WIVERN: a Mission to Observe Global in-cloud Winds, Clouds and Precipitation as part of the ESA Earth Explorer 11 Programme

esa

wivern

PROBING
CLOUDY SKIES
FOR A WIND OF CHANGE

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all the WIVERN MAG and ESA team

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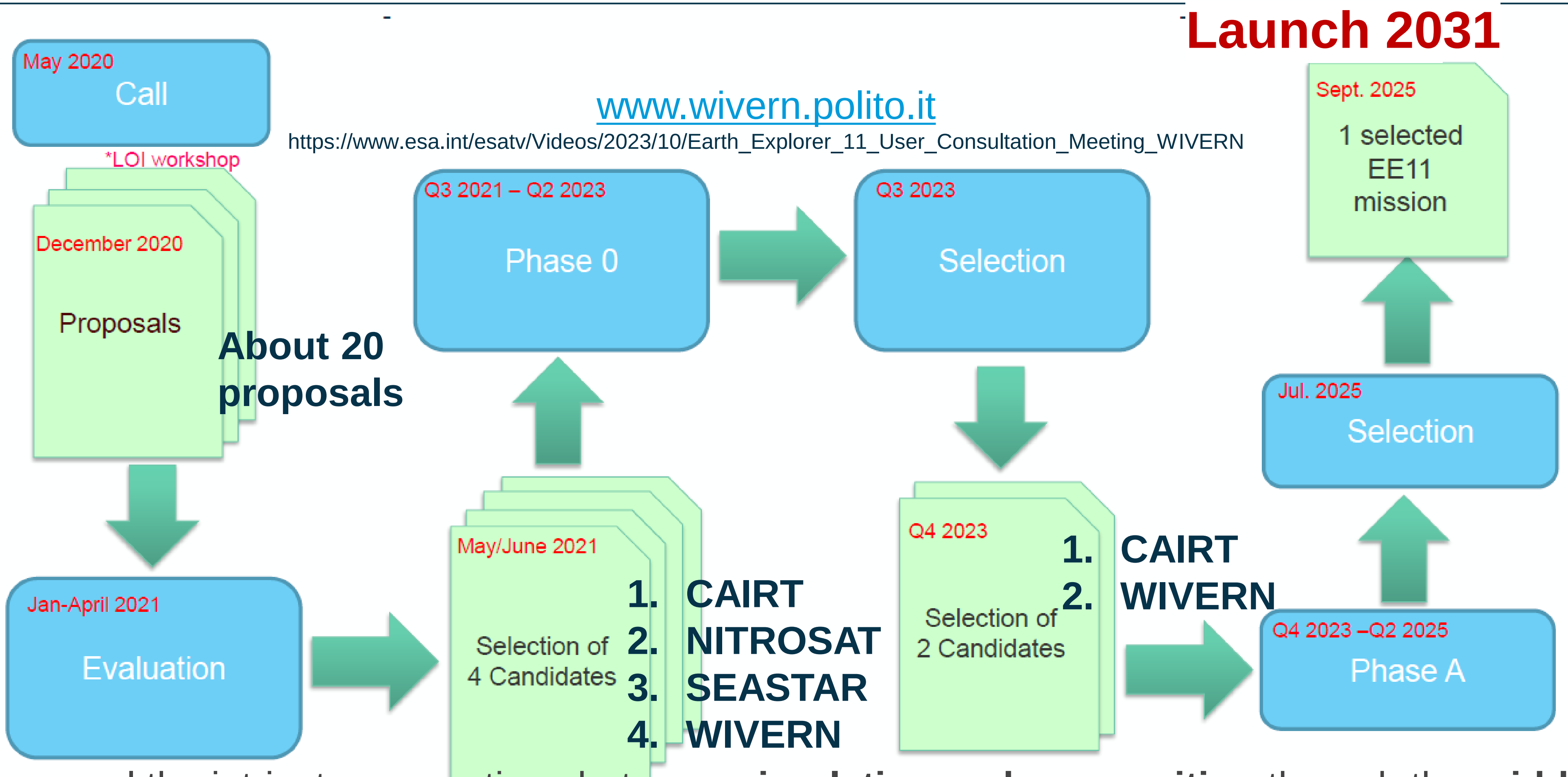
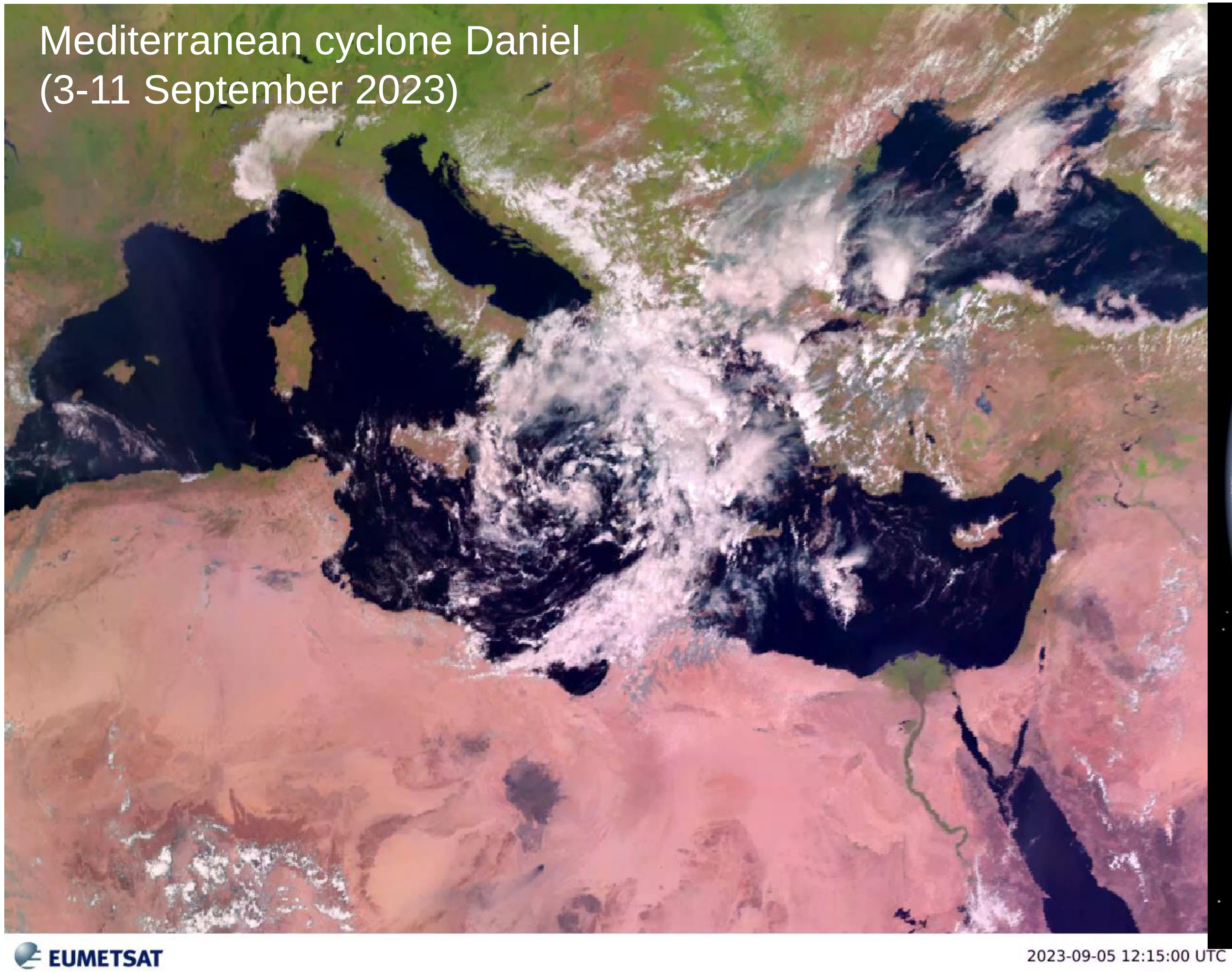
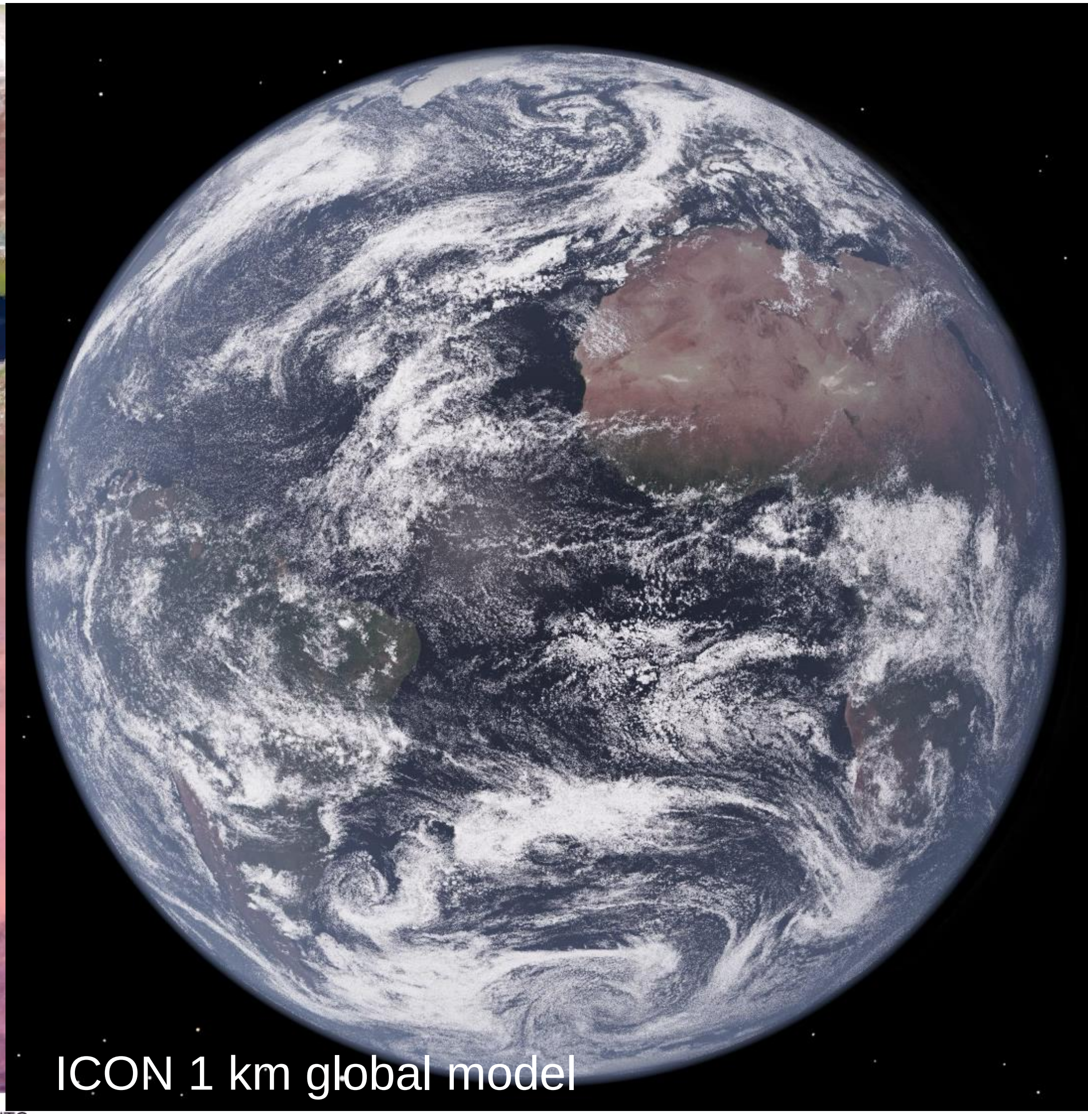
ESA Earth Explorer 11 roadmap



