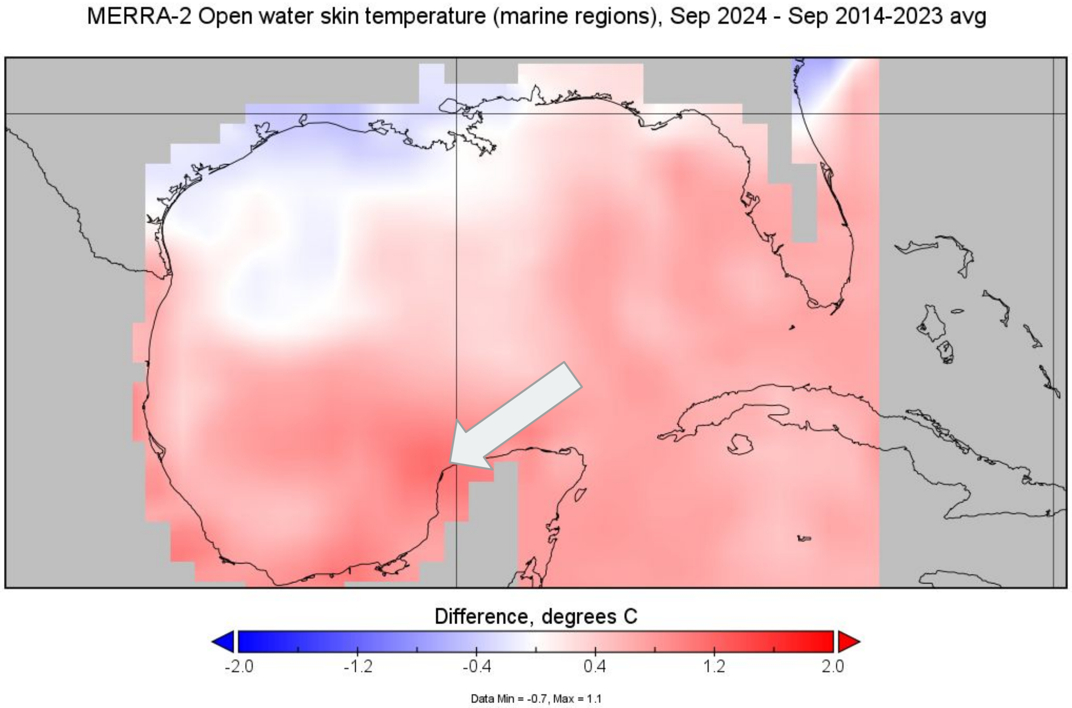
Favorable Environment for Intensification







Images created with Giovanni, giovanni.gsfc.nasa.gov and Panoply, https://www.giss.nasa.gov/tools/panoply/

