

Observing Rapid Evolution Phenomena with the ESA Earth Explorer 11 WIVERN Mission

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ESA Earth Explorer Program

ESA's EE program family of satellites

- Advancing Earth science through observation of Earth's key systems
- Each Earth Explorers is dedicated to observing a different aspect of Earth
- Objective: to understand the Earth as a geosphere and the complex interactions between spheres and sub-spheres



Where we are

WIVERN mission officially selected as EE 11 by ESA
Currently in Phase B1

WIVERN Science Objectives

WIVERN Primary and Secondary Science Objectives

PRIMARY:

- Understanding storms
- Constraining Cloud & Precipitation Impacts on Climate
- Improving NWP and Earth System Models



Bridging Observational Gaps in Polar Sea Ice and Snow

SECONDARY:

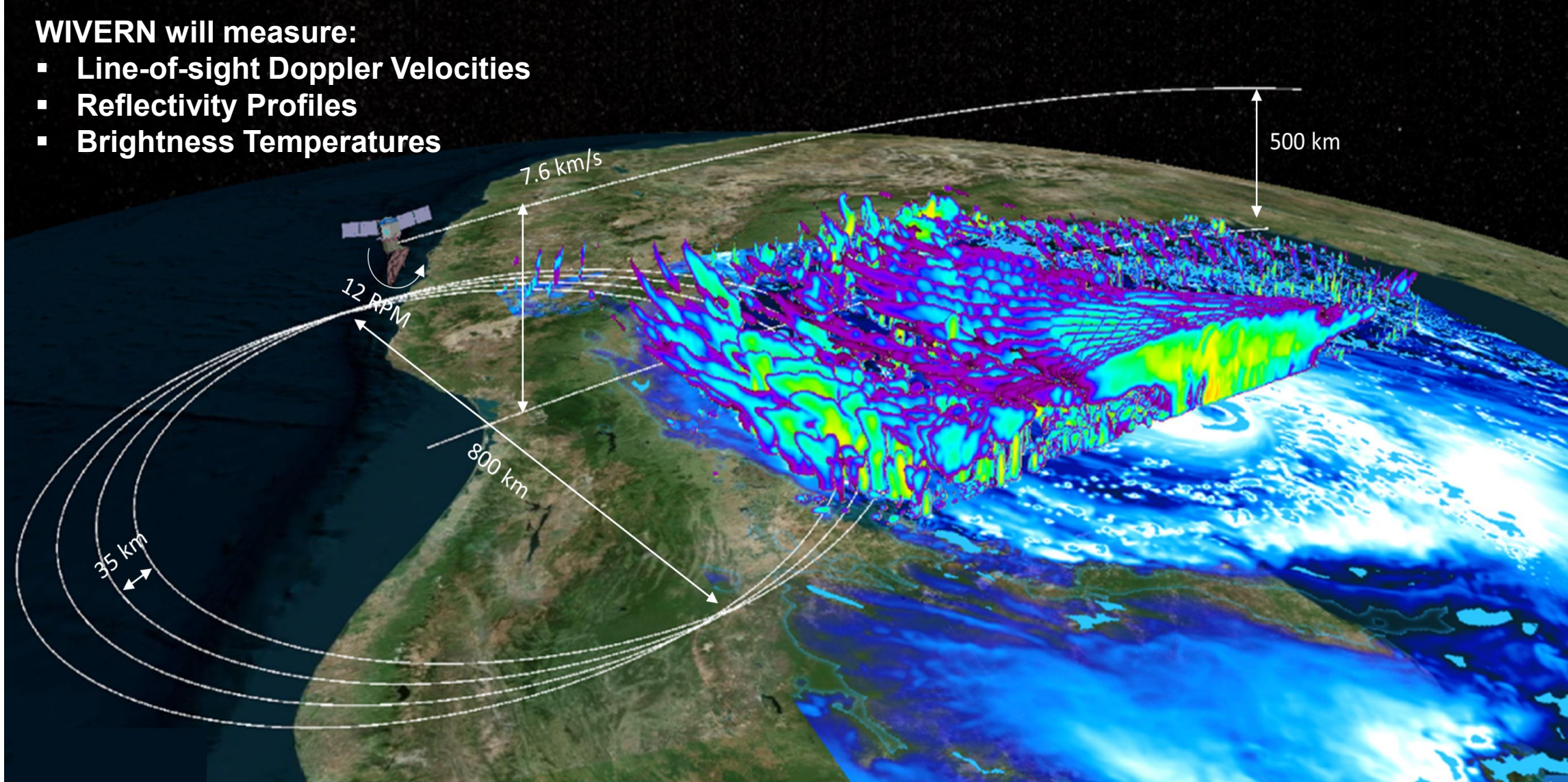
Advancing Ocean Surface Current Studies

Tropical cyclones (TCs) used as case study: internal structure and dynamics is not well understood currently

The WIVERN observation concept [1]

WIVERN will measure:

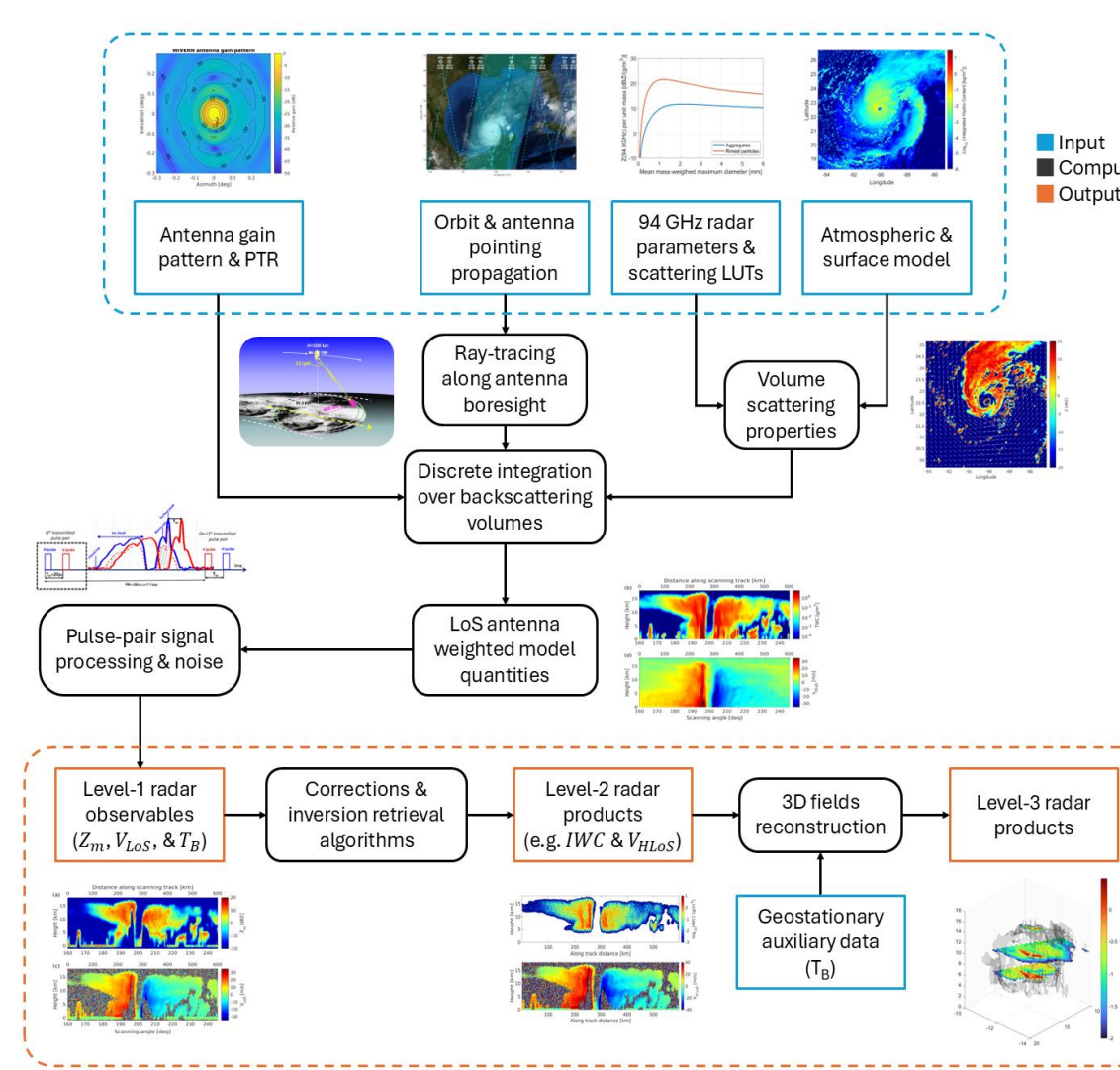
- Line-of-sight Doppler Velocities
- Reflectivity Profiles
- Brightness Temperatures