CAIRT: unravel the intricate connections between **circulation and composition** through the **middle atmosphere**.
NITROSAT: detecting **reactive nitrogen** from farms, industries, transport, fires and urban areas.
SEASTAR: observing **small-scale ocean dynamics** in coastal areas, shelf seas and the marginal ice zone.
WIVERN: deliver the first space-based observations of **in-cloud winds**.

Why WIVERN? The next decade perspective





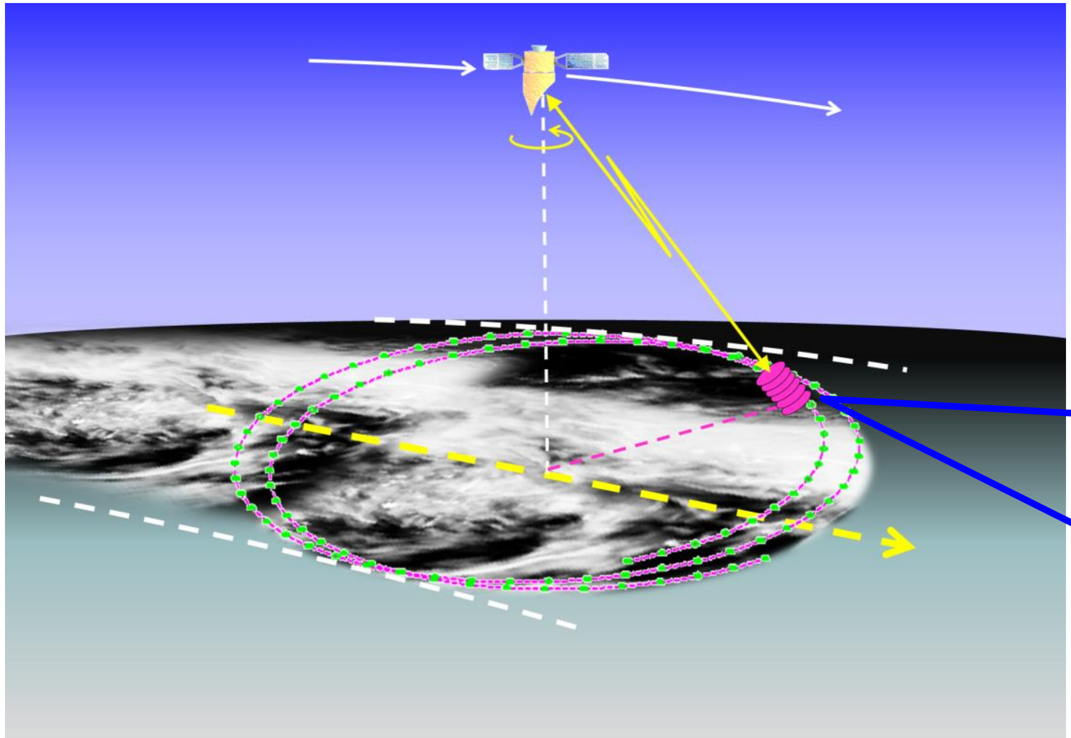
Three Scientific Pillars of WIVERN

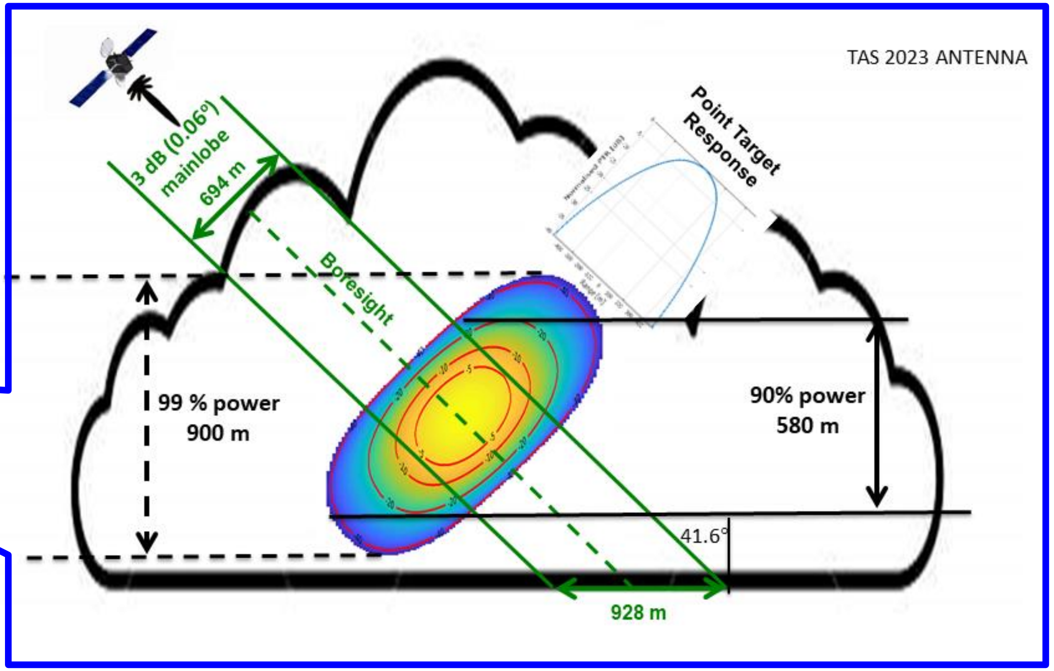
Pillar	Question
Wind	➢ Can we measure **3-dimensional winds within clouds** to better define the state of the Earth's atmosphere and its dynamics on a global scale?
Clouds & Precipitation	➢ Can WIVERN improve **clouds and precipitation representation in the next generation of km scale global models**, and enhance **confidence in our prediction of regional climate change**?
Convection	➢ Can WIVERN help **better understanding the dynamics of convection and its impact on moisture transport?**

The science impact question: can WIVERN also demonstrate a significant positive impact on weather forecasting?