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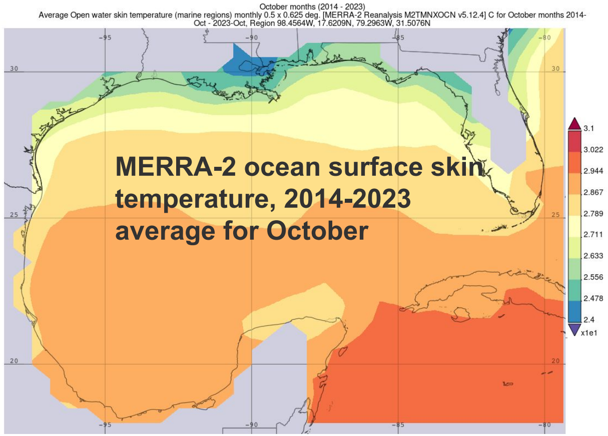
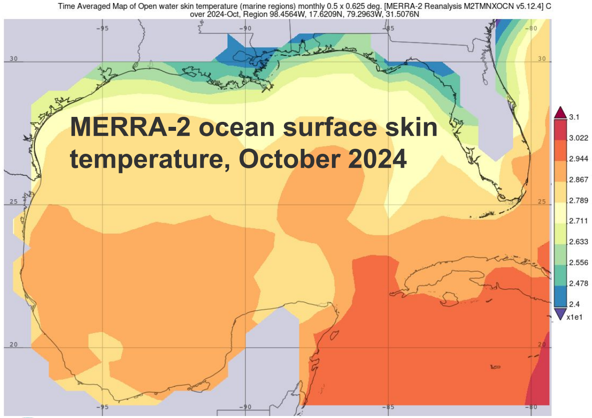
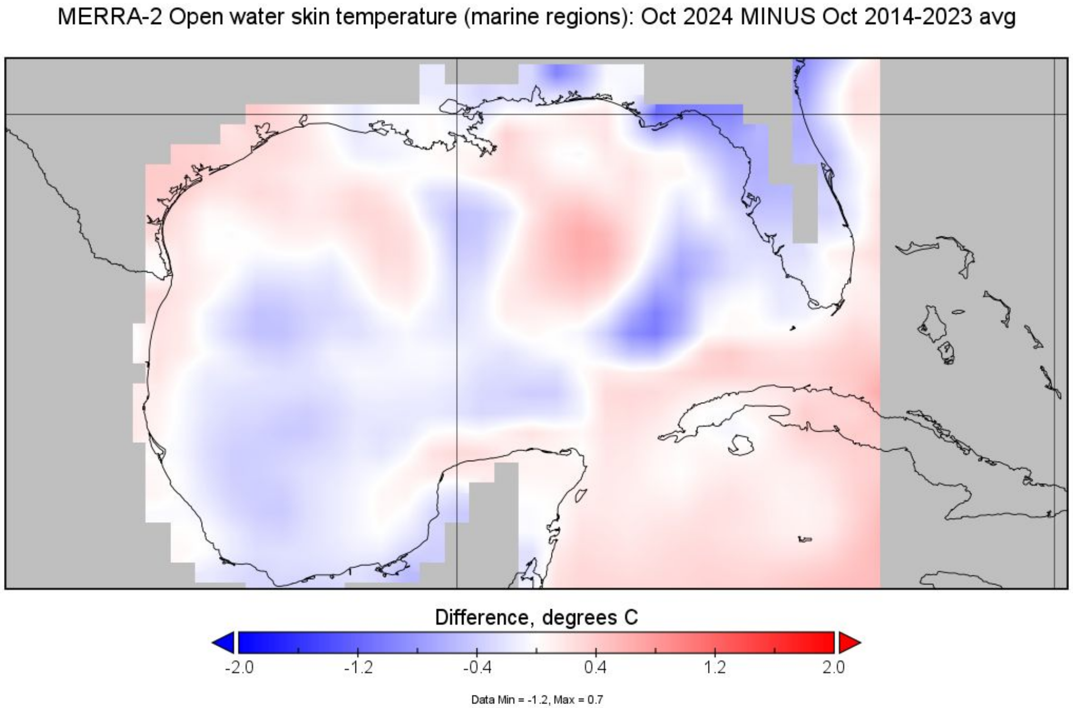
Effect on the Gulf of Mexico







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TROPICS Mission Overview

Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats

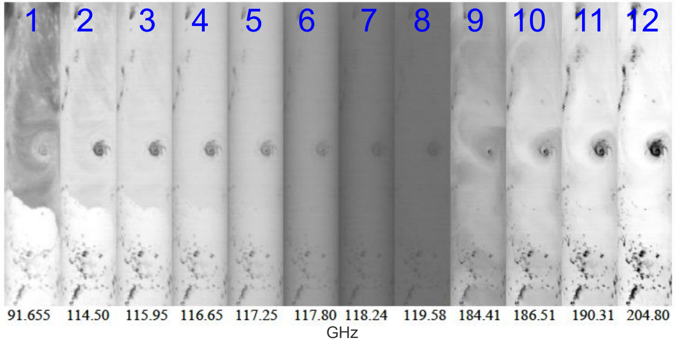
4 CubeSat constellation in LEO providing passive microwave radiometric measurements in 12 channels (W, F and G bands)

- Lower development cost, shorter development time
- Lighter for launches, great for shared rides

4 day ground latency
~1 hour NRT latency for operational forecasting

Video Credit: Sean Loughran and Nick Zorn (MIT LL)

Level	Shortname	Variable(s)	Meteorological Application
L1A	Antenna Temperature	Antenna temperature	NWP forecast modeling
L1B	Brightness Temperature	Brightness temperature	NWP forecast modeling
L2A	Unified Resolution Brightness Temperature **(URAD)**	Resampled brightness temperature	NWP forecast modeling
L2B	Precipitation Retrieval and Profiling Scheme **(PRPS)**	Rain rate	Useful for rainfall once tropical system has made landfall
L2B	Atmospheric Vertical Temperature and Moisture Profile **(MIRS)**	Temperature, moisture vertical profiles, total precipitable water	Analyzing temperature and precip vertical structure of tropical cyclones
L2B	Tropical Cyclone Intensity Estimate algorithm **(TCIE)**	Minimum sea level pressure, maximum sustained winds	Evaluating the TC strength



Right: Example of the 12 channels of the TROPICS sensor ranging from 91.655 (left) through to 204.8 GHz (right) for Hurricane Sam on 27 September 2021.

