The WInd VElocity Radar Nephoscope (WIVERN): a candidate mission to measure global in-cloud winds, clouds and precipitation for the ESA Earth Explorer 11

wiuern

PROBING
CLOUDY SKIES
FOR A WIND OF CHANGE

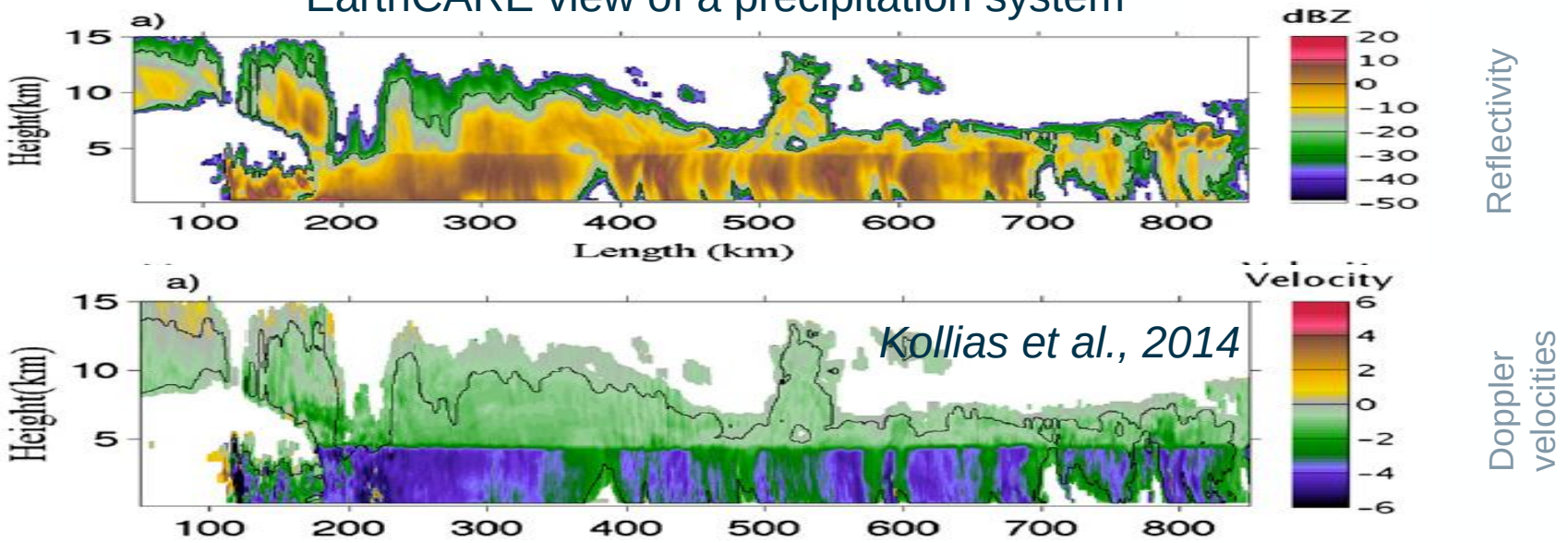
WIVERN MAG, SciRecS, SWEEP and ESA team

presented by A. Battaglia

The revolution of a Doppler conically scanning cloud radar

Early indications from EarthCARE radar data (Kubota's talk) suggest that a nadir-looking cloud Doppler radar can map global sedimentation velocities and vertical motions.

EarthCARE view of a precipitation system



Building on the EarthCARE W-band CPR technology/experience, the WIVERN mission will revolutionise the use of spaceborne cloud radars by introducing

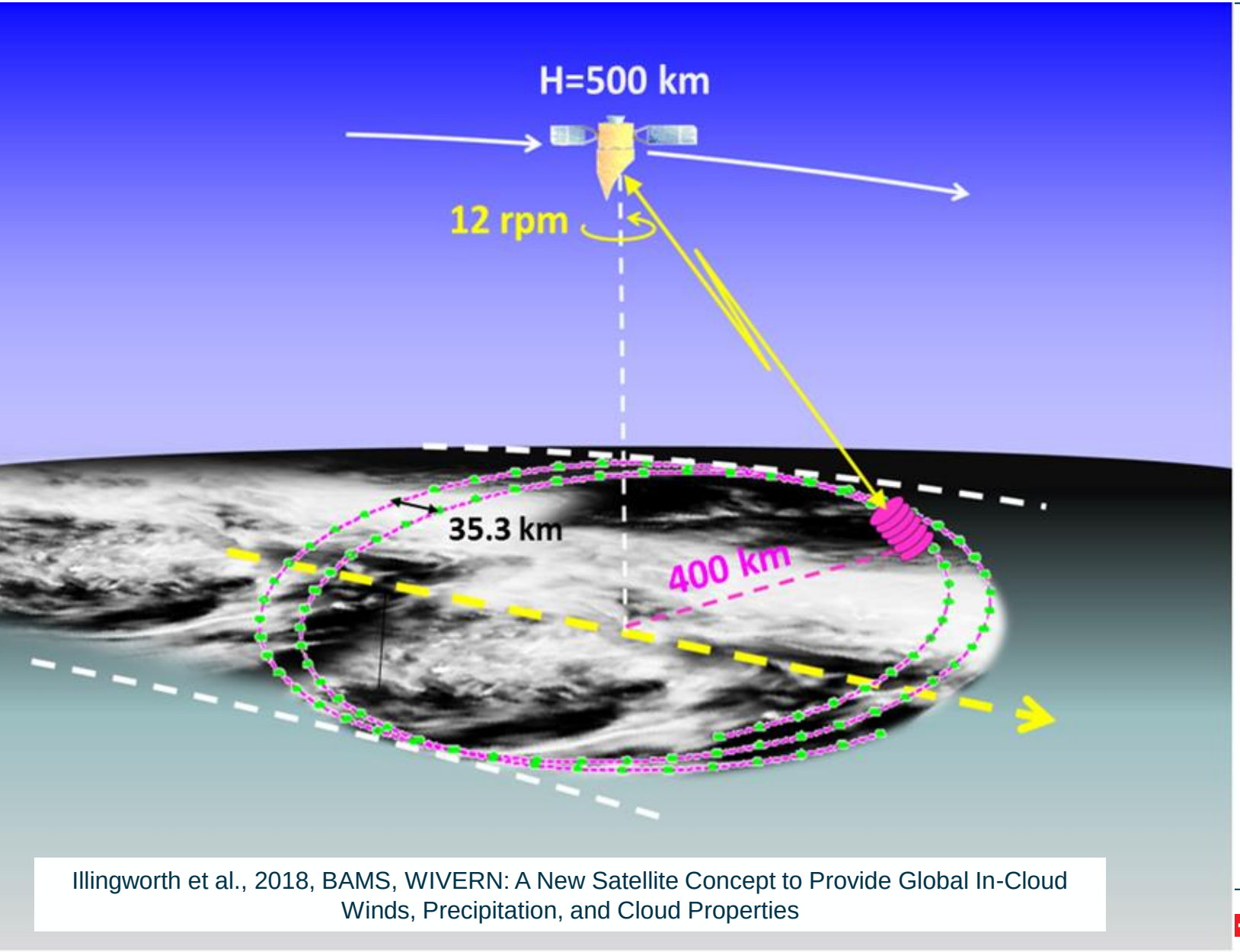
1) wide swath conical scanning;
2) polarization diversity Doppler technology.

