LEO products and capabilities for tropical cyclone monitoring:

Current uses and a wish list for the future

National Environmental Satellite, Data, and Information Service

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LEO Satellite Uses: Tropical Cyclone

Focusing on LEO satellites designed for precipitation estimation

1. Monitoring convective structure and physical attributes
2. Monitoring environmental moisture conditions
3. Intensity and structure estimates, balanced winds
4. Surface winds

Monitoring convective structure and physical attributes

Raw 88-92 GHz (H-polarized, conical & cross-track), PCT

A long history of use starting with SSMI (1987)

Highest spatial resolution (historically)

Detects both deep convection (scattering) and shallow convection(emissivity)

Use Cases

1. Center location
2. Degree of banding
3. Eye formation
4. Secondary eyewall formation/evolution

WMO trains forecasters… see (Link#1,Link#2)

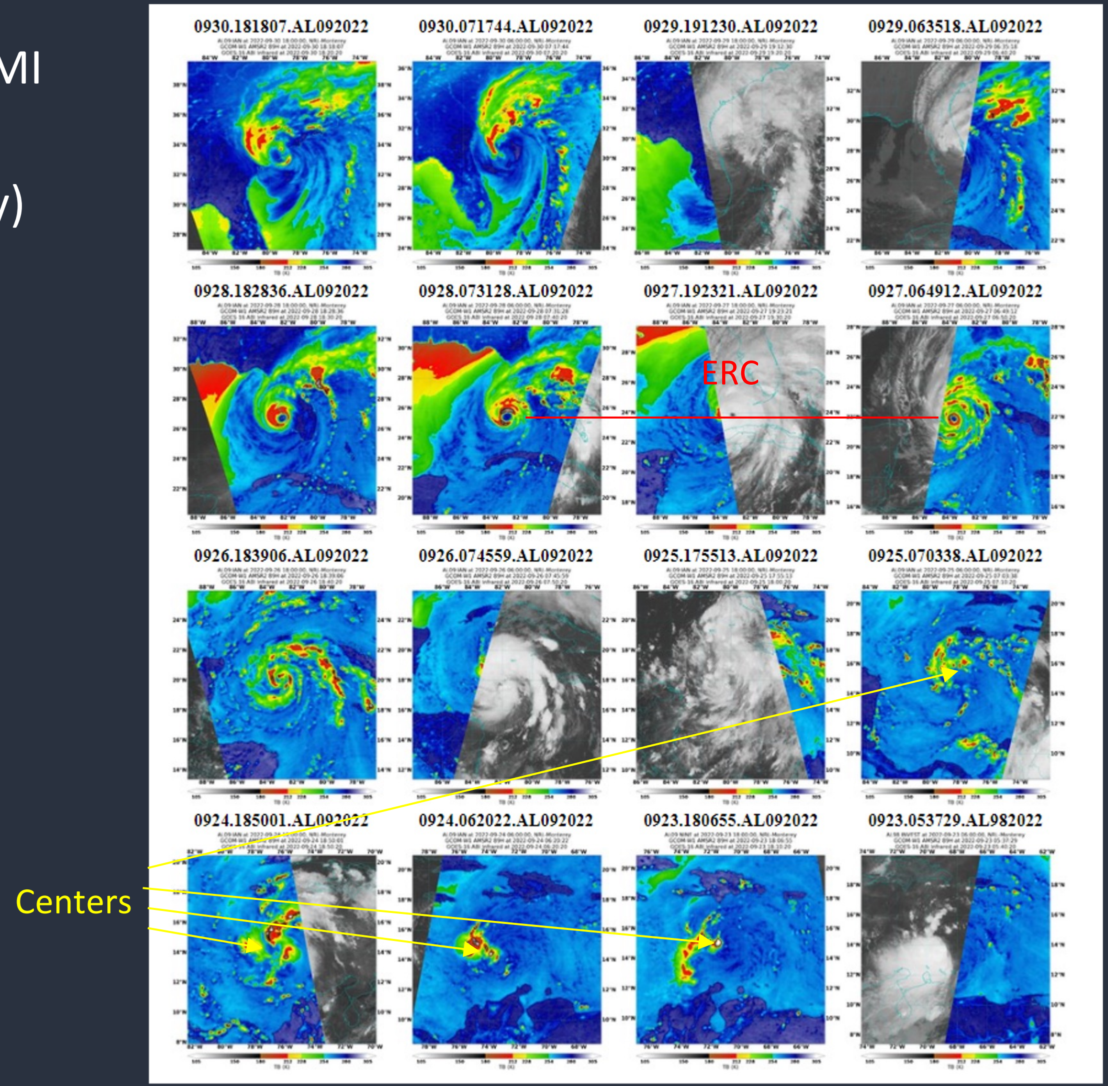


Figure shows an sequence of twice-daily AMSR2 89GHz-H images of Hurricane Ian (2022). From the lower right (30 kt) through landfall in Florida.

In the early stages, emissivity differences with the ocean, and banding indicated by the scattering provide centers below the IR-obscured scene

As the eye develops the eye and band structure can be monitored revealing that an eyewall replacement cycle (ERC) likely occurred a day or so before landfall.

Monitoring convective structure and physical attributes

Raw 37 GHz (H-polarized, conical), PCT

A long history of use starting with AMSR (

Channel is sensitive to warm rain processes, can see structure early

Detects both deep convection (scattering) and shallow convection(emissivity)

Use Cases

1. Center location
2. Degree of banding
3. Eye formation (earlier)
4. Secondary eyewall formation/evolution (earlier)
5. Help with rapid intensification

WMO trains forecasters… see (Link#1,Link#2)