Ch. 1, 9: precipitation retrievals and scattering responses
Ch. 12: identification and classification of ice particles
Ch. 2-8: mainly temperature profiles, delineation of liquid/frozen precipitation

Cyclogenesis of Milton

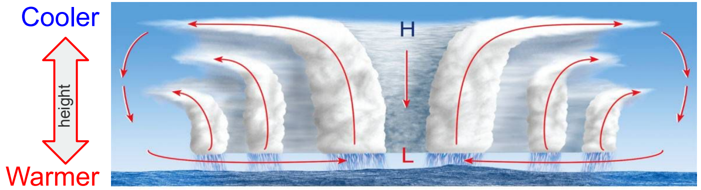
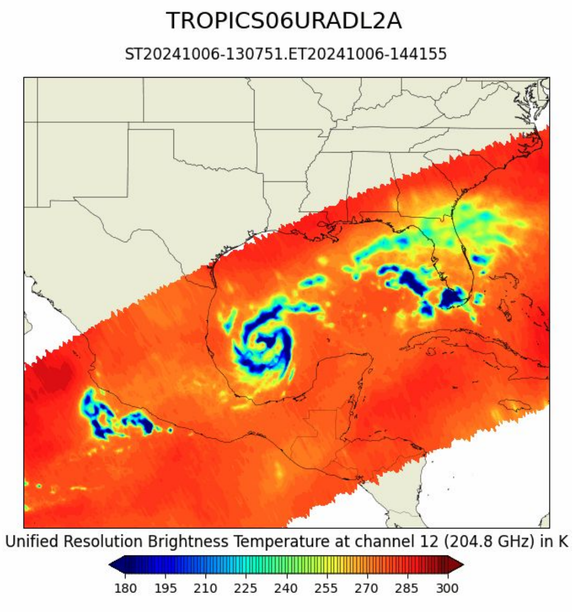


Image courtesy of Northern Vermont University

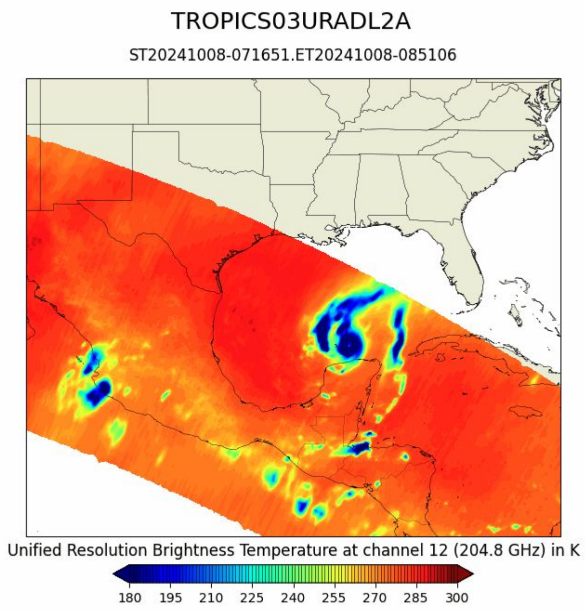
L2A URAD: Resampled Brightness Temperature (K)



(left) TROPICS06 observed Milton organizing on 10/06 and developing as a tropical storm.

On 10/07 Milton rapidly intensified from a Cat 1 to Cat 5 Hurricane, the second fastest intensification on record.

(right) TROPICS03 observed Milton on 10/08 as a well-developed Cat 5 during an eyewall replacement cycle and with a clear eye.