- 94 GHz, 3 m antenna → footprint size (< 1 km) and vertical resolution (600 m) → ideal to capture variability of convective phenomena
- Swath dimension: 800 km → capable of mapping 3D wind fields inside entire mesoscale convective systems
- Doppler velocity Nyquist interval: ± 40 m/s, i.e. sufficient to measure hurricane-force winds
- Measurements at 42° incidence

Simulating observations

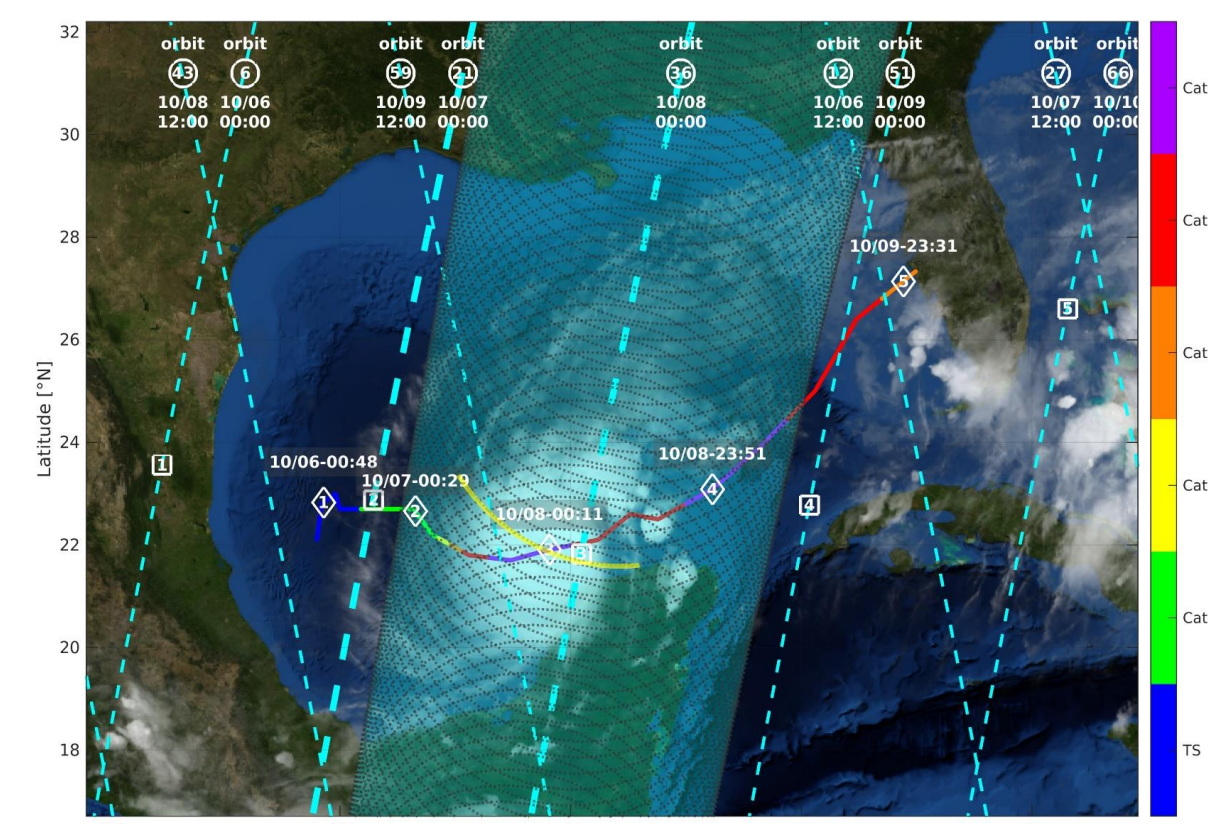
End-to-end simulator block diagram