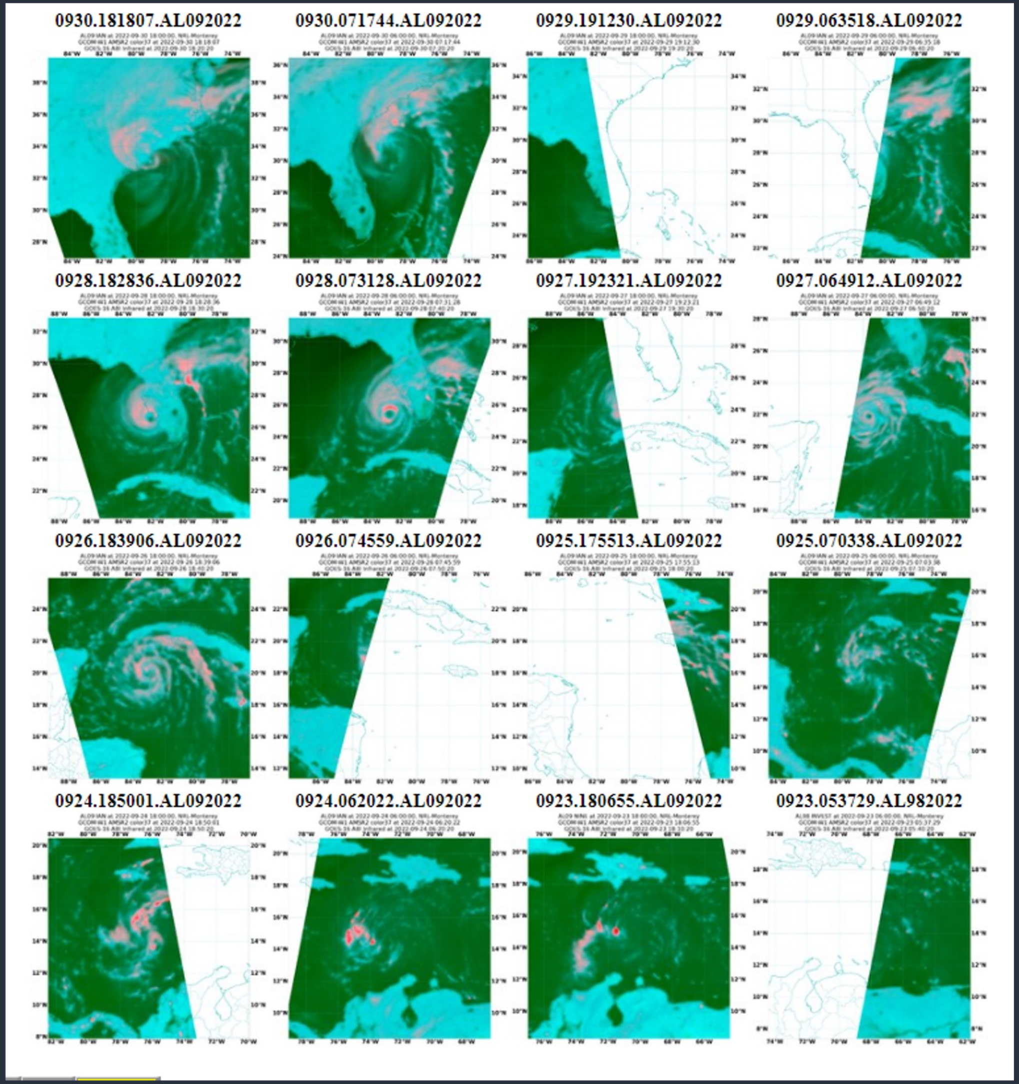


Figure shows an sequence of twice-daily AMSR2 37GHz-PCT images of Hurricane Ian (2022). From the lower right (30 kt) through landfall in Florida.

In the early stages, emissivity differences with the ocean, and banding indicated by the scattering provide centers below the IR-obscured scene

As the eye develops the eye and band structure can be monitored revealing that an eyewall replacement cycle (ERC) likely occurred a day or so before landfall.

Features that appear in 89 GHz appear a bit earlier in 37GHz (warm rain processes) and are important to evolving convective organization.

Monitoring environmental moisture conditions

MIRS-based Advective Layered Precipitable Water Product

The moisture around tropical cyclones is not always obvious

When dry air makes its way near the center it can effect eyewall convection and intensity

Microwave imagery and NWP are the only means to monitor

But, MI provides static images, and

NWP is not always correct.

A path forward from static images of TPW or Layered TPW: Advective Layered Precipitable Water (ALPW) where MIRS provides the moisture profiles and NWP advects it.