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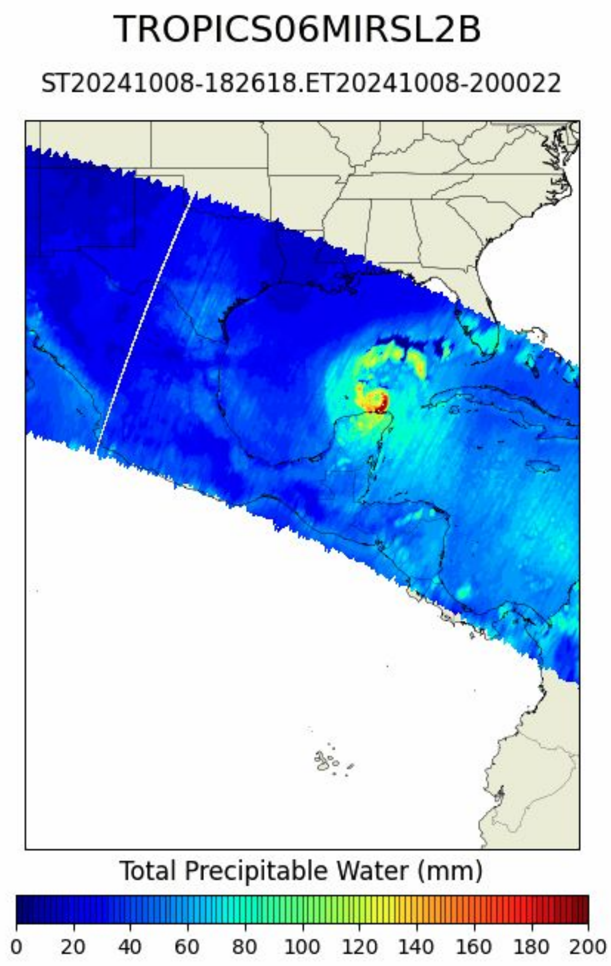
Milton Intensifying

L2B MIRS: Vertically integrated water vapor

As Milton travels over anomalously warm waters in Gulf of Mexico, TROPICS06 observes increasing water vapor content in the outer rain band of the storm on 10/08.

Milton will “carry” this total precipitable water (200 mm) as it heads to landfall in Florida as almost 8 inches of rain.



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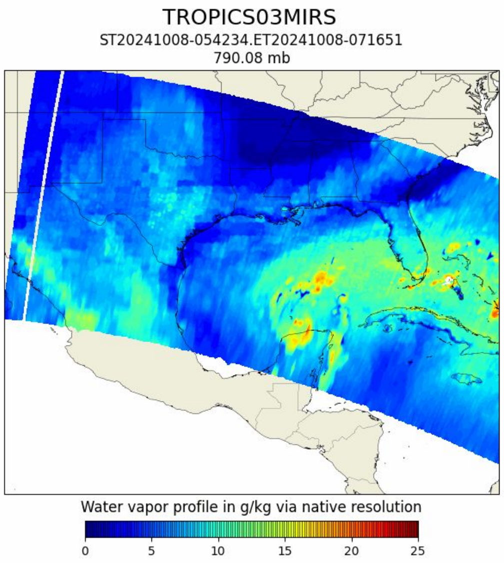
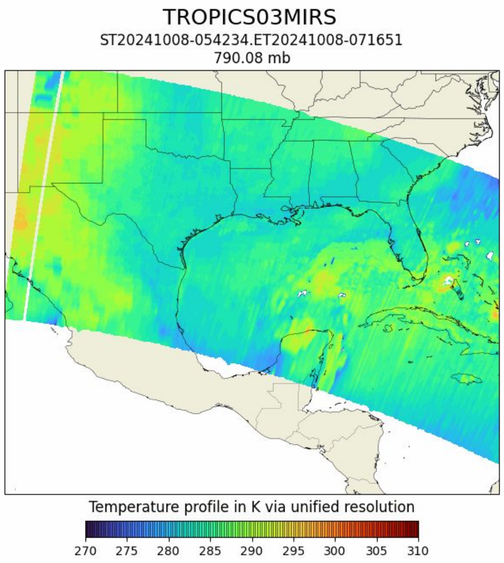
Vertical Structures





Using the same data product as previous, the vertical water vapor mixing ratio **(left)** and temperature **(right)** profile variables demonstrate the vertical anatomy of Milton, October 8th, 2024 18:26 - 20:00 UTC.

