

Impact of WIVERN wind observations on NWP Arpege model using an Ensemble Data Assimilation method

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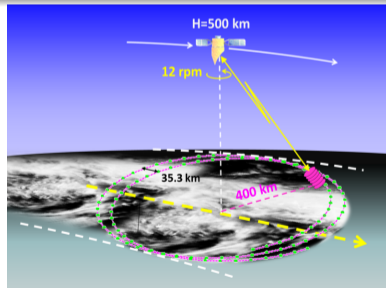
International Wind Workshop Group 16, Montreal 8 -12 may 2023



Context

- Lack of direct wind observations in the current WMO Global Observing System (OSCAR 2018).
- To fulfill this gap, WIVERN mission was selected by ESA as one of the Earth Explorer 11 candidate missions to enter Phase 0 (down selection to enter phase A in october 2023).

- Conically scanning dual-polarisation Doppler W band radar.
- 800km wide swath and a vertical resolution of 640m.
- Horizontal resolution $\approx 20\text{km}$.
- In-cloud wind observations.



■ Objectives

- Assimilate simulated WIVERN observations to evaluate its impact on NWP model forecasts.
- Compare this impact with other existing wind observations (AEOLUS)

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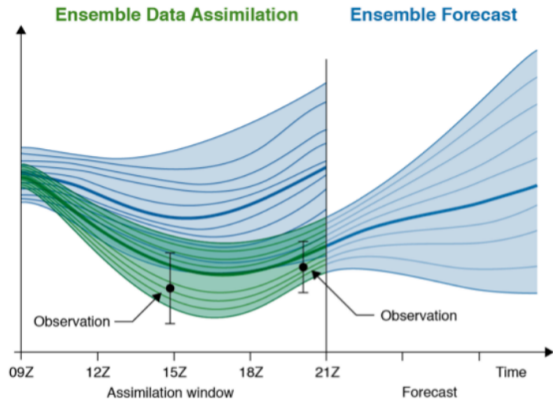
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■ Outline

- Methodology : use of an Ensemble Data Assimilation (**EDA**) approach.
- Impact assessments.

The EDA method from ECMWF

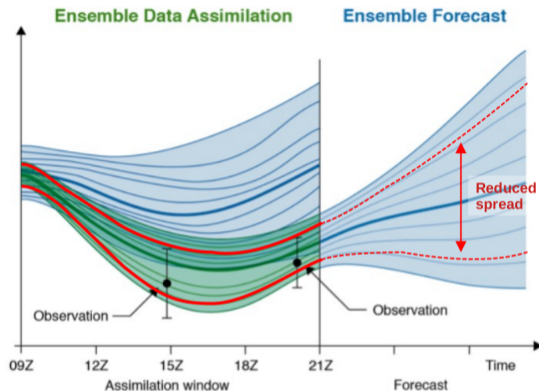
- EDA consists in a finite number of 4DVar analysis to provide flow-dependent background error statistics (operational at MF since July 2008).
- Since 15 years, ECMWF use EDA to study the impact of new observations (*Tan et al. 2007*, *Harnisch et al. 2013*, *Lean et al. 2022*).



Bormann (2023)

The EDA method from ECMWF

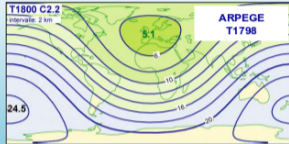
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- Since 15 years, ECMWF use EDA to study the impact of new observations (*Tan et al. 2007*, *Harnisch et al. 2013*, *Lean et al. 2022*).
- Allows to assimilate **simulated observations** along with real observations (cheaper than OSSEs).



Bormann (2023)

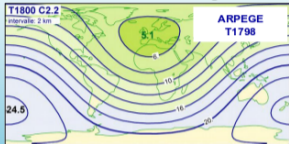
Methodology

Nature run: ARPEGE High resolution

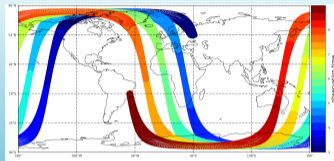


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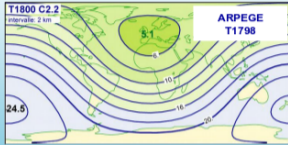


Interpolation at WIVERN observations time and location.