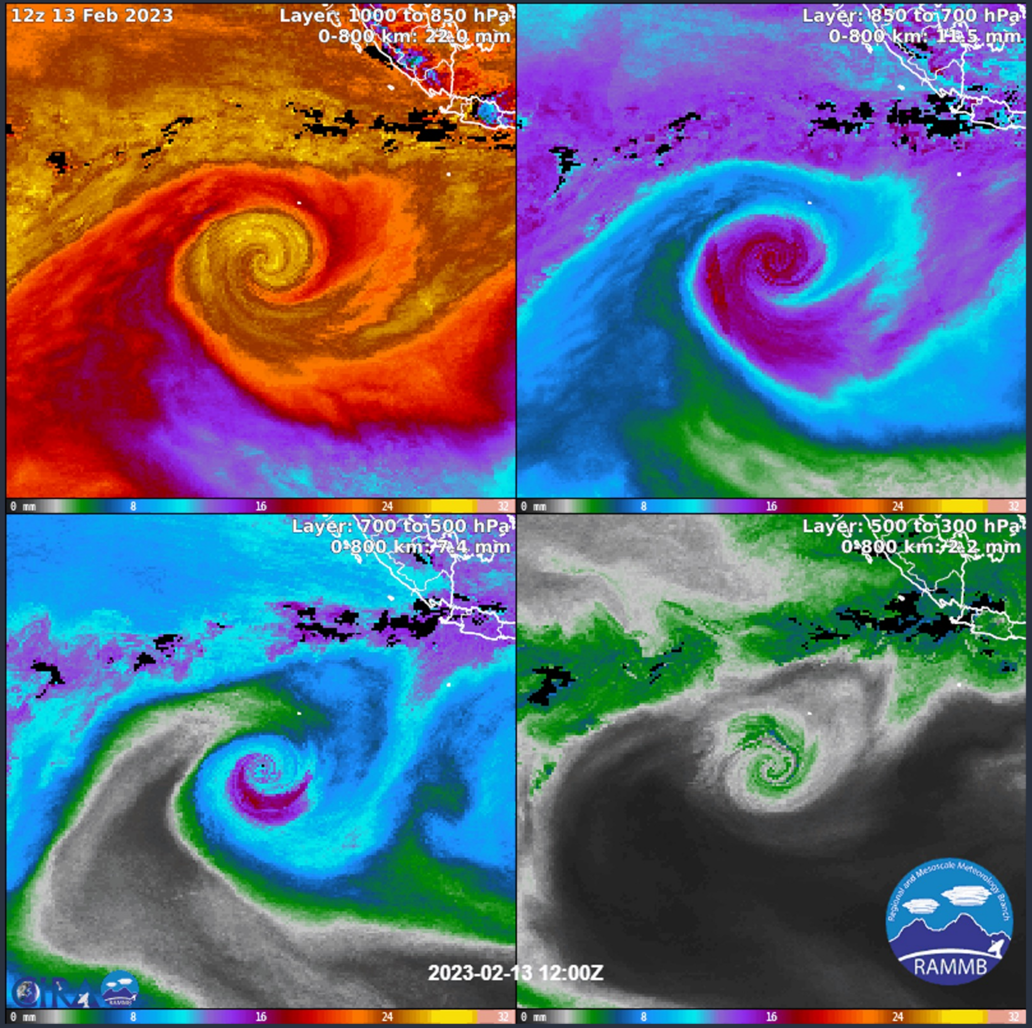
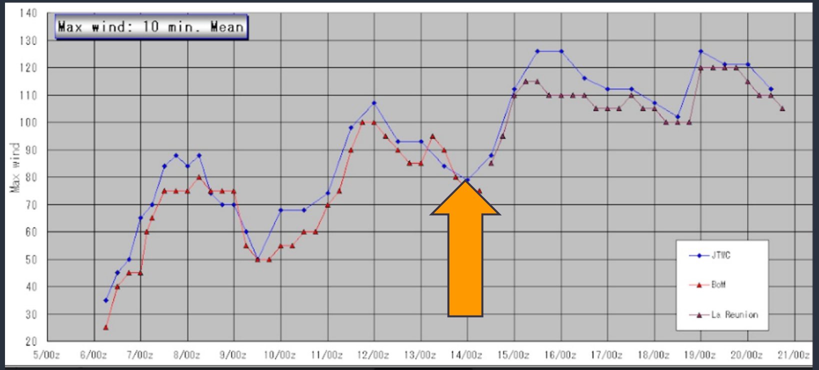


Figure shows a loop of ALPW of Tropical Cyclone Freddy in the South Indian Ocean. The time period shown is 13 Feb 12UTC to 14 Feb 00 UTC.

At this time TC Freddy is wrapping a mid-latitude air mass around its primary circulation, and it appears that some of that moisture is making it to the eyewall region.

At this time Freddy was shown to experience a short-term reduction in intensity, though many other factors including cooler SSTs may have contributed.