- Comprehensive end-to-end simulator to reproduce WIVERN observables from atmospheric and surface targets [2, 3, 4]
- Cloud resolving models provide 3D fields of atmospheric quantities
- These quantities then converted into 94 GHz radar properties
- Each footprint is illuminated by the WIVERN antenna and scanning pattern around the given orbit
- Level-1 observables are then computed using WIVERN sampling

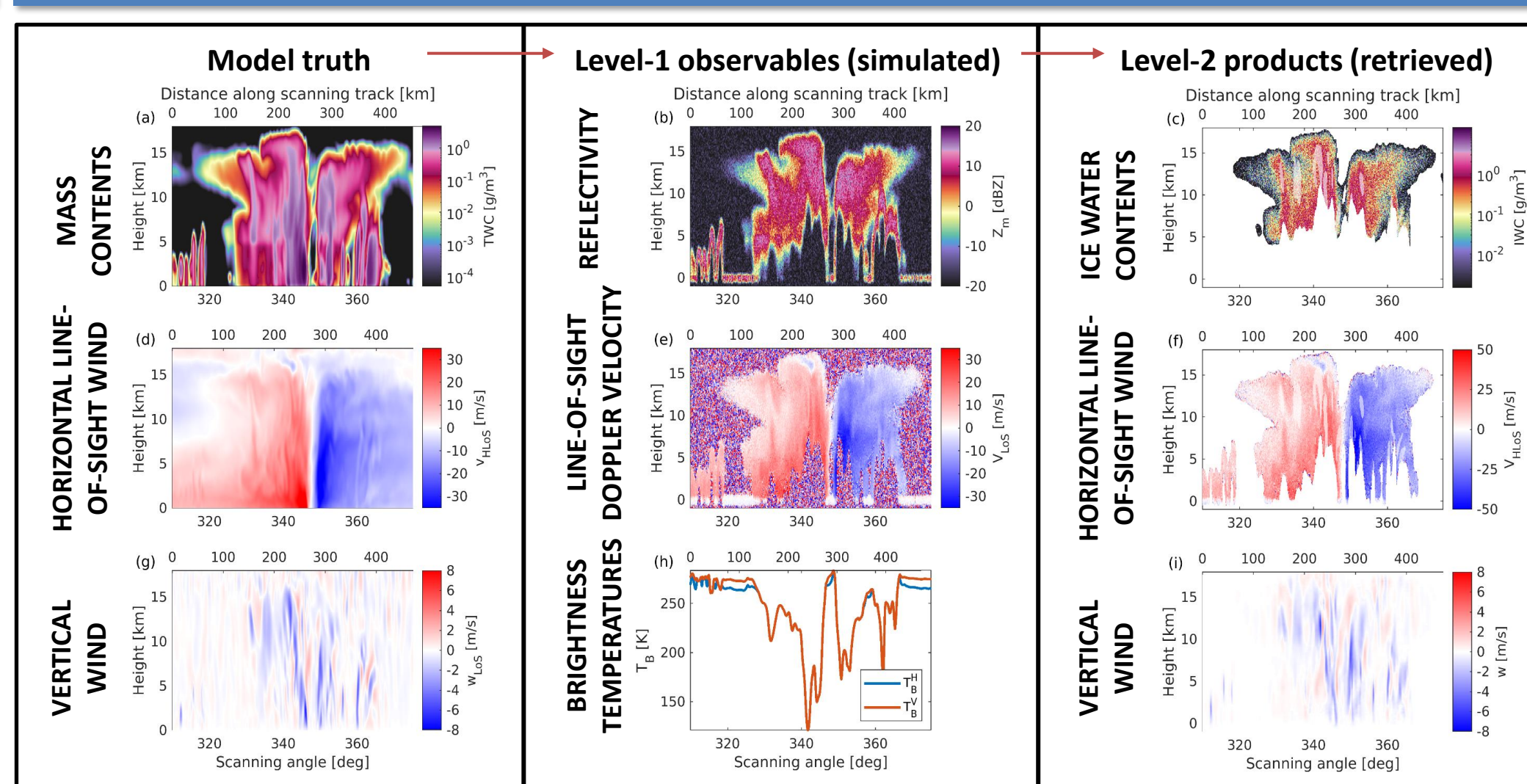
Tropical cyclones (TC) studies [5]