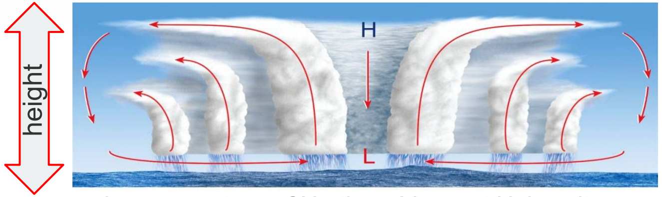
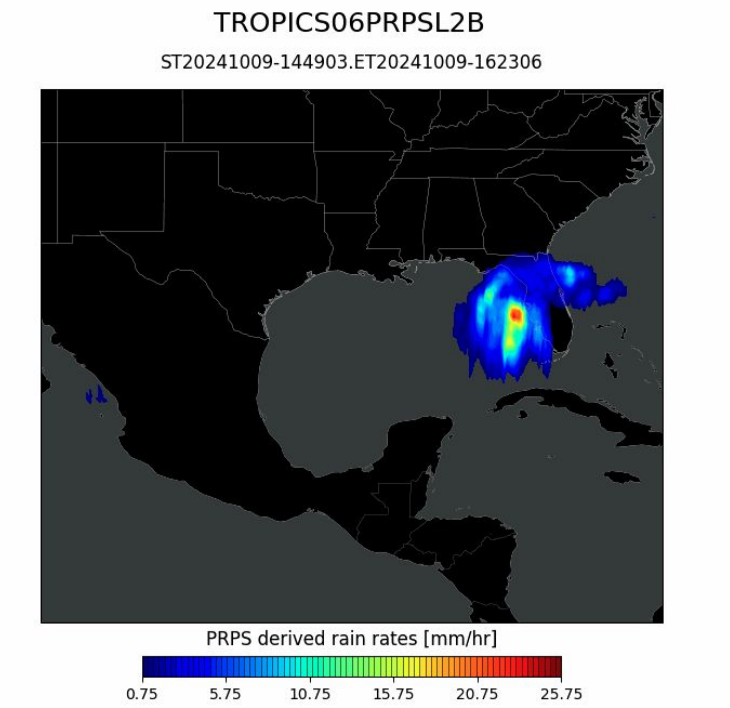


Image courtesy of Northern Vermont University

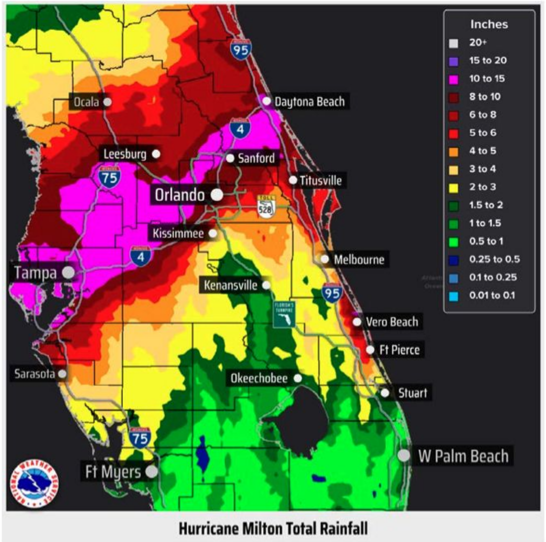
TROPICS Captures Milton's Landfall

L2B PRPS: Rain Rates (mm/hr)



Inner core rain rate max of ~1 inch per hour as Milton reached Florida's west coast as a Category 3 hurricane on October 9, 2024.

Excessive rain as Milton makes landfall

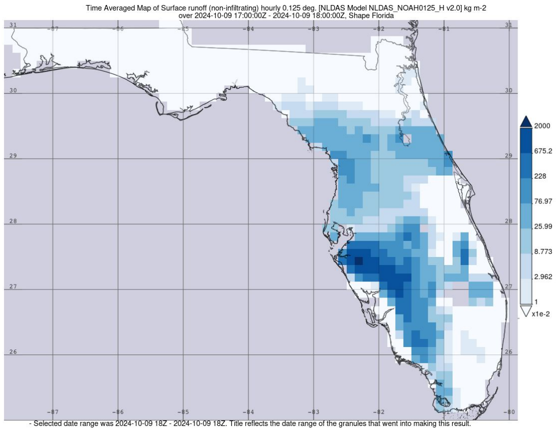


Estimated storm total rainfall amounts from Hurricane Milton, observed from 8:00am October 9 to 8:00am October 11 (source: NWS Melbourne Office).

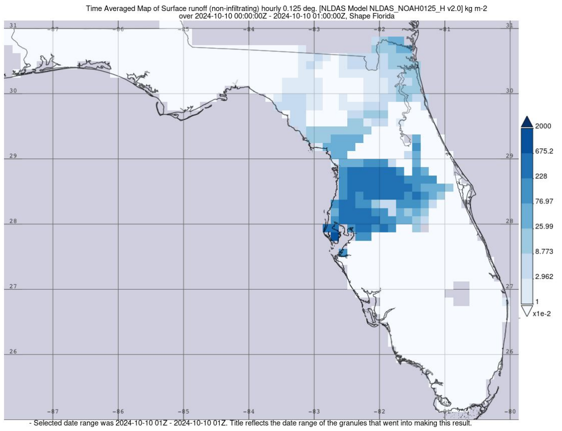
Florida Climate Center Post-Storm Summary Report depicts total rainfall along the west coast and central Florida from October 9-11, 2024. *Courtesy of Emily Powell,* epowell@coaps.fsu.edu