Intensity and structure estimates, balanced winds

Hurricane Structure and Intensity Algorithm (HISA)

HISA is an algorithm that provides estimates of TC intensity (Vmax, MSLP) and structure (34-, 50-, 64-knot wind radii, balanced winds @ standard pressure levels)

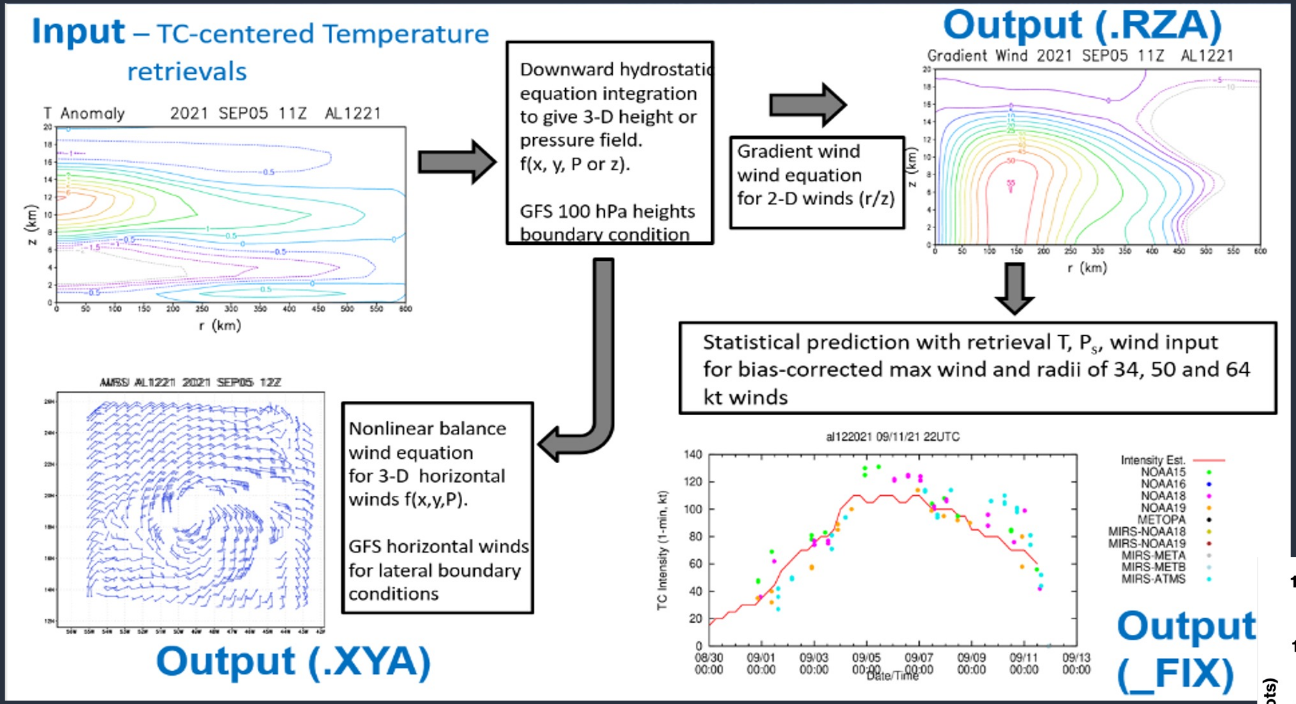
- MiRS retrievals
- Statistical retrievals (NCEP)

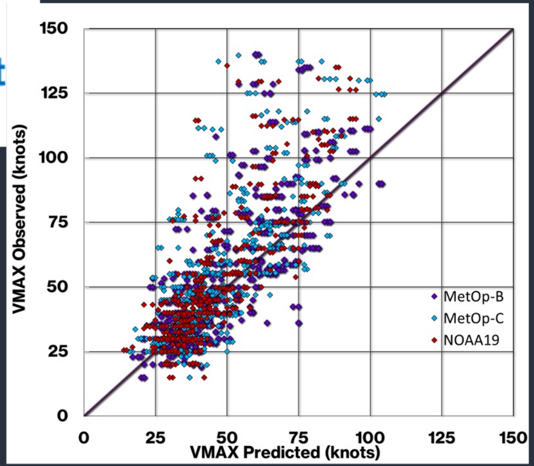
Outputs (netCDF):

1. Azimuth-averaged (T, RH, Z, U, V)
2. 2-D (T, RH, Z, U)

Output (text)

1. TC fix (ATCF format)





Algorithm is being updated, but still seems to struggle with small and intense storms

Produces very good estimates of Wind Radii.