How? The WIVERN Instrument

- W-band (94 GHz, -15 dBZ single-pulse sensitivity, -20 dBZ @1 km integration)
- 500 km altitude, conically scanning at 42^o (830 km swath), ~12 rpm (8 pulses per km)
- Doppler (polarization diversity, T_{HV}=20 μs) for up to ±40 m/s line-of-sight (LoS) horizontal winds
- Big >3 m antenna (θ_{3dB}≈0.07^o) (vertical resolution of 600 m, horizontal < 1km),
- Radiometric mode with km-scale resolution and ~2 K relative accuracy
- Polar orbit with 1.5 day average revisit time





Through what? WIVERN L2 Data Products

Doppler measurements

Reflectivity and brightness temperature measurements

Wind products

Horizontal wind speed component

Convective classification and vertical motion

Cloud & precipitation products

Rain/Snow Rates

Liquid Water Path

Ice Water Content

WIVERN Flagship Product

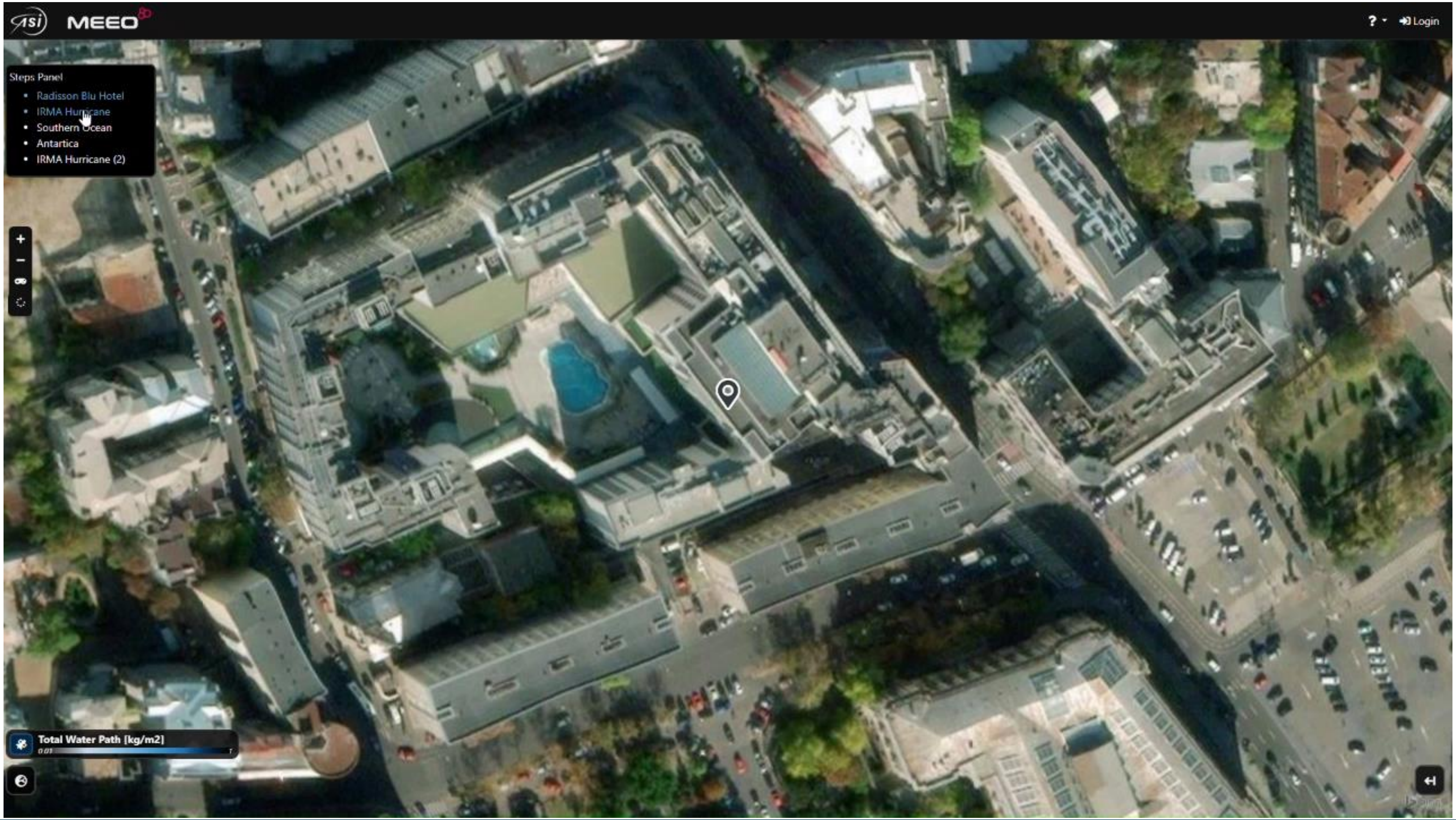
- Wind Horizontal Line-of-Sight product

$$V_{HLoS} = \frac{V_{LoS} - V_{NG}\,(\theta_i, \phi) - (w + V_T^D)\cos(\theta_i)}{\sin(\theta_i)}$$

- Synergy with EC for mass-relevant cloud/precipitation &convection products

Horizontal Line-of-Sight Wind

https://dev.explorer.wivern.adamplatform.eu/



Horizontal Line-of-Sight Doppler velocity error budget

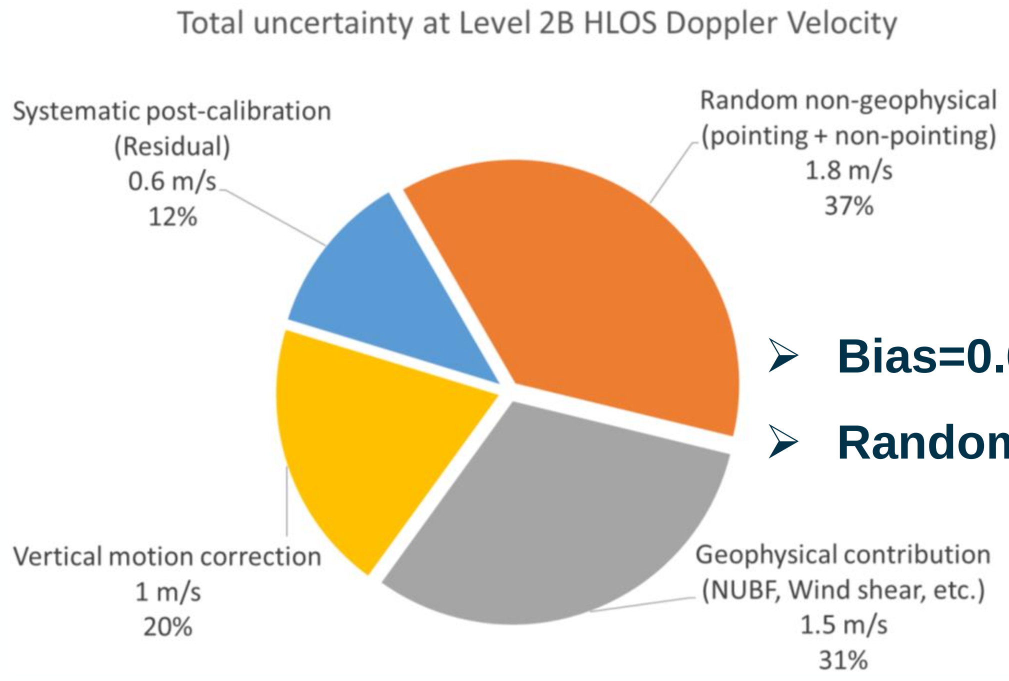
Level 2B HLoS
Total uncertainty

Total uncertainty HLoS
2.65 m/s (G) / 2.80 m/s (T)

