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

Nicolas Sasso [1], Mary Borderies[1], Anthony Illingworth[2], Alessandro Battaglia[3], Maryam Pourshamsi[4], Philippe Chambon [1], Loik Berre[1], Jean-Francois Mahfouf[1],

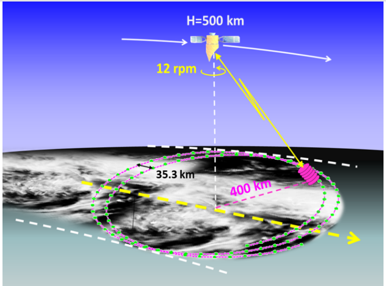
[1] Météo-France / DESR / CNRM
[2] University of Reading, Reading,UK
[3] Politecnico di Torino, Torino, Italy
[4] ESA-ESTEC, Noordwijk, Netherlands

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 $\approx 20km$.
- 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)

Objectives

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

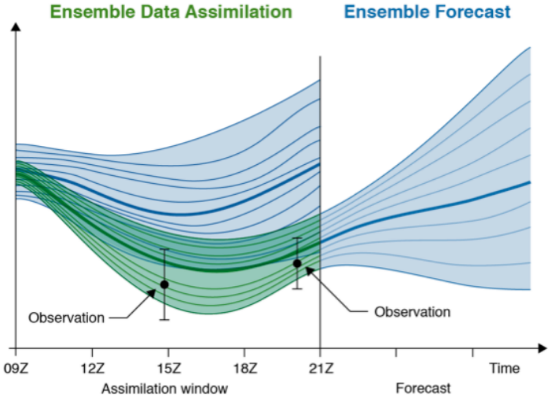
Outline

- 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*).

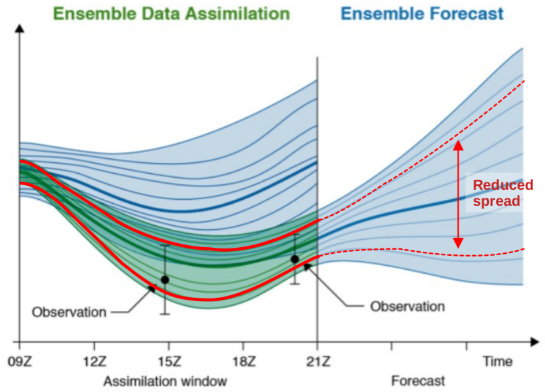


Bormann (2023)

The EDA method from ECMWF

- 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*).

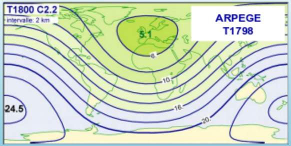


Bormann (2023)

- Allows to assimilate simulated observations along with real observations (cheaper than OSSEs).

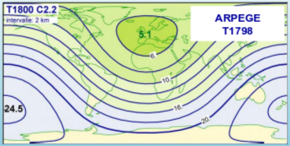
Methodology

Nature run: ARPEGE High resolution

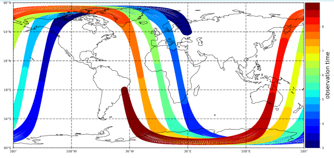


Methodology

Nature run: ARPEGE High resolution

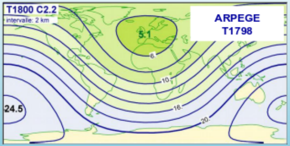


Interpolation at WIVERN observations time and location.

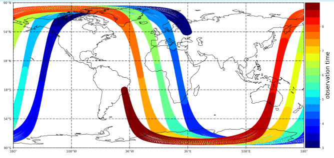


Methodology

Nature run: ARPEGE High resolution



Interpolation at WIVERN observations time and location.



Forward operator to simulate HLOS winds

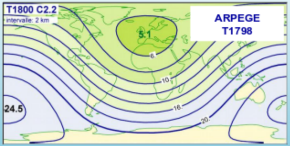
$$HLOS = -u\sin\theta - v\cos\theta.$$

With

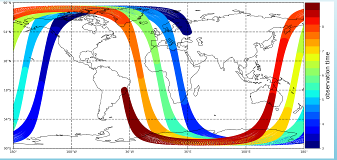
- θ = line of sight azimuth angle.
- RTTOV spaceborne simulator to detect scenes where WIVERN will observe winds.