This will make possible for the first time from space:

1) to unravel the 3D mesoscale structure of cloud systems (as GPM-DPR has done for precipitation);
2) to acquire Doppler observations of horizontal (high) in-cloud winds.

Flavour how these ground-breaking new capabilities will enable cutting-edge discovery science and high-impact applications.

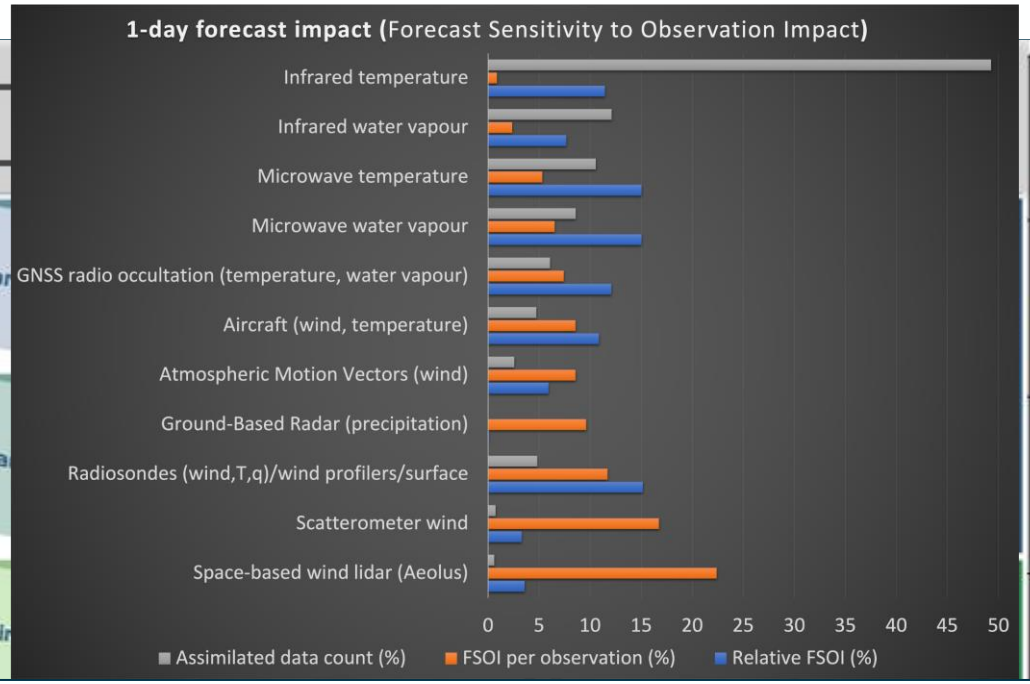
WIVERN radar instrument concept

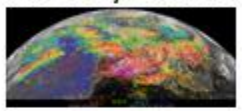
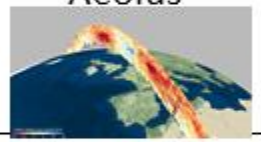


Illingworth et al., 2018, BAMS, WIVERN: A New Satellite Concept to Provide Global In-Cloud Winds, Precipitation, and Cloud Properties

- W-band (94 GHz, -15 dBZ single-pulse sensitivity)
- 500 km altitude, conically scanning at 42º (➔ 830 km swath, 1.5 day average revisit time), ~12 rpm (8 pulses per km)
- Doppler (polarization diversity) for up to ±40 m/s line-of-sight (LoS) horizontal winds
- Big >3 m antenna ($\theta_{3dB} \approx 0.07^{o}$) (vertical resolution of 600 m, horizontal < 1km),