Random/s

Horizontal

Geoph



WMO requirements for NWP

	HLoS Uncertainty	Horizontal Resolution	Vertical Resolution
Goal	0.7 m s^{-1}	15 km	0.5 km
Breakthrough	2.1 m s^{-1}	100 km	0.7 km
Threshold	5.6 m s^{-1}	500 km	1 km

- **Bias=0.6 m/s**
- **Random= 2.5 m/s**

uncertainty of ~2.7 m/s

threshold compliant

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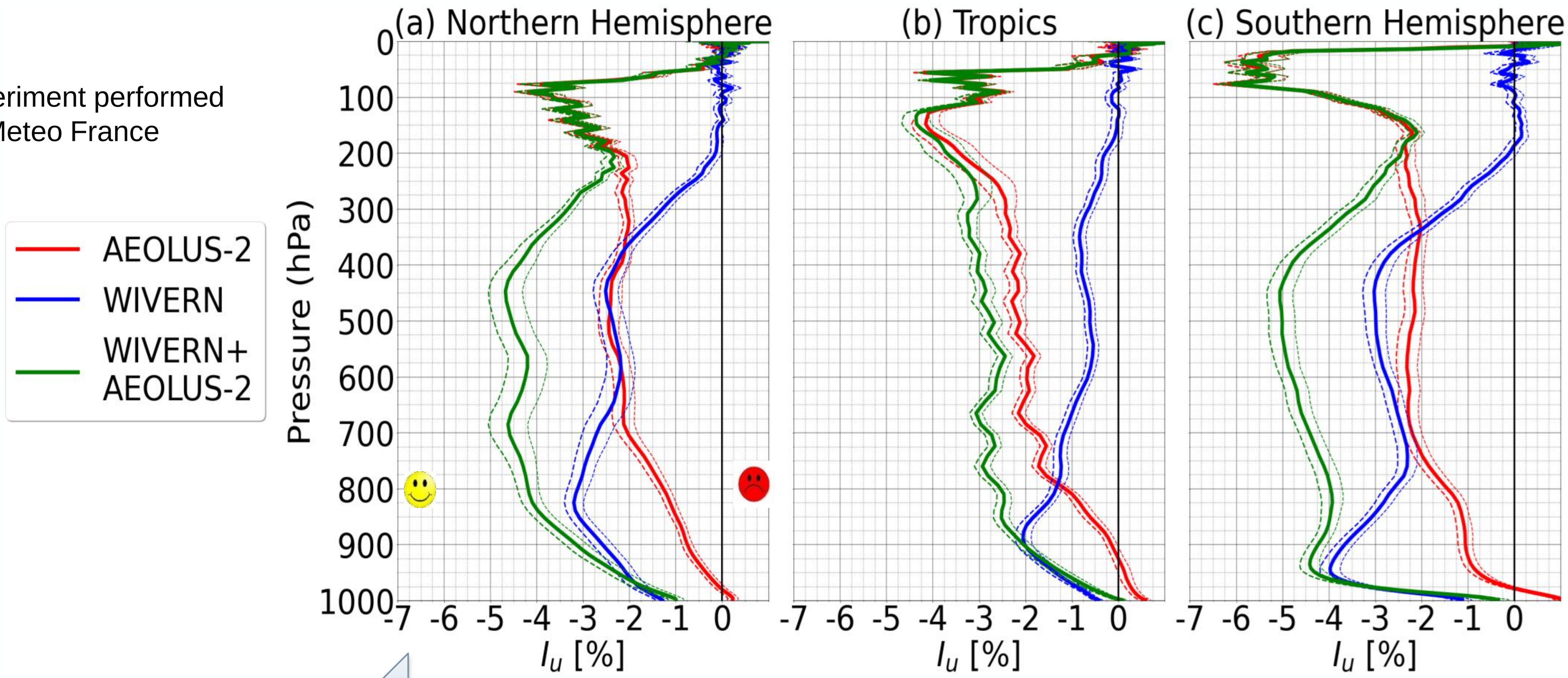
WIVERN + Aeolus-2: complementary Impact

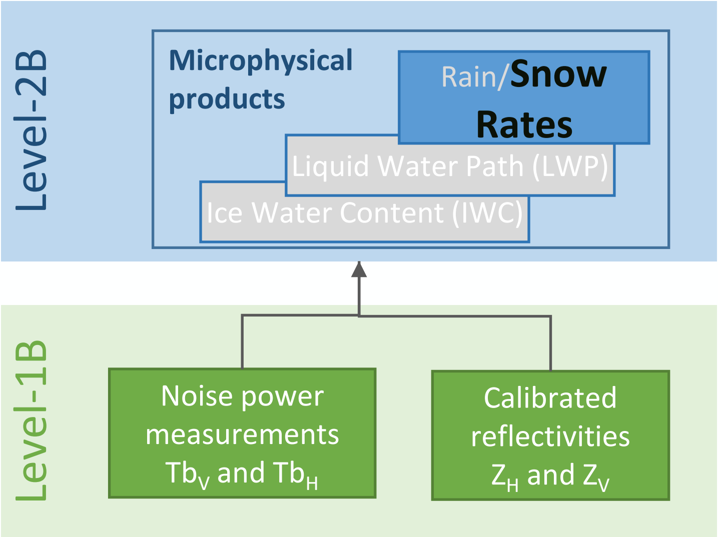
- **The assimilation of Aeolus** (spaceborne Doppler lidar) clear-air and Mie winds **significantly improved the forecasts of NWP models** (e.g. Rennie et al., 2021) ➔ wind obs provide the largest impact per observation
- **Does the assimilation of the WIVERN** in-cloud winds f**urther improve NWP forecast accuracy?**