Consecutive simulated passes over hurricane Milton (Oct 2024)



- Path of hurricane Milton from 6th to 10th October 2024 with color-coded intensity
- Cyan dashed lines: nine WIVERN ground-tracks during these four days passing in the region
- Five tracks within 400 km from the hurricane eye (diamonds), squares are the corresponding satellite position (a full swath is shown, shaded)
- Rapid intensification occurred between passes labeled 2 and 3 (thicker dashed line)

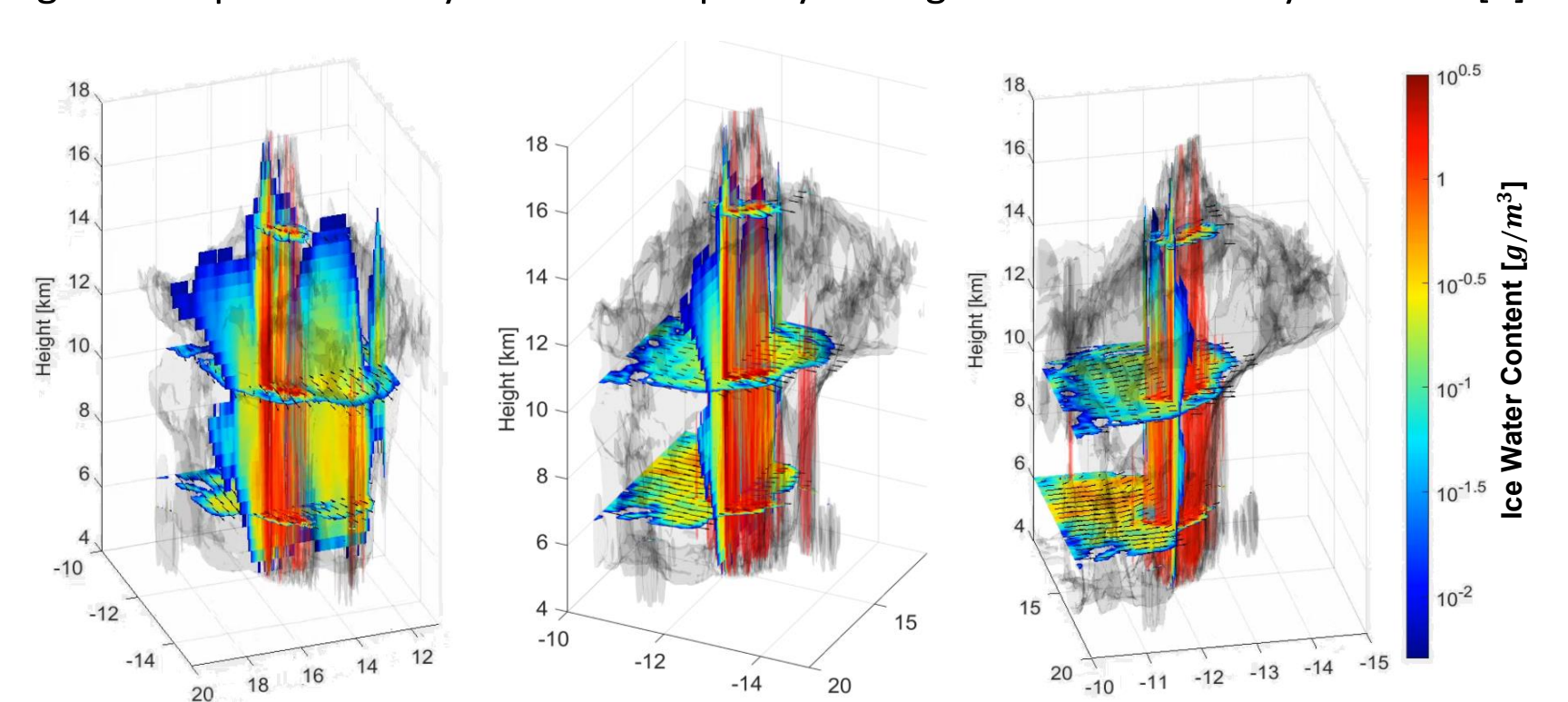
WIVERN measurements and retrievals



- Curtain plots for a sector of the scan passing over the cyclone eye (highlighted in yellow)