Filling the gap in wind observations



The main sources of wind measurements	Error [ms^{-1}]	Obs available for DA every 6 h	Pros & Cons
GEO VIS/IR AMV 	~4	≈5,000,000	Quasi global coverage at high temporal resolution; only cloud tops with uncertainties related to height
Aeolus 	~4 or >	≈50,000	Vertical profiles in clear sky and in thin clouds. Moderate errors for Rayleigh winds, low revisit time
Aircraft 	~2 or >	≈270,000	Very accurate; vertical profiles near airports; only at flight time/height

Two specific WMO recommendations:

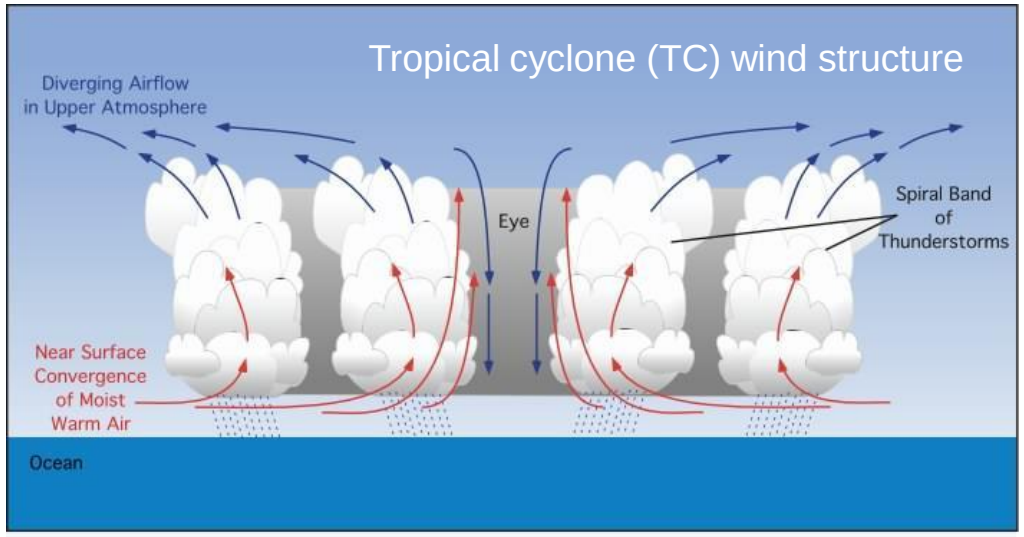
- *"Space agencies are encouraged to continue pursuing wind profile measurements from space."*
- *"Effort is encouraged to assess complementarities/synergies between different wind measurement systems/technologies (e.g. Aeolus and AMV)."*

WIVERN will provide f**or the first time**, **global observations of the vertical structure of winds in <u>cloudy regions,</u>** *complementing measurements of future space-borne Doppler lidars (e.g. Aeolus-2).*

Why horizontal winds in cloudy-regions?

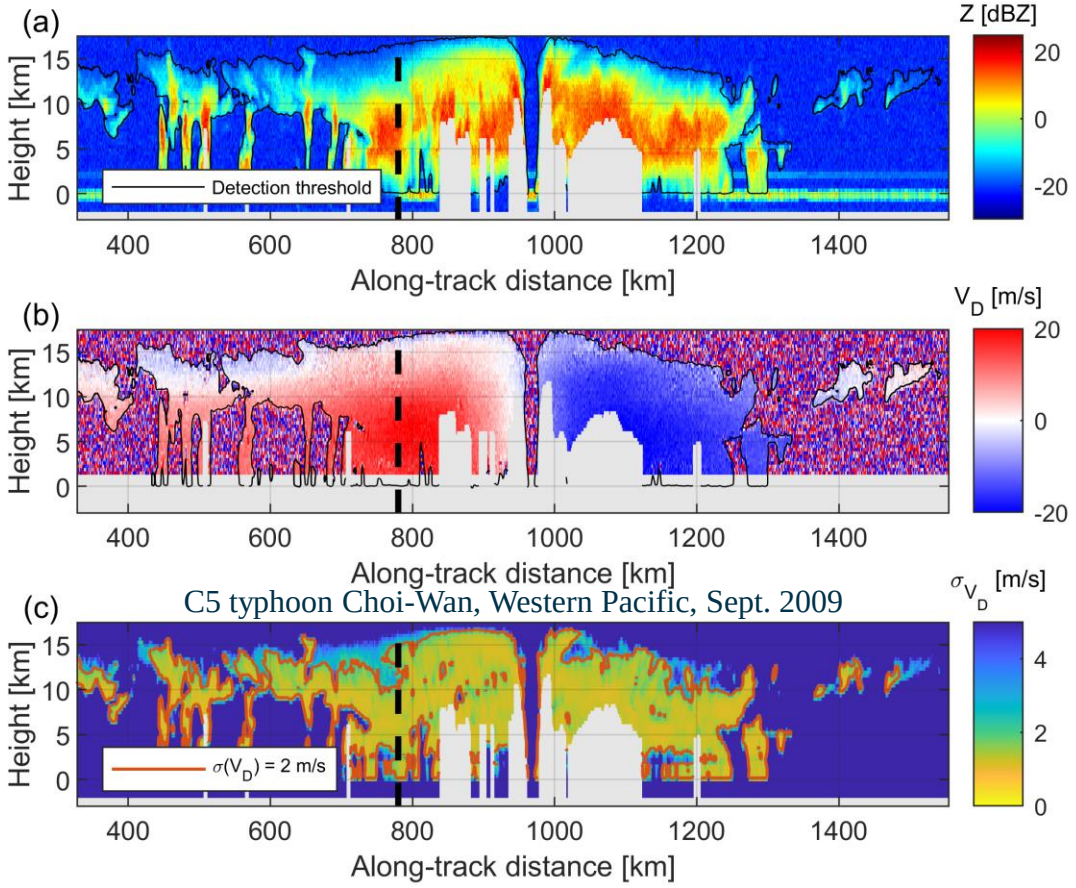
Science question

What are the **dynamical characteristics** of **weather systems globally**? How does the **mesoscale airflow** relate to **the intensification and decay** of damaging tropical & mid-latitude **storms**?