EDA experiment performed at Meteo France



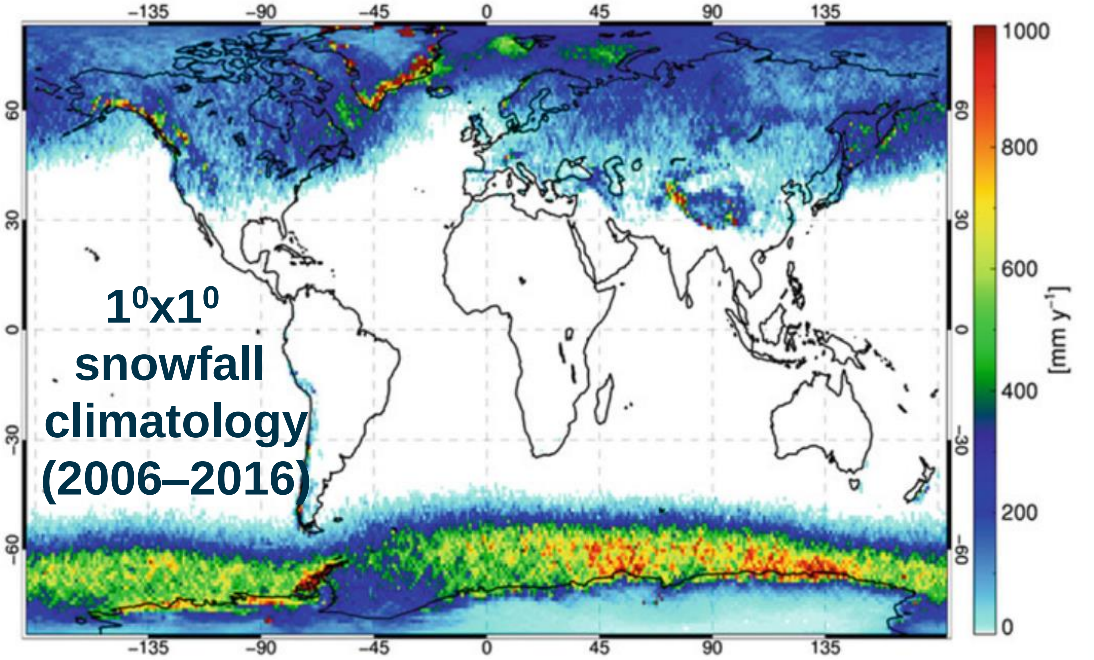
Reduction of the EDA spread

Z&T_B-based products: snowfall rate



- ❑ Snowfall is paramount to understand cryosphere (ice sheet mass balance) and the energy budget in polar regions (latent heat).
- ❑ Radar retrievals based on well established power-laws: Snow Rate=f(Z,T).
- ❑ CloudSat was the best source for snowfall climatology and training datasets but poor sampling

Kulie et al., 2020



Three advantages of WIVERN

1. 70 times better spatial sampling than CloudSat and upcoming EarthCARE due to scanning
2. Radiometer mode & polarimetric measurements can reduce uncertainties
3. Reduced ground clutter blind zone especially over ocean