Outputs (2-D winds) are used for the Multi-platform TC surface wind analysis.

Surface winds

AMSR2

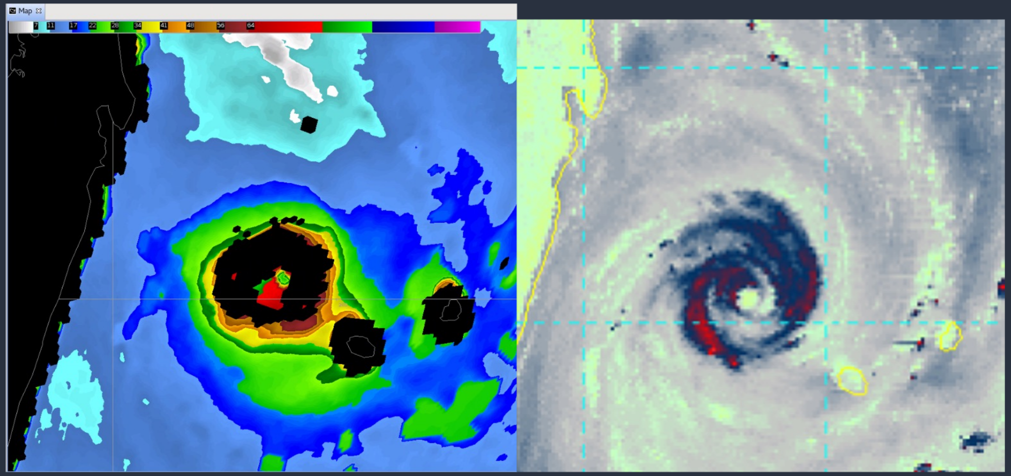
Surface wind speeds and vectors are the more important of the TC requirements

- Need 6-hourly estimates of surface winds from the radius of gales to the radius of maximum wind
- Scatterometers (China, India, Europe) start to saturate at 25 m/s
- SAR is limited (but awesome)
- L-Band (GNSS-R, SMAP, SMOS) have low resolution and are research satellites

(see Knaff et al. 2021)

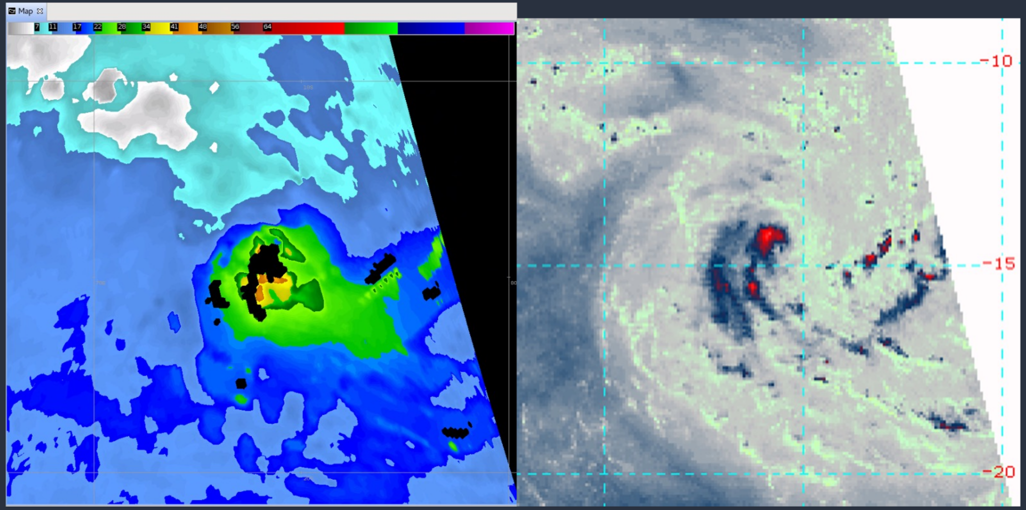
Multi-channel microwave radiometers can estimate extreme winds (> 25 m/s) in precipitating conditions (will little saturation)