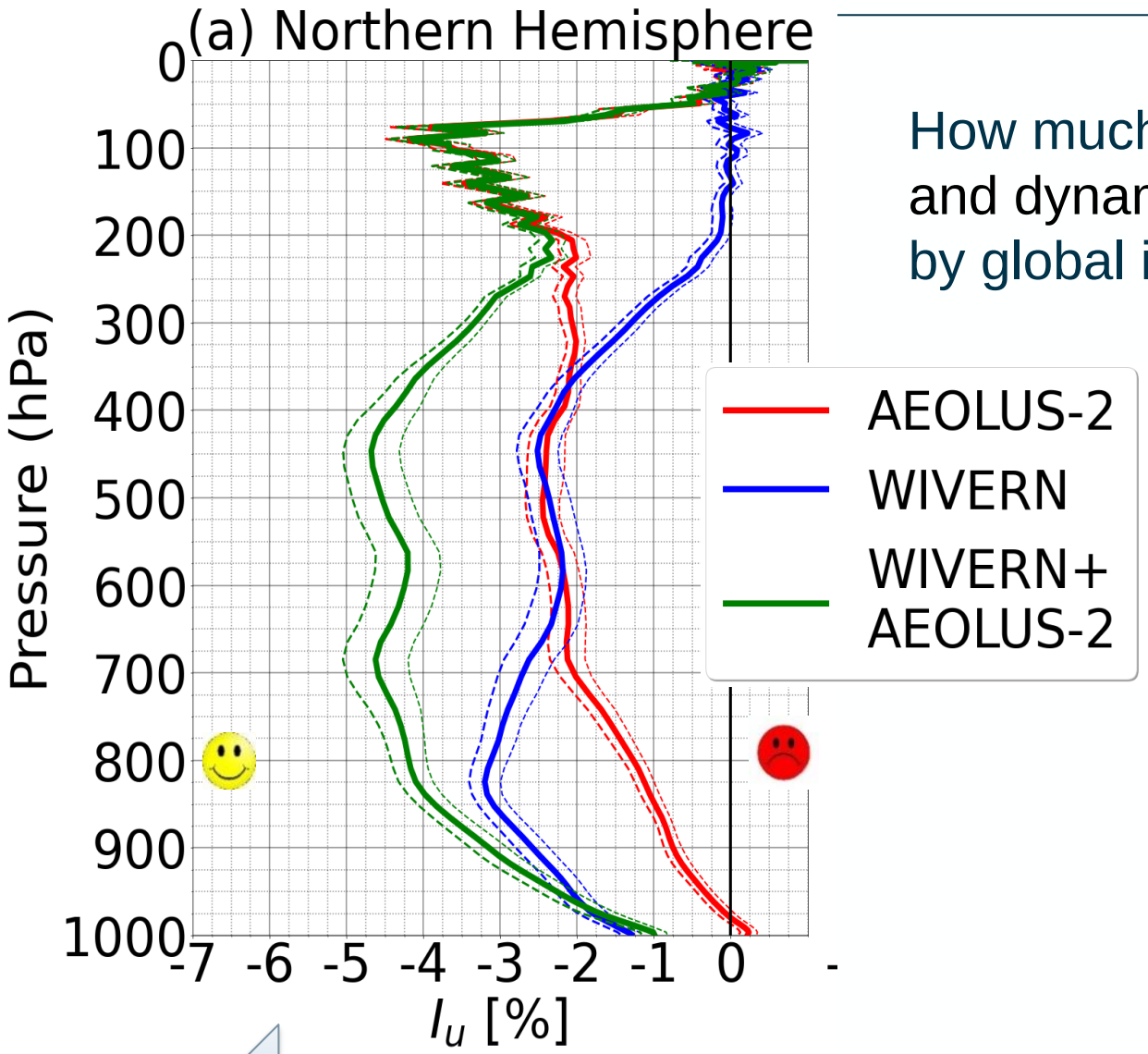


Simulations built on a 3-year CloudSat-based dataset ➔ WIVERN will be able to map winds particularly inside the glaciated part of TC (≈200M winds with error less than 3 m/s every year)➔ improve our understanding of the processes driving their evolution, hence their forecast.

Tridon et al., 2023, Earth and Space Science
Filling the Gap of Wind Observations Inside Tropical Cyclones,



Why horizontal winds in cloudy-regions?



Impact question

How much can weather predictability (timing, structure, and dynamics of the state of the atmosphere) be advanced by global in-cloud wind measurements?