Gauging the anvil mass in organized mesoscale systems

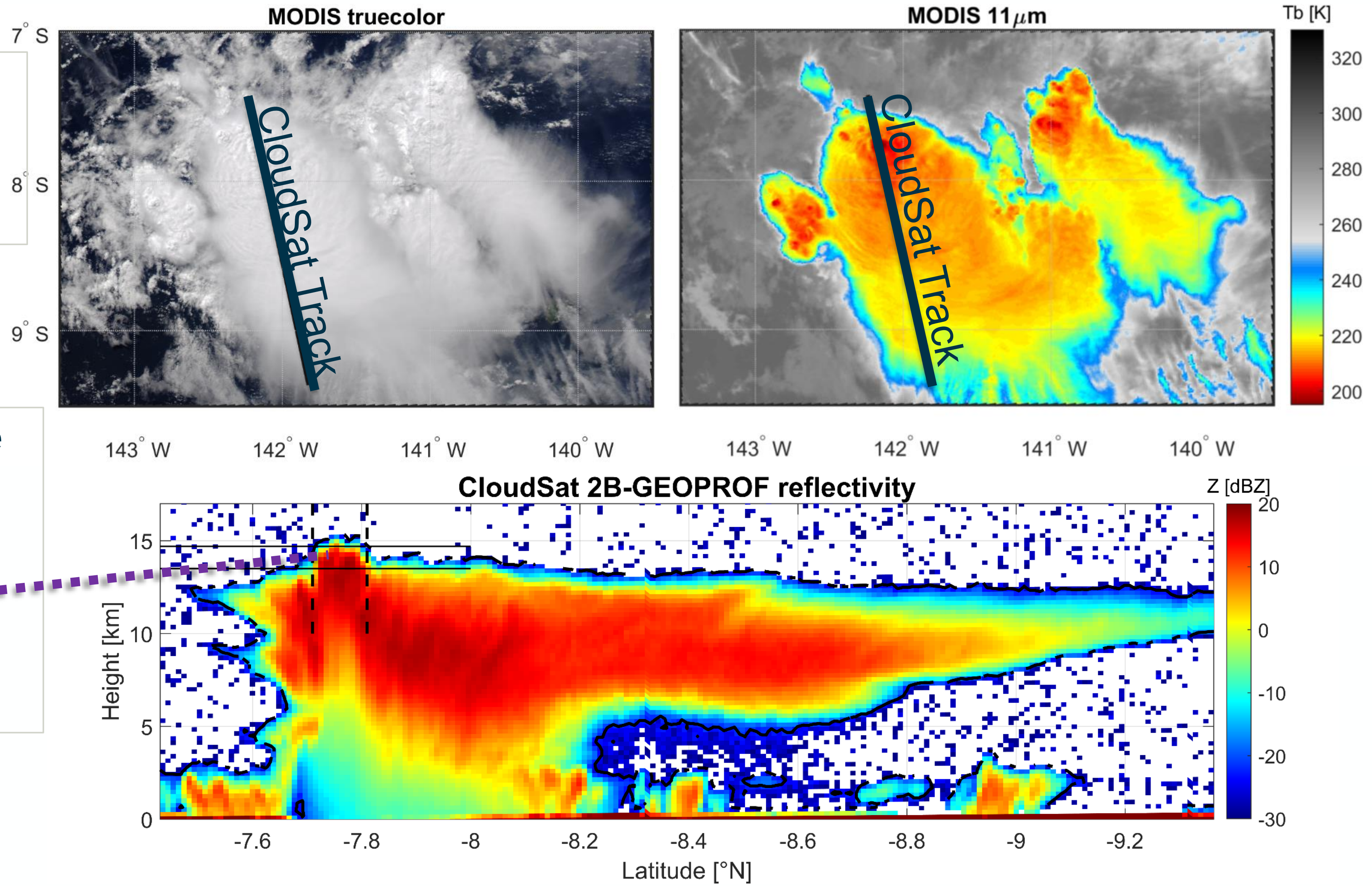
CloudSat 1 km wide track

GEO provides general context via VIS/IR images

CloudSat provides a single vertical slice of radar reflectivity

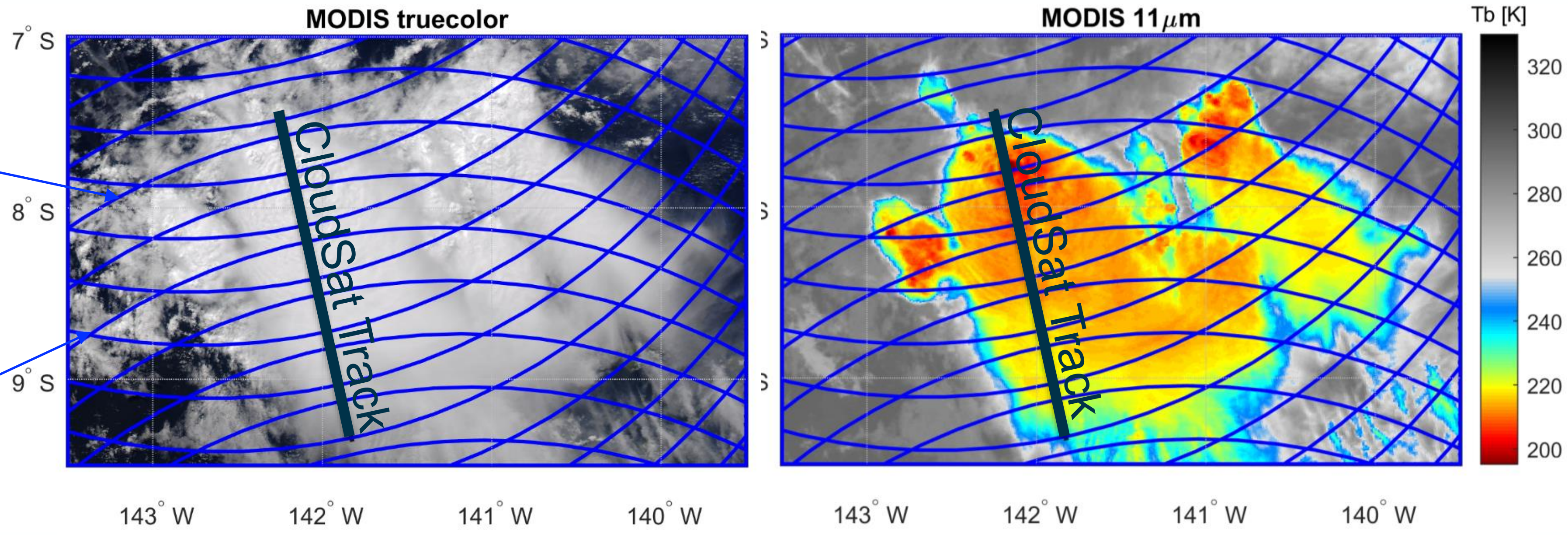
Overshooting convection

Extensive anvil

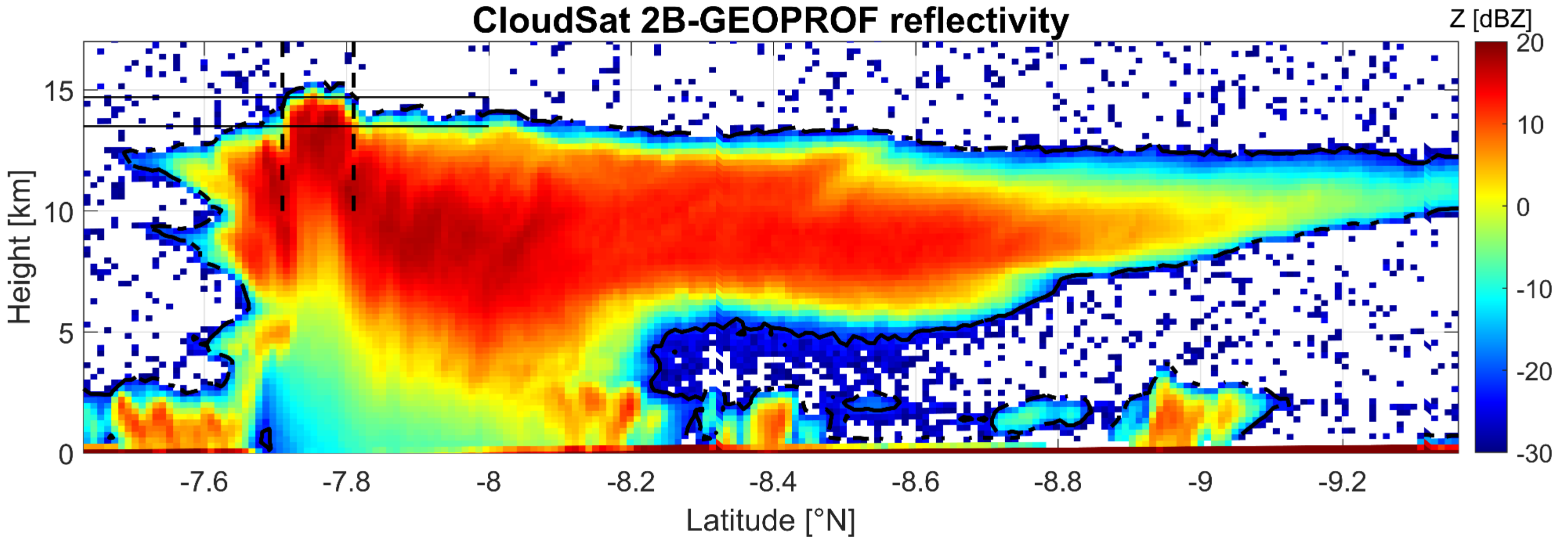


Gauging the anvil mass in organized mesoscale systems

WIVERN will provide many more vertical slices through the whole storm.