AMSR and AMSR2, & WindSAT (to a lesser extent) have shown promising results and produced useful products



Provides information about the radius of gales and to a lesser extent 50-kt winds

Shows that heavy precipitation effects retrieval



Invest upgraded at 06 UTC 22 February (35-kt) and 40 kt 6h later in part based on this information

Shows that heavy precipitation effects retrieval

General Comments

NHC, CPHC and JTWC do not make precipitation forecasts nor do they provide estimates of rain (though many think they do)

The use of passive microwave imagery is important to the tropical cyclone forecasting process, but through the use of raw imagery and TC-specific products (precipitation is low resolution, and has poor aesthetics)

Greater spatial and temporal resolution and lower latency is thus a common desire

NWP struggles to assimilate microwave channels (microphysics is immature)

NOAA has no operational AMSR2 or scatterometers, and no plans for either

Wish List

Lower latency of passive microwave images and products

More 89 & 37 GHz radiometers

Precipitation missions that include a surface wind requirement

Conical sounders/imagers rather than cross-track

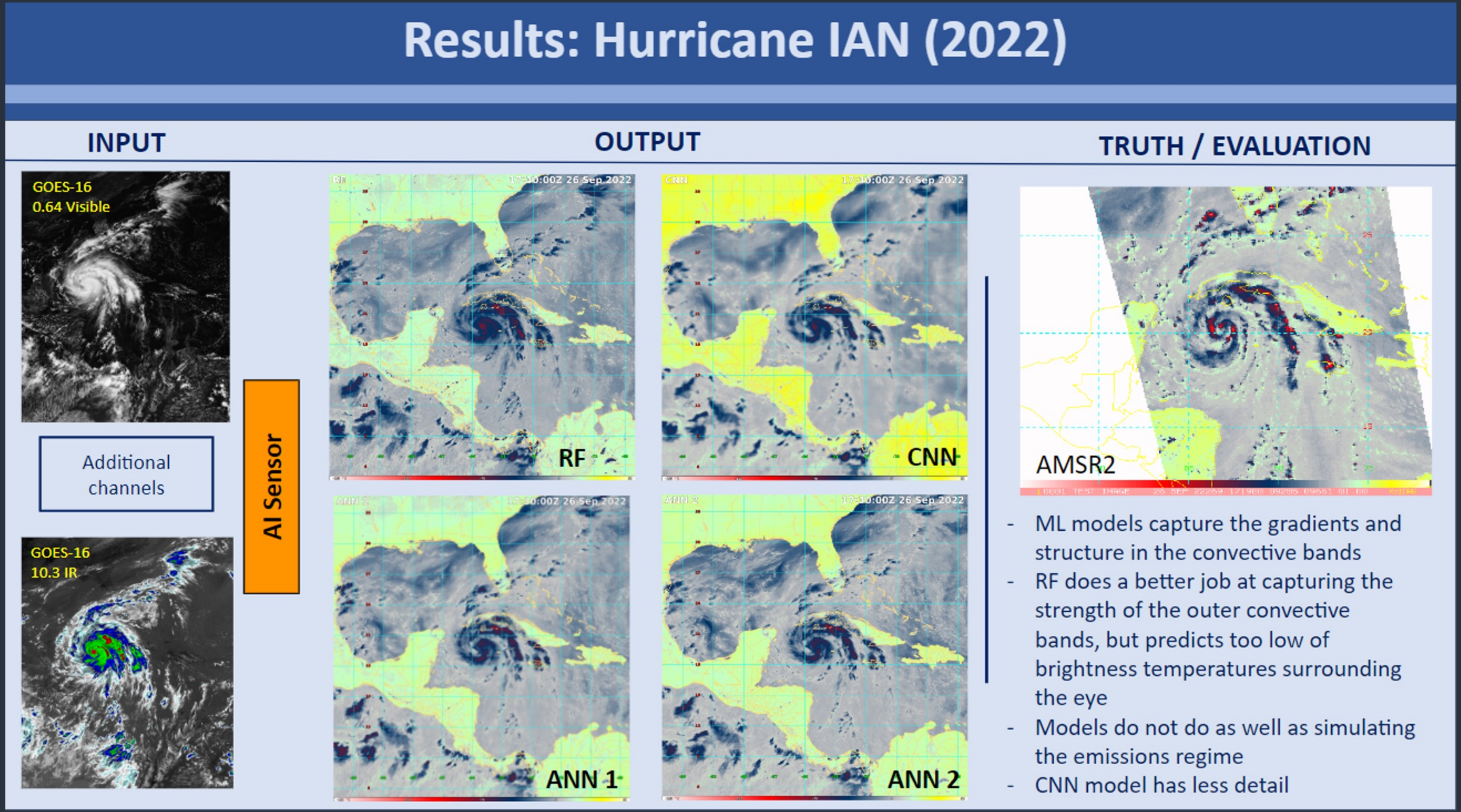
TC-dedicated or a USA cross-polarized SAR that could target TCs