Experiment conducted by Meteo France in 2022-2023 (on going Observing System Simulation Experiment)

Aeolus used as touchstone: clear-air and Mie Aeolus winds **significantly improved the forecasts of NWP models** (e.g. Rennie et al., 2021) ➔ wind observations provide the largest impact per observation in DA

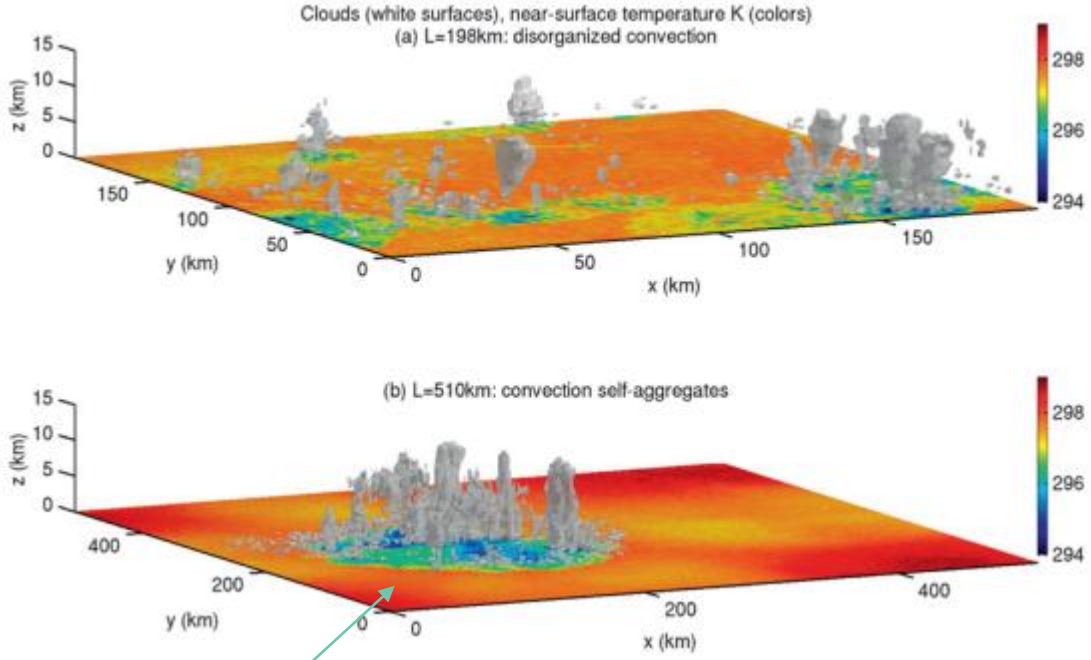
- **The assimilation of the WIVERN** in-cloud winds **further improves NWP forecast accuracy** with high impact in low troposphere and mid/high latitudes ➔ WIVERN complementary to Aeolus

WIVERN: a new look at mesoscale organisation

Science question

How do environmental properties such as wind shear, aerosol load, sea/land surface temperatures influence **the organisation of mesoscale convective systems**, the profile of **detrained ice mass** and their **efficiency in producing precipitation**?

How will the convective organization and the anvil clouds change with climate warming ?



Small scale simulation:
pop corn convection

Large scale simulation:
self-aggregation

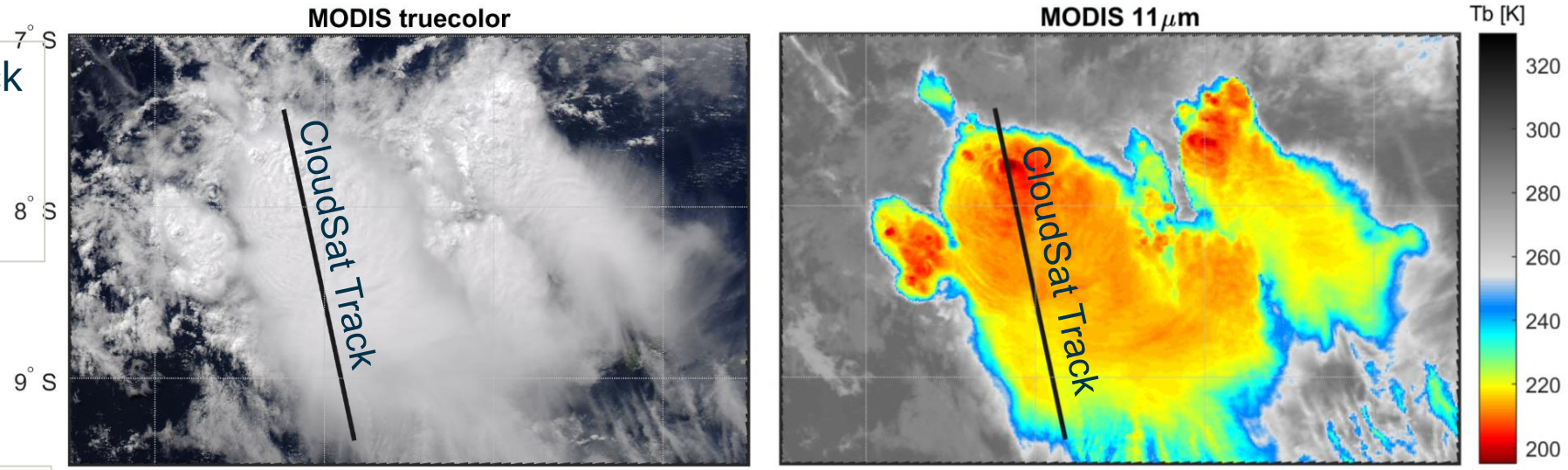
Only one convectively active moist region