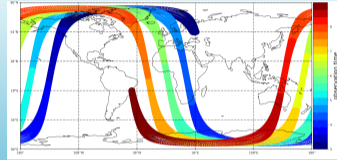


Methodology

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Interpolation at WIVERN observations time and location.



Forward operator to simulate HLOS winds

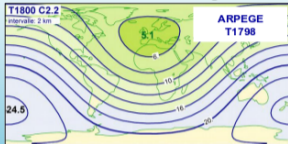
$$HLOS = -u \sin \theta - v \cos \theta.$$

With

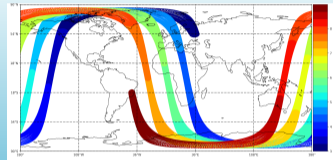
- θ = line of sight azimuth angle.
- RTTOV spaceborne simulator to detect scenes where WIVERN will observe winds.

Methodology

Nature run: ARPEGE High resolution



Interpolation at WIVERN observations time and location.



AEARP

- 50 members running a 4Dvar with perturbed observations.
- Horizontal resolution of 40km.
- 6h cycling.
- One minimization at 400km (instead of 2 for the deterministic model).
- Observation error $\sigma_o = 3$ m/s.

Forward operator to simulate HLOS winds

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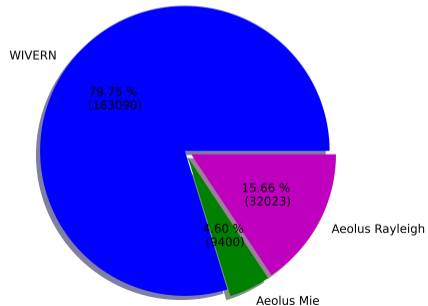
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Experimental setup

- Parameters of the experiments :

Run	AEOLUS Cloudy	AEOLUS Clear	WIVERN	Others
Reference	-	-	-	X
AEOLUS Mie-Cloudy	X	-	-	X
AEOLUS Rayleigh-Clear	-	X	-	X
WIVERN	-	-	X	X
AEOLUS (all) + WIVERN	X	X	X	X

- Period of study :
08/09/2021 - 03/10/2021
→ 25 days period



Definition of the EDA spread ratio.

- Definition of the metric following *Lean et al. 2022* and *Bormann et al. 2023*

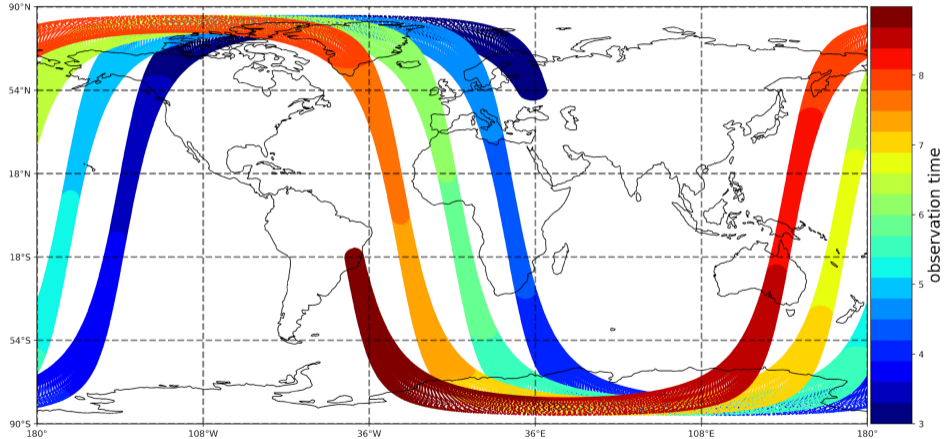
$$I(z) = \frac{s_{run}(z) - s_{ref}(z)}{s_{ref}(z)}$$

with s_{run} and s_{ref} the EDA spread of respectively the *run* and the *reference run*.