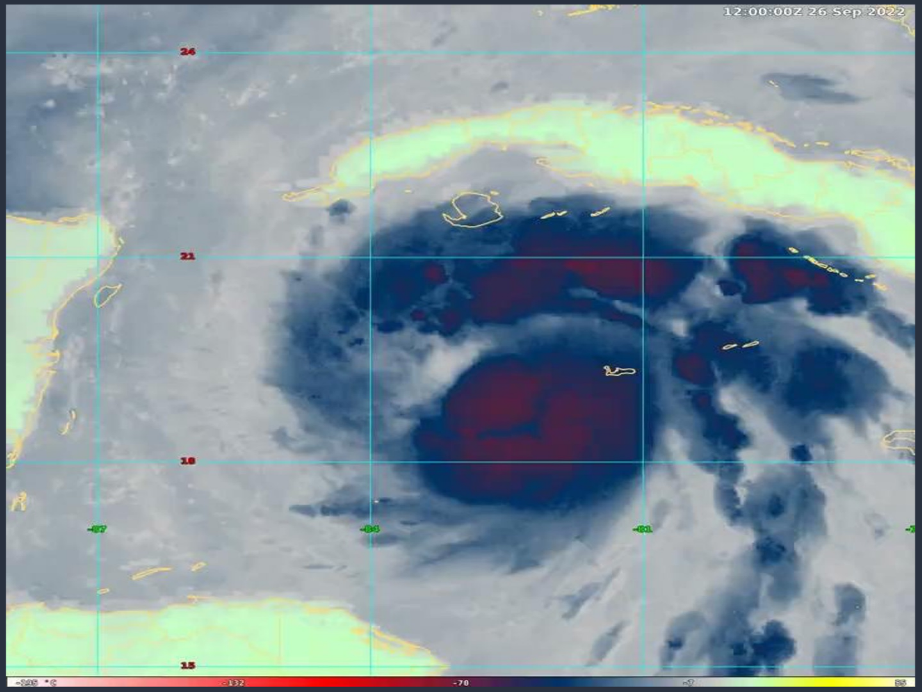
More & USA scatterometer (preferably multi-channel and cross-polarized)

Research that shows the utility of current precipitation products with respect to the tropical cyclone analysis and forecasting problems

One possible short-term solution

Estimating 89 and 37 GHz (and other precipitation channels) from Geo





No longer funded by NOAA

Questions