Extracted from Muller & Held 2012

WIVERN: a new look into mesoscale organization

CloudSat/EC 1 km wide track

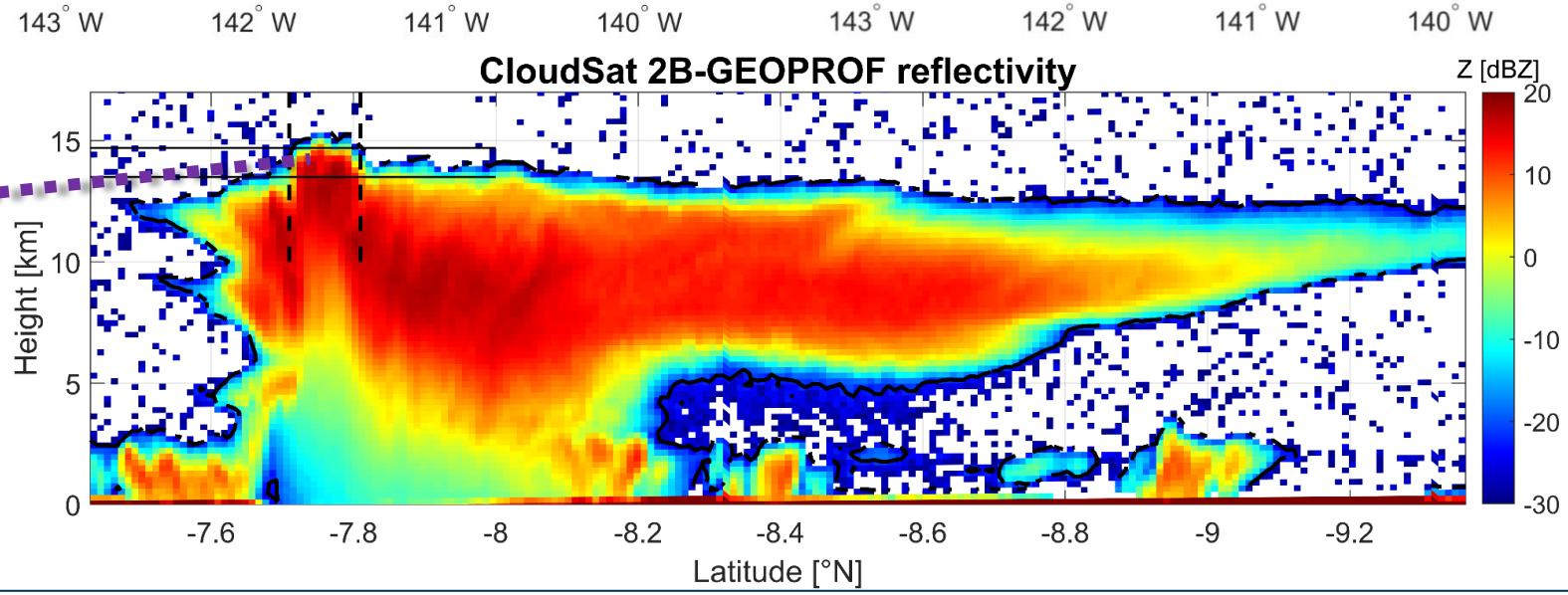
Compare with MODIS visible and IR track



CloudSat provides a single vertical slice of radar reflectivity

Overshooting convection