- $I < 0$ means a positive impact of the assimilation of new observations.

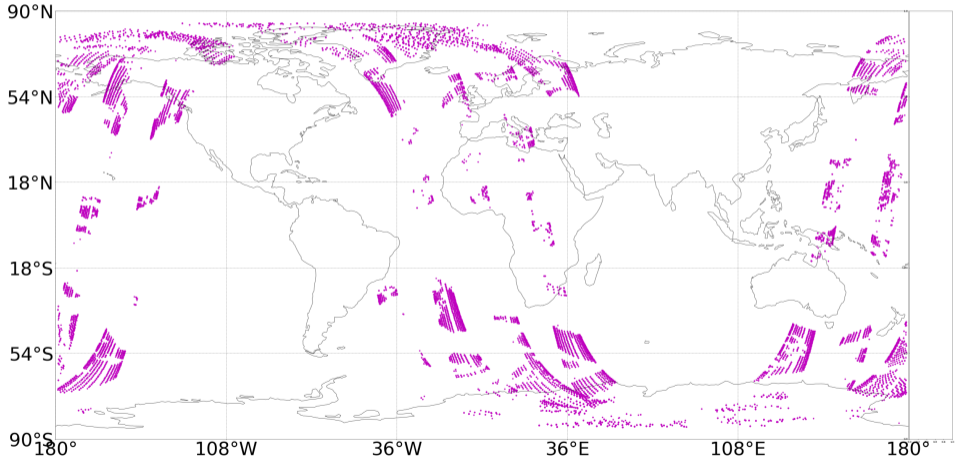
Results: first assimilation time.

1 Orbits of WIVERN over a 6h assimilation time.



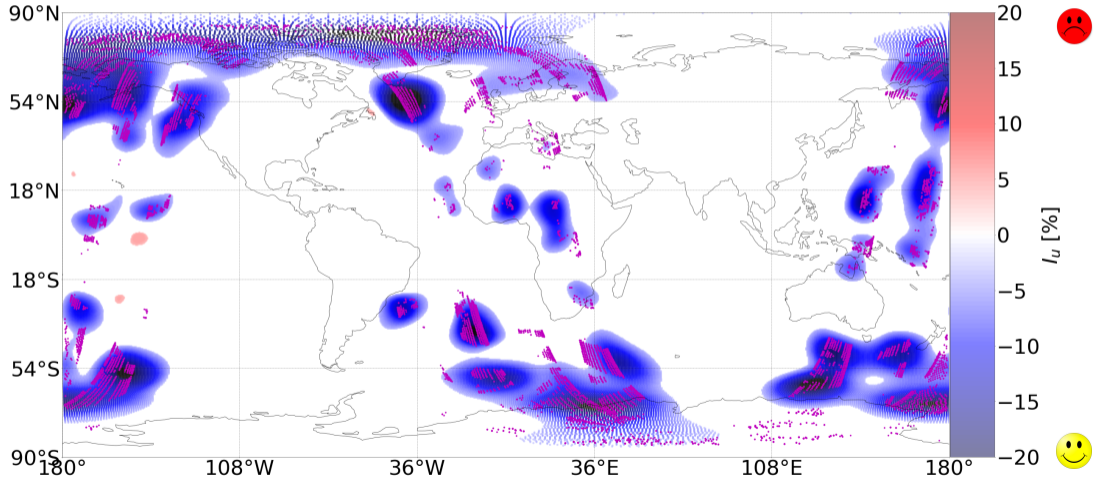
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2 WIVERN simulated observation locations, at an altitude of 644 hPa.



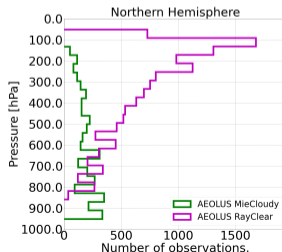
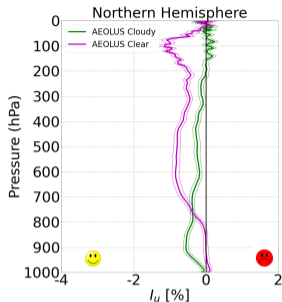
Results: first assimilation time.