Runoff and streamflow after Milton, from NLDAS

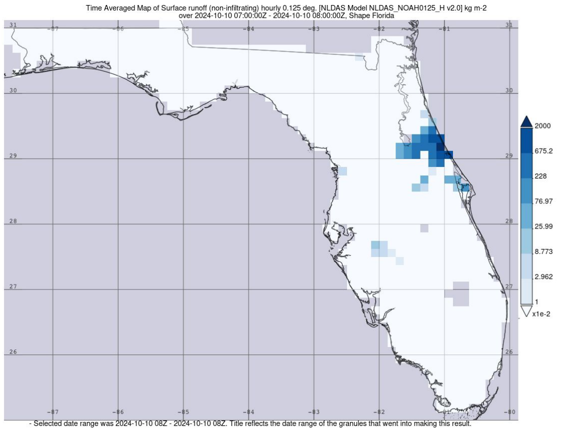
Surface Runoff



10-09 18Z



10-10 01Z



10-09 18Z

Images created with Giovanni, giovanni.gsfc.nasa.gov

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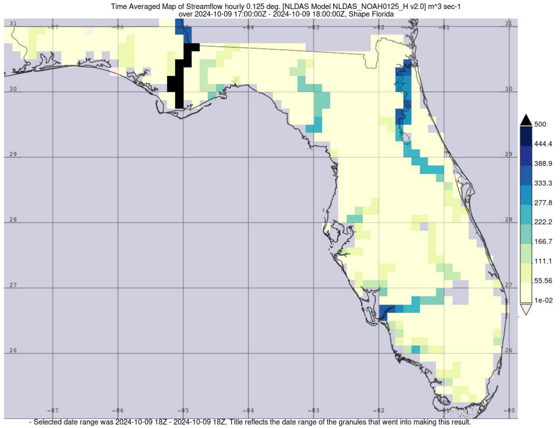
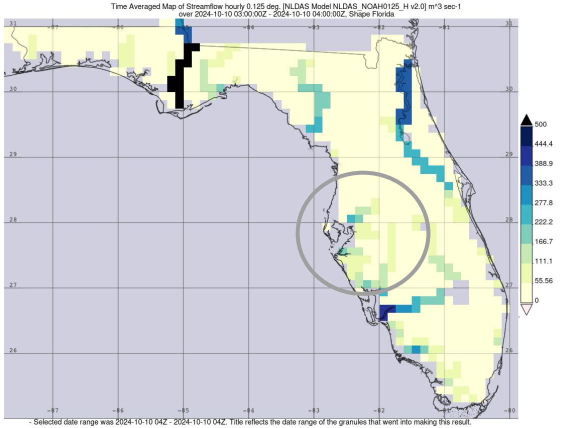
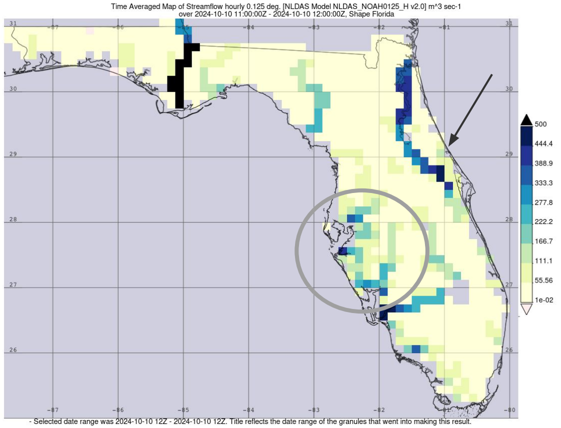
Runoff and streamflow after Milton, from NLDAS
Streamflow