Methodology

Nature run: ARPEGE High resolution



Interpolation at WIVERN observations time and location.



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.

AEARP

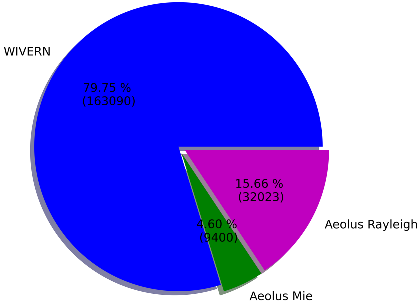
- 50 members running a 4Dvar with perturbed observations.
- Horizontal resolution of 40km.
- 6h cycling.
- One minimization at 400km (instead of 2 for the deterministic model).
- Observation error $\sigma_o = 3$ m/s.

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*

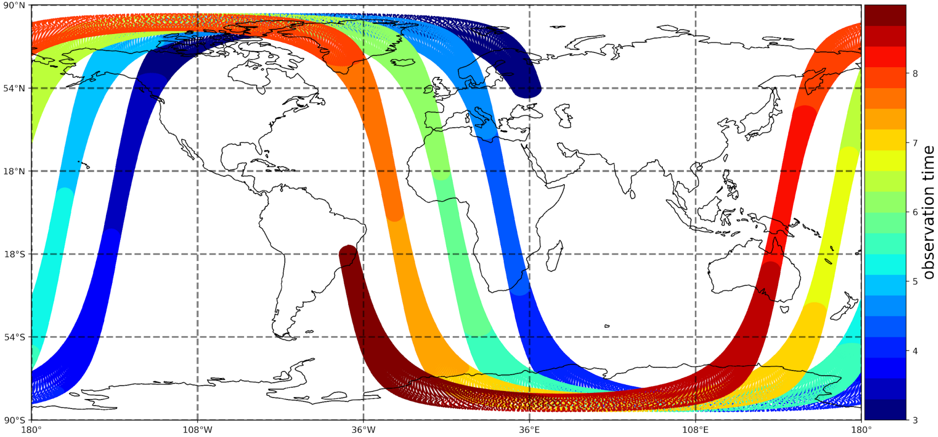
$$I(z) = \frac{s_{run}(z) - s_{ref}(z)}{s_{ref}(z)}$$

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.

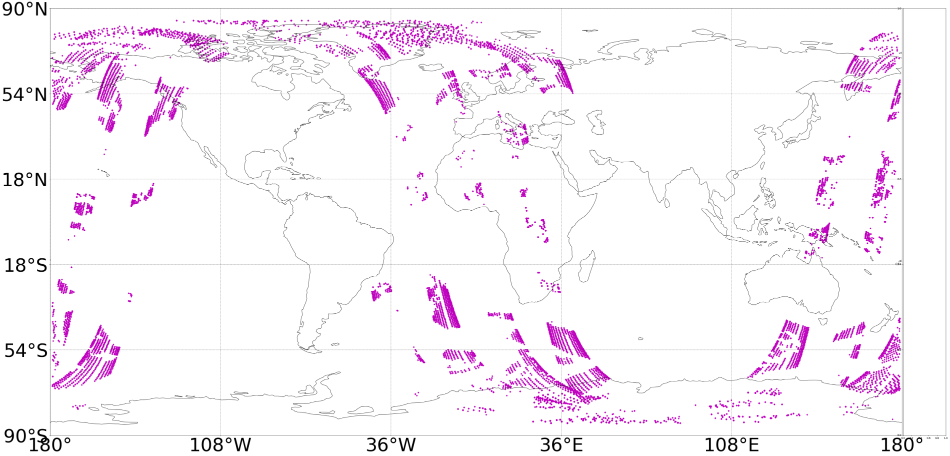
Results: first assimilation time.