3 2D field of spread ratio at an altitude of 644 hPa.



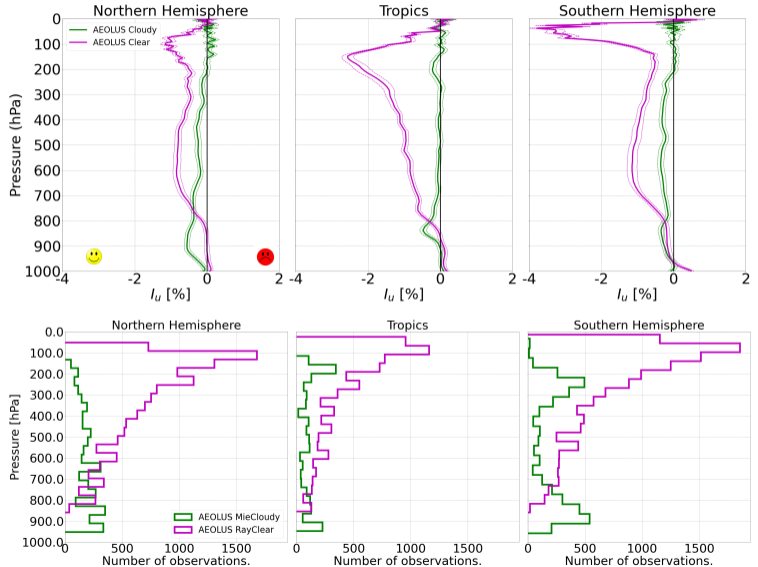
Results over a 25 days period

- Impact of AEOLUS Clear greater than AEOLUS Cloudy, consistent with the work of *Pourret et al.(2021)*



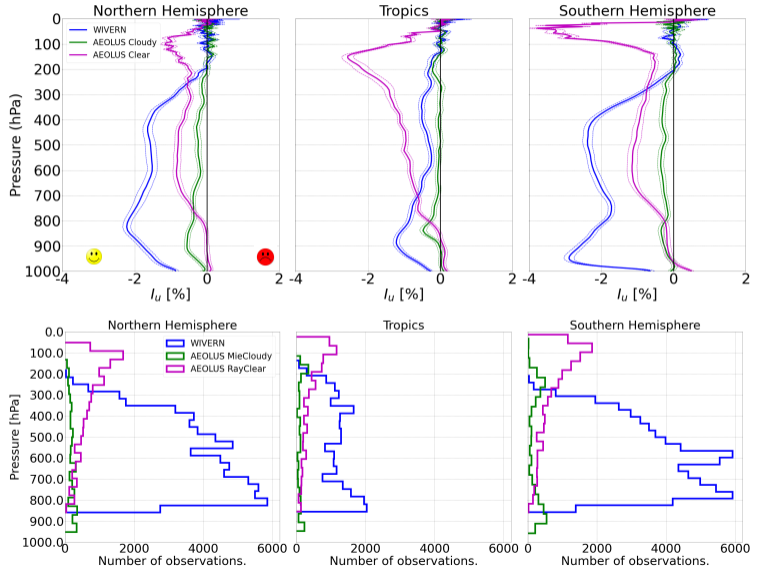
Results over a 25 days period

- Impact of **AEOLUS Clear** greater than **AEOLUS Cloudy**, consistent with the work of *Pourret et al. (2021)*