Geostationary will fill the gaps at cloud top between the WIVERN slices and also provide temporal evolution



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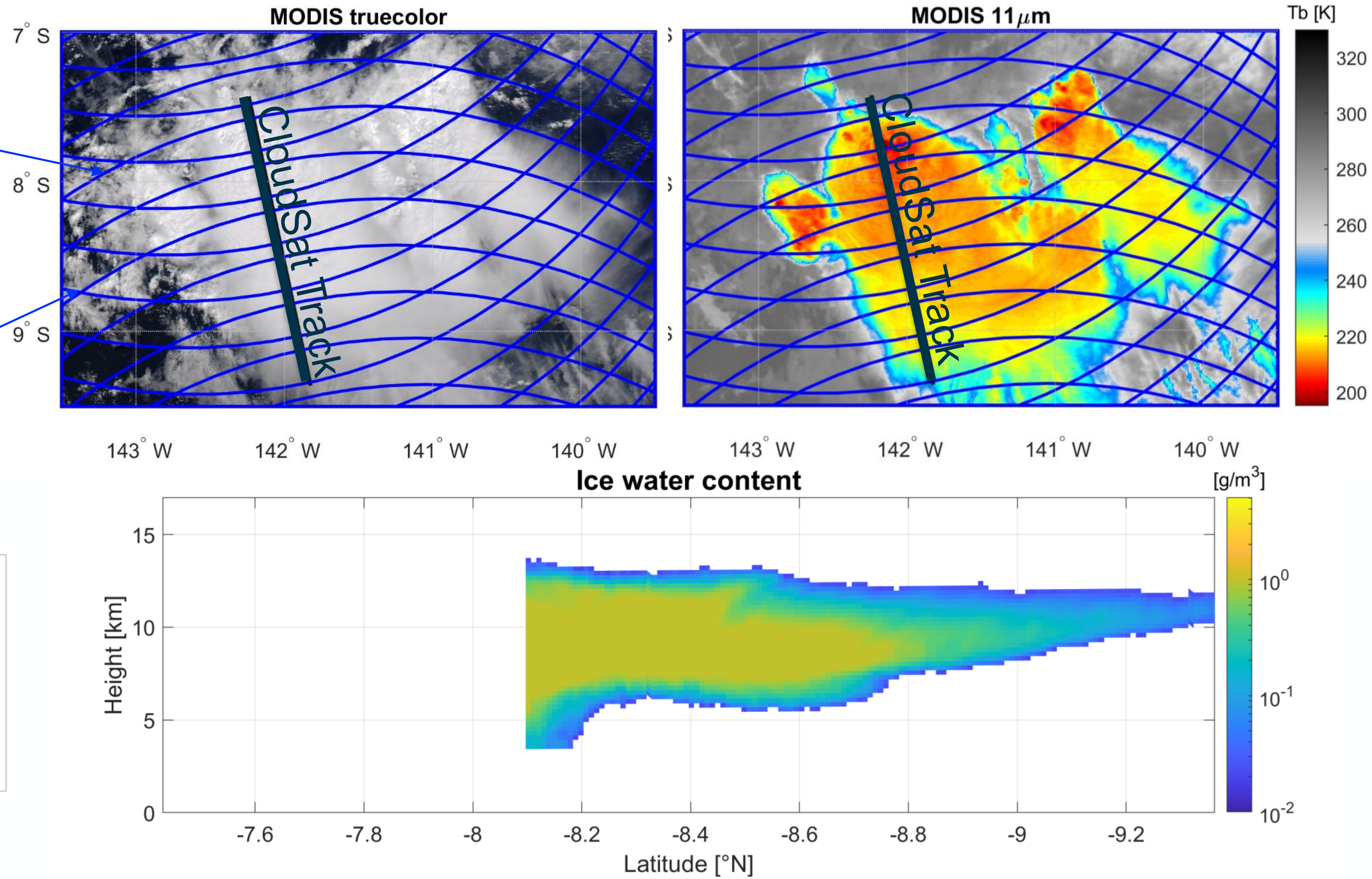

Estimate of ice water content in the anvil.

Helps estimate convective mass flux in the storm.

Conclusions and outlook

- WIVERN was one of the 4 ESA EE11 candidate missions, now **recommended for Phase A** by ACEO
- Hinges upon a single cutting-edge **conically scanning W-band radar with polarization diversity Doppler** ➔ large Nyquist for sampling winds in **high-impact weather** such as tropical cyclones
- Flagship product: **vertically resolved in-cloud winds** over a large swath ➔ plenty of accurate (<3m/s) winds (>2 million line of sight wind measurements at 20 km resolution per day) with a **significant impact on data assimilation** (complement Aeolus 2 in cloudy mid/low troposphere)

Synergy/complementarity with EC

❖ EarthCARE: **characterization of W-band vertical Doppler** (NUBF corrections, sedimentation)

❖ WIVERN: extension of **mass-important cloud/precipitation products** for **climate record** (no other 94 GHz proposed for 2030-40 decade), lower sensitivity but **30-40 times better sampling**(revisit each 20x20 km^2 box on average every 1.6 days at the equator and daily at mid-latitudes).

❖ Possible synergistic activities

- **Algorithm development** (e.g. warm rain/convective snowfall, based on Z&T_B)
- Development of **synergy with GEO** (e.g. for convection/anvil characterization)
- **CAL/VAL and data assimilation of Z and T_B** (EDA experiment planned for WIVERN at ECMWF)

Thanks for the attention

Paper and info @ www.wivern.polito.it

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***«The future's in the air
I can feel it everywhere
blowing with the wind of change»***

from Wind of change by Skorpions