10-09 18Z



10-10 04Z



10-10 12Z

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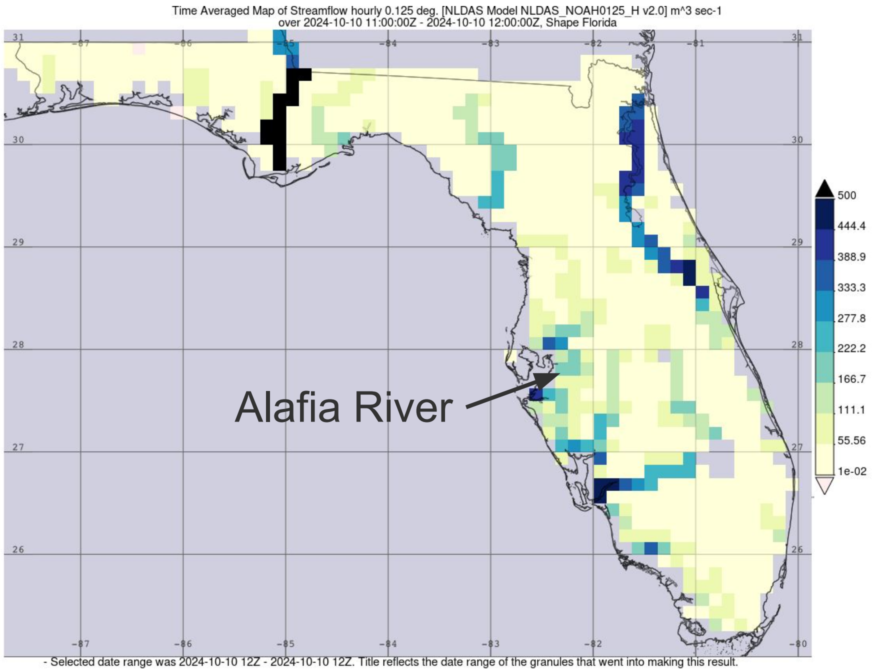
Runoff and streamflow after Milton, from NLDAS
Streamflow



Alafia River flooding
Storm chaser Aaron Rigsby drone video

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Jupyter Notebook Python Analysis

Tools Used

- Jupyter Notebook in Google Colab (Python)
- Earthdata Search
  - OPeNDAP Variable Subsetting
  - Public Cloud Endpoints
- *No downloading needed!*

Collections Analyzed

- TROPICS
  - TROPICS03URADL2A_1.0
  - TROPICS06PRPSL2B_1.0
  - TROPICS06MIRSL2B_1.0
  - TROPICS03TCIEL2B_1.0

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What are Data Processing Levels?

Data Level	Description
Level 0	Reconstructed, unprocessed instrument and payload data at full resolution, with any and all communications artifacts (e.g., synchronization frames, communications headers, duplicate data) removed.
Level 1A	Level 1A (L1A) data are reconstructed, unprocessed instrument data at full resolution, time-referenced, and annotated with ancillary information. This ancillary information can include radiometric and geometric calibration coefficients and georeferencing parameters (e.g., platform ephemeris).
Level 1B	L1B data are L1A data that have been processed to instrument units (not all instruments have L1B source data).
Level 1C	L1C data are L1B data that include new variables to describe the spectra. These variables allow the user to identify which L1C channels have been copied directly from the L1B and which have been synthesized from L1B and why.
Level 2	Derived geophysical variables at the same resolution and location as L1 source data.
Level 2A	L2A data contains information derived from the geolocated instrument data, such as ground elevation, highest and lowest surface return elevations, energy quantile heights ("relative height" metrics), and other waveform-derived metrics describing the intercepted surface.
Level 2B	L2B data are L2A data that have been processed to instrument units (not all instruments will have a L2B equivalent).
Level 3	Variables mapped on uniform space-time grid scales, usually with some completeness and consistency.
Level 3A	L3A data are generally periodic summaries (weekly, 10-day, monthly) of L2 products.
Level 4	Model output or results from analyses of lower-level data (e.g., variables derived from multiple measurements).

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Source

How is “Level 2” Data Structured?

- Typically in GIF, NetCDF, or HDF
- “X” and “Y” are referred to as “Along-Track” and “Cross-Track”
  - Data is *not gridded*
  - Some collections, such as TCIE, may only be 1 point
- Not available for whole globe at once
- Quality Control variables are critical
- Reading manuals and READMEs are critical
  - Variables, metadata different for each collection