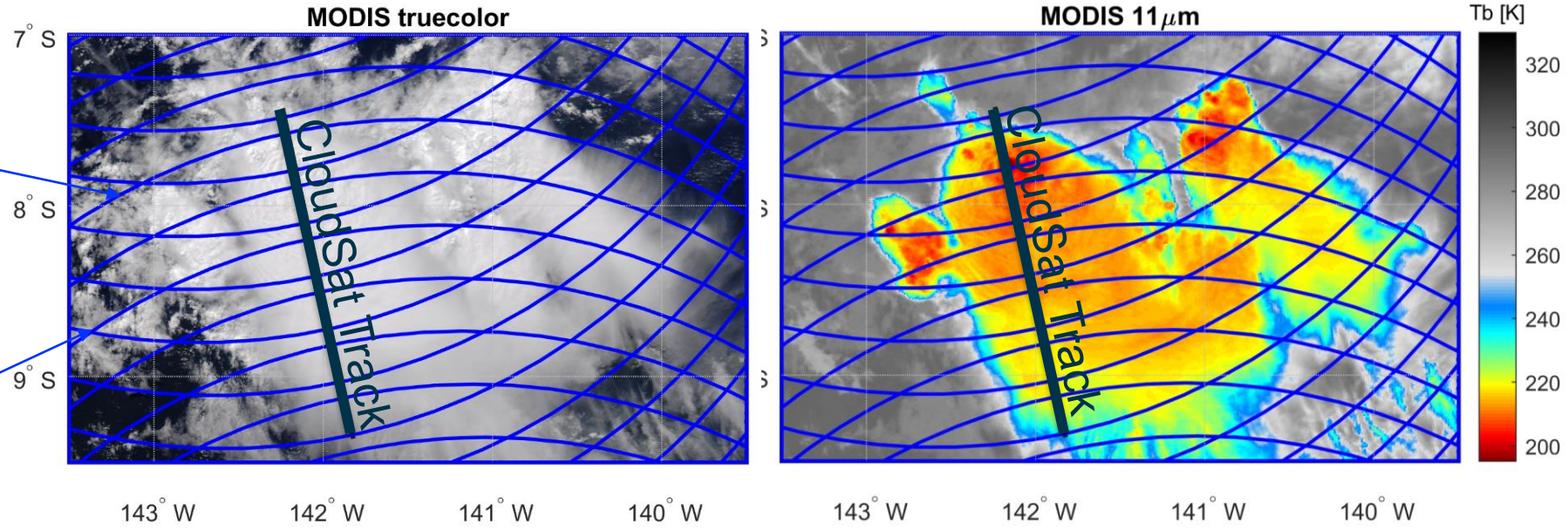
Extensive anvil

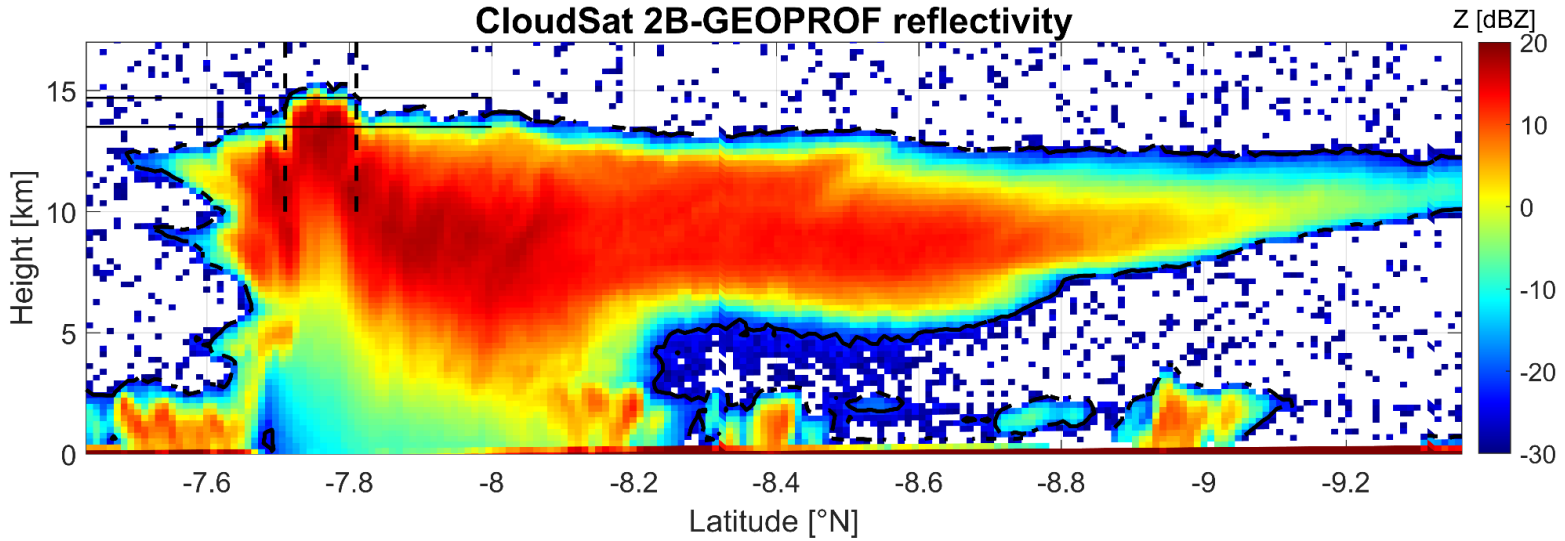


WIVERN mesoscale perspective

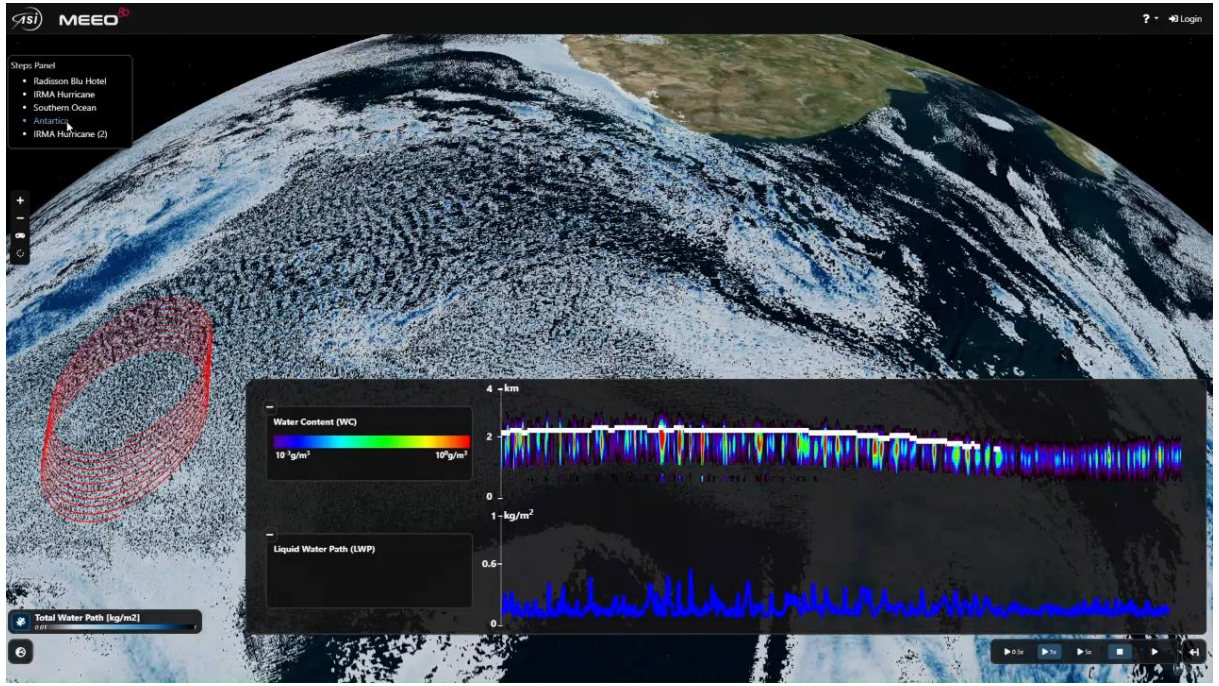
WIVERN will provide multiple vertical slices through the whole storm and will capture the mesoscale structure.