- Cross section of the cyclone structure: eye with clear sky at the center, thick eyewall with anvil on top it, under which rainbands and hydrometeors are present, moving away from the eye
- Several of these cuts can be used to reconstruct 3D fields of atmospheric quantities from sparse data
- Thanks to the multiple cross-cuts through the hurricane and reduced surface clutter [6], Level-3 products enable studies about the distribution of wind inside the storm

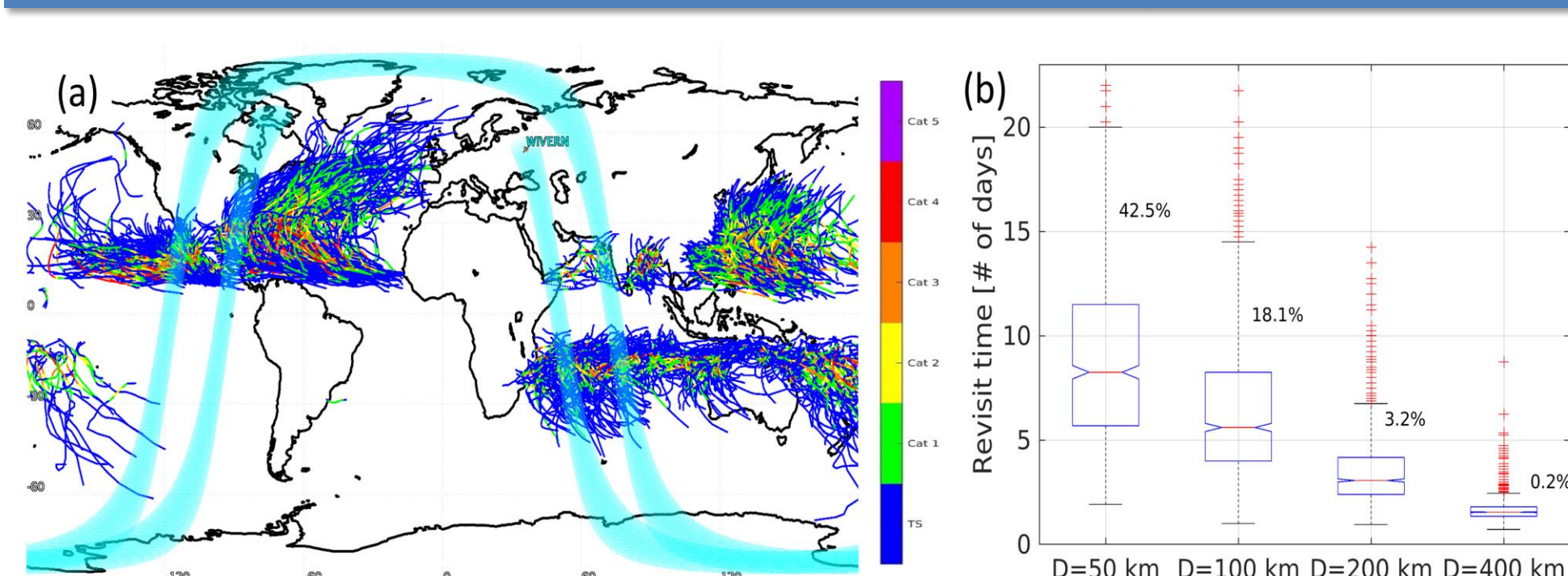
Reconstructing 3D storm structures and dynamics