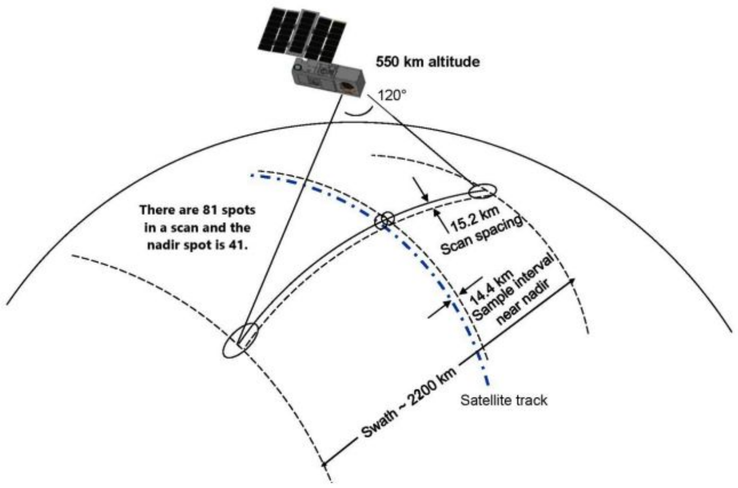

Figure 4 – Illustration of the radiometric measurements projected on to the surface of the Earth. The cross-track spacing is 14.4 km and the along-track spacing is 15.2 km.

Figure is referenced from TROPICS User Guide

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Workflow

Grab granule titles from Earthdata Search

`TROPICS06.MIRS.L2B.Orbit07877.V02-07.ST20241008-182618.ET20241008-200022.CT20241115-012205.nc`

Create and Access OPeNDAP Subset URLs for PRPS, MIRS, URAD

`TROPICS06.MIRS.L2B.Orbit07877.V02-07.ST20241008-182618.ET20241008-200022.CT20241115-012205.nc`

\+ (x3)

`.?dap4.ce=TPW%3BQc%eb`

Access and Combine TCIE

1. **Query TROPICS03 and TROPICS06**
2. **Combine and sort variables using time attributes**
3. **“Stream” using earthaccess and Xarray**

Create plots!

- URAD Brightness Temperature after peak strength (8 Oct. 00Z)
- MIRS Total Precipitable Water (8 Oct. 18Z)
- PRPS Precipitation Rates at FL landfall (9 Oct. 14Z)
- TCIE-Derived Max Wind/MSLP with Time (6 Oct. to 14 Oct.)

Google Colab Live Demo

Run Notebook:

Open in Colab

- Google & Earthdata Login account required
  - Token and ".netrc" will be deleted when runtime ends
- Runtime will be deleted after 90 minutes of closing the browser, 12 hours of idling
- Create Earthdata Login Account

Conclusions

Oct. 5	Oct. 6	Oct. 7	Oct. 8	Oct. 9	Oct. 10	Oct. 11	Oct. 12	Oct. 13
Trop. Depression	Tropical Storm	Category 1-5	Category 5	Landfall as Cat. 3	←	Extratropical Cyclone	→	Dissipated

- GES DISC datasets support analysis of high-impact events
- Hurricane Milton was of the most intense hurricanes on record in the Atlantic basin
  - TROPICS Mission Cubesats provide spatially, temporally high-resolution data
    - Able to visualize hurricane thermodynamic and precipitation structure
    - “Milestones” of Milton captured
- Understanding data processing levels and data structure is crucial
- Google Colab Jupyter Notebook allows users to conduct their own analyses
  - GES DISC Tutorials available to guide users through finding and accessing datasets

More information and documentation

- Giovanni: https://giovanni.gsfc.nasa.gov/
- Panoply: https://www.giss.nasa.gov/tools/panoply/
- TROPICS Mission homepage: http://tropics.ll.mit.edu/
- TROPICS User Guide: https://docserver.gesdisc.eosdis.nasa.gov/public/project/TROPICS/TROPICS_UserGuide_base_Sept2023.pdf
- Create a Gmail Account for using Google Colab (Free): https://support.google.com/mail/answer/56256?hl=en
- "How to Register for an Earthdata Login Profile": https://urs.earthdata.nasa.gov/documentation/for_users/how_to_register
- All Jupyter Notebook Tutorials: https://disc.gsfc.nasa.gov/information/howto?page=1&dataTools=Jupyter%20Notebook
  - "How to Access GES DISC Data using Python": https://disc.gsfc.nasa.gov/information/howto?title=How%20to%20Access%20GES%20DISC%20Data%20Using%20Python
  - "How to Generate Earthdata Prerequisite Files": https://disc.gsfc.nasa.gov/information/howto?title=How%20to%20Generate%20Earthdata%20Prerequisite%20Files
- NASA Earthdata Search: https://search.earthdata.nasa.gov/search

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earthdata.nasa.gov

Thank you

Acknowledgements:

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Lauren Hill-Beaton (lauren.k.hill-beaton@nasa.gov) and Ariana McDermott (ariana.m.louise@nasa.gov) for imagery

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