Geostationary will fill the gaps between the WIVERN slices at the overpass time + propagation backward/forward in time

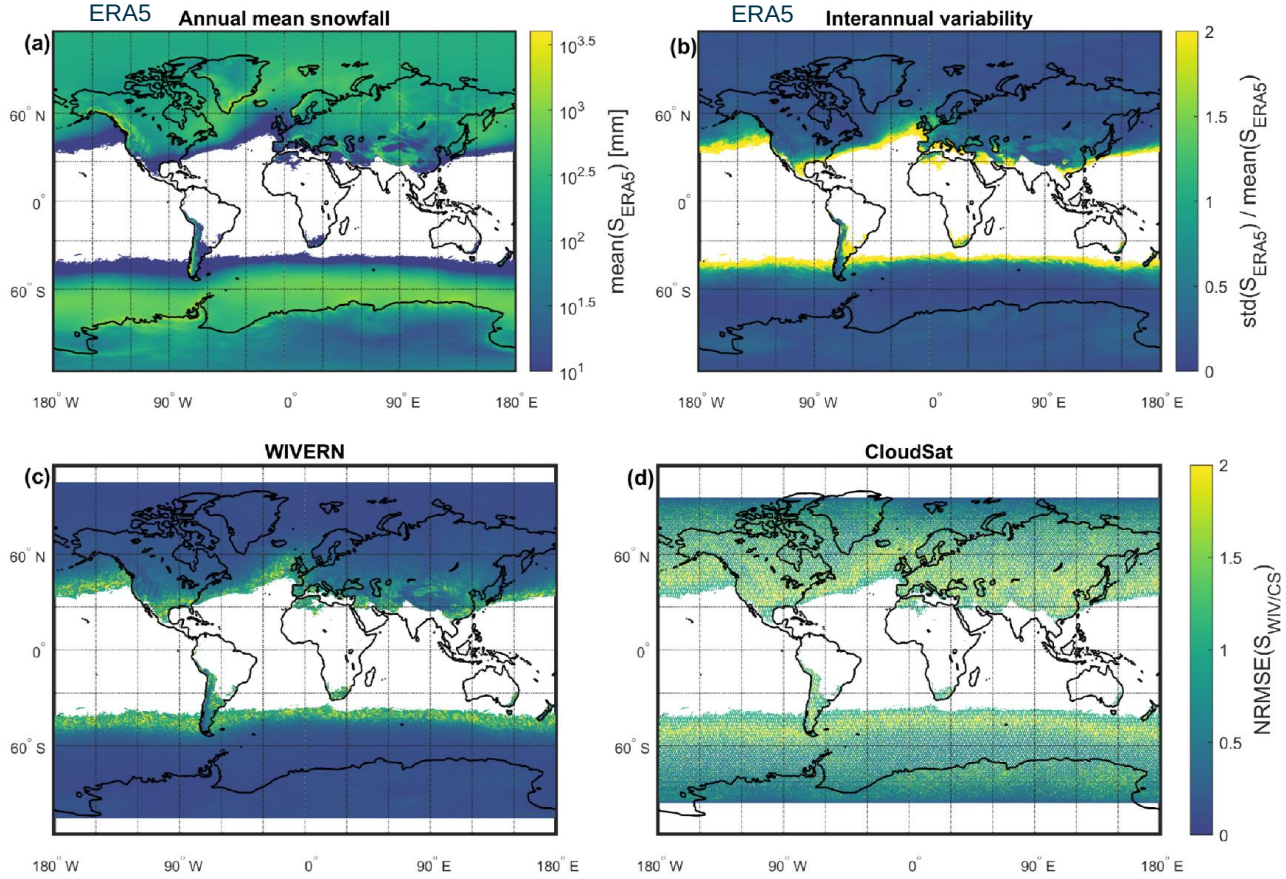




The sampling revolution for cloud&precipitation products



Example: for snowfall product
at 0.25º x 0.25º annual scale



Sampling errors are the dominating source of errors in radar-based cloud/precipitation products.

WIVERN will be able to provide statistically significant mean vertical profiles of clouds and precipitation at the regional level on monthly temporal scales ➔ key to validate the next generation of Earth System models or regional modelling (e.g. ice sheet balance)

Scarsi et al., 2024, Cryosphere, How to reduce sampling errors in spaceborne cloud radar-based snowfall estimates, submitted

Summary (focus on science aspects)

WIVERN mission hinges upon a cutting-edge **wide-swath conical scanning W-band radar with polarization diversity Doppler capability.**

1) The large Nyquist velocity will enable **measurements of horizontal winds in high-impact weather** such as tropical cyclones (Level 2 wind product).
This will help addressing SQ on the intensification and decay of damaging tropical & mid-latitude storms and provide unique measurements for DA (with strong societal impact via NWP), perfectly complementing the GOS envisaged for the 30s.

2) The large swath will unravel the **3D mesoscale structure of convective cloud systems** directly addressing SQ on convective organization and detrained mass in the anvil.
Despite reduced sensitivity (-20 dBZ @1km) WIVERN Z-based products will make possible to build **cloud&precipitation datasets (snowfall, light rainfall, condensed mass vertical profiles) at unprecedented spatial and temporal scales** ➔ key to validate regional modelling and the next generation of km-scale Earth System models.

Thanks for the attention

Paper and info @ www.wivern.polito.it

wiuern

PROBING
CLOUDY SKIES
FOR A WIND OF CHANGE

talking about revolution ….
«The future's in the air
I can feel it everywhere
blowing with the wind of change»
from Wind of change by Skorpions