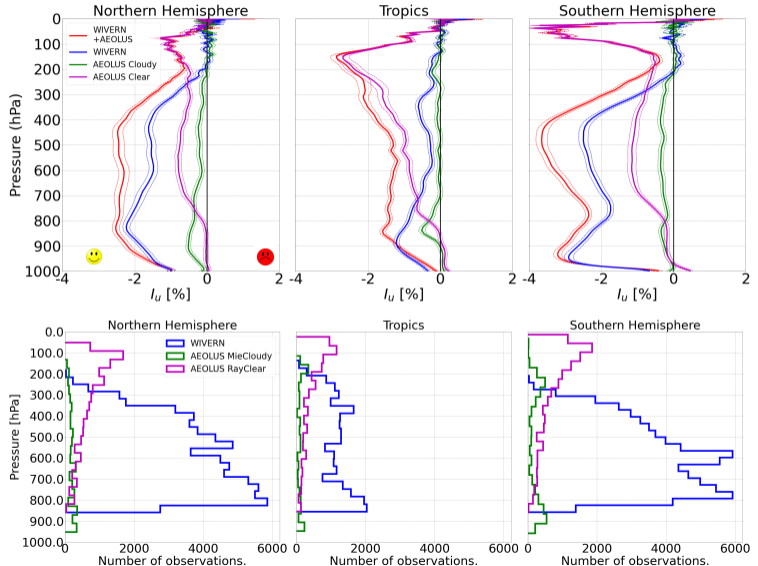
Results over a 25 days period

- Impact of **AEOLUS Clear** greater than **AEOLUS Cloudy**, consistent with the work of *Pourret et al.(2021)*
- Significant impact on of **WIVERN** the lower troposphere
- Complementarity between **AEOLUS** and **WIVERN**(In-clouds measurements).

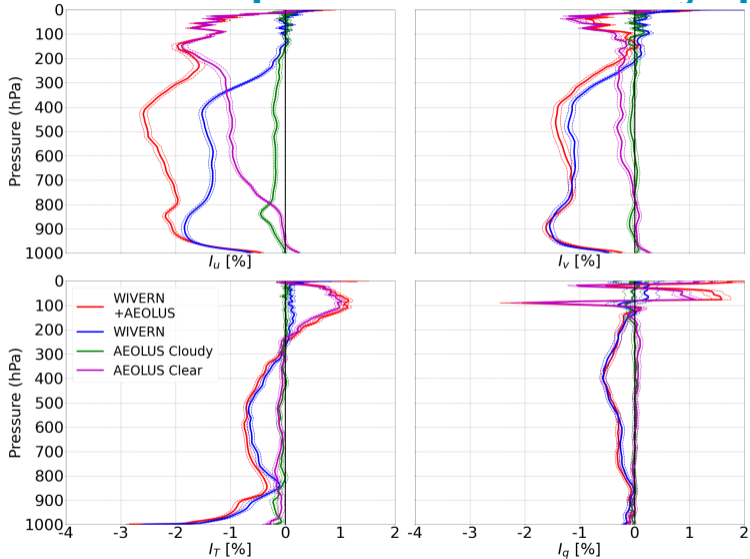


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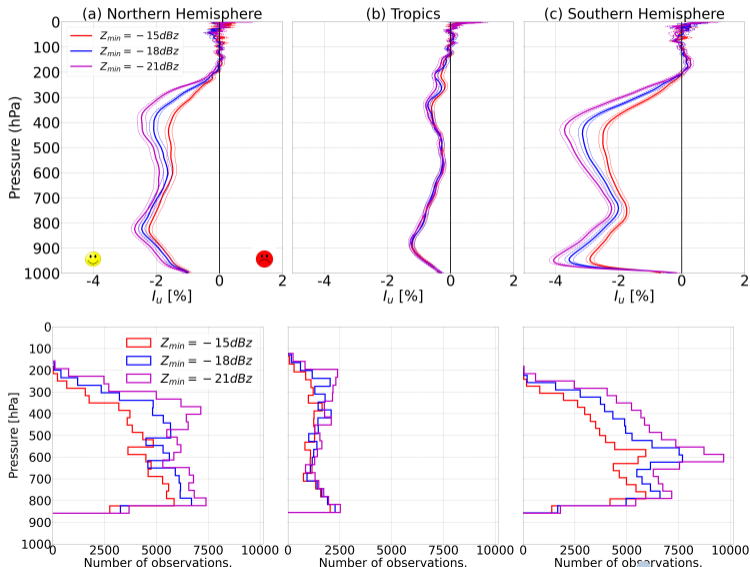


Global vertical profiles over a 25 days period



Effect of radar sensitivity Z_{min} over a 25-days period

- Experiments without AEOLUS data assimilation.
- The positive impact of WIVERN increases with the sensitivity.
- Lower effect of sensitivity in the tropics.