Horizontal vector winds and ice water contents can be reconstructed on a 3D regular grid from the irregular sparse WIVERN sampling [7], particularly in the glaciated part of the cyclone where plenty of targets are detected by WIVERN [8]

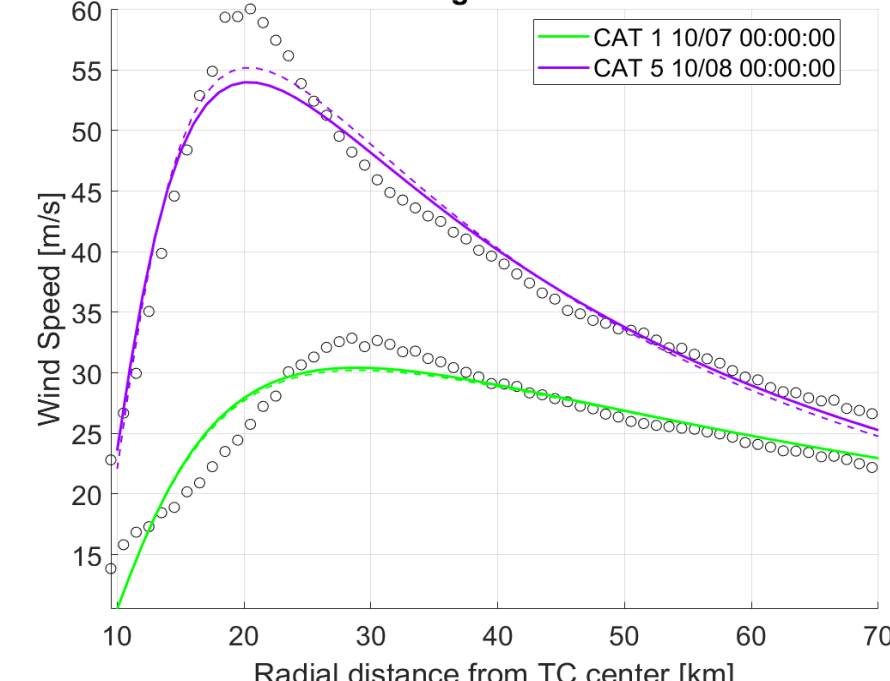


- WIVERN can provide three-dimensional views of the winds inside tropical cyclones, capturing the vertical wind shear and regions of wind convergence and divergence
- Mass of the tropical cyclone anvil can also be profiled, as a function of distance from the eye, thus revealing the mechanisms behind its formation
- For long-lasting systems, WIVERN close-in-time overpasses can capture storm rapid intensification or decay [5].

Tropical cyclones sampling and rapid intensification



- A characterization of the intensity based on a simple model proposed by Holland [9] is used (figure on the right)
- The model is compared with artificial observation for the two consecutive passages labeled 2 and 3 over hurricane Milton, 24 hours apart, before and after rapid intensification
- Distributions in function of distance from the eye before and after the rapid intensification are plotted, as predicted by the model (continuous lines) or as reconstructed from the simulations and retrievals (circles)



- Ground-tracks of the last 35 years TC that reached at least Category 1 are shown on the side with the revisit time for the WIVERN ground-track to pass within a given distance (D) from the TC eye
- The rapid intensification time window of one to two days, is well within WIVERN's average revisit time to capture this dynamic

Conclusions and take-home message

WIVERN will provide for the first time vertically resolved profiles of in-cloud winds and cloud structure across scales from 1 to 1000 km using its ground-breaking sampling and Doppler radar capabilities. This will apply to all storms, including extreme weather phenomena (e.g. tropical cyclones).

These novel measurements will:

- Provide insights in how storm dynamics work;
- Constrain cloud and precipitation in systems (e.g. anvil, stratocumulus clouds and snowstorms) paramount for climate feedbacks;
- Be invaluable for providing initial conditions for Numerical Weather Prediction models and for benchmarking Earth System Models.

Bibliography and Acknowledgements

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All WIVERN publications are available at <https://wivern.polito.it/publications/>
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