Conclusions

- First mission to observe in-cloud wind observations at a global scale.
- Significant positive impact of the assimilation of WIVERN HLOS winds on reducing EDA spread.
- Complementarity with AEOLUS wind observations on the vertical.

Perspectives

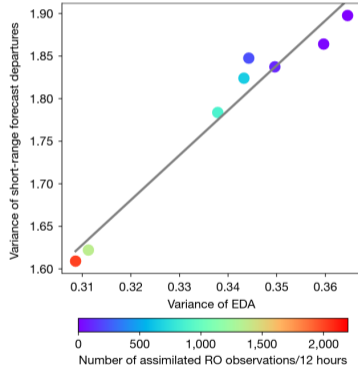
- *On-going work* : sensitivity to observation error σ_o .
- Poor period for AEOLUS → Evaluate complementarity with AEOLUS-2 simulated winds.

A satellite photograph of Earth showing the Arctic region. The image displays a vast expanse of white ice sheets and glaciers, interspersed with dark, rugged terrain. The curvature of the Earth is visible at the top of the frame, where the dark space of the atmosphere meets the horizon.

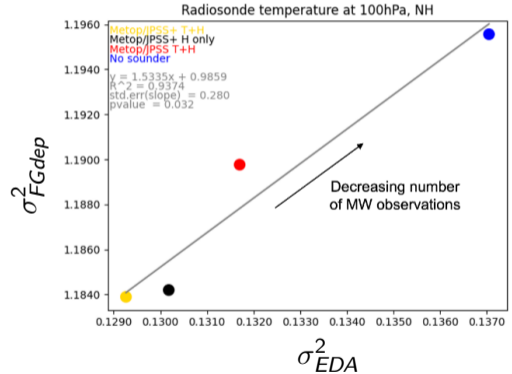
Thank you for your attention

The EDA method

- Linear relationship between forecast error reduction and EDA spread reduction.

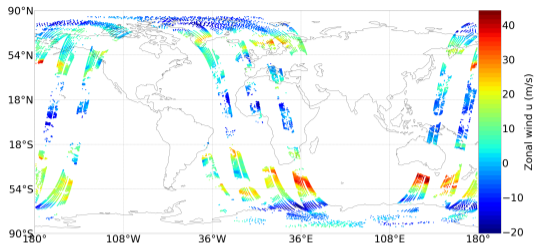


Bormann et al., 2023

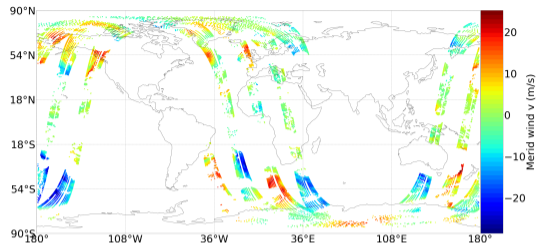


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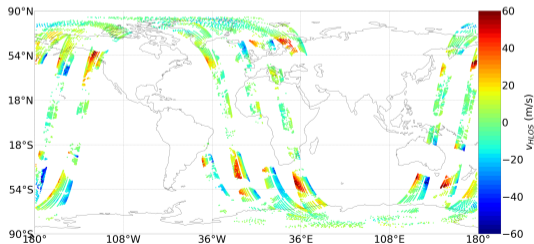
Simulated WIVERN observations :



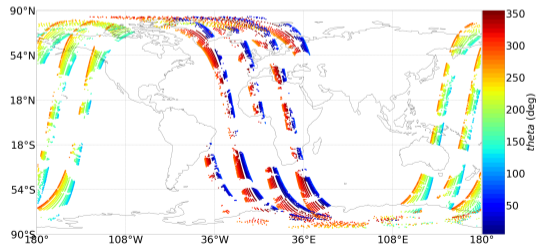
Zonal wind u (m/s)



Merid wind v (m/s)



HLOS wind (m/s)



Azimuth angle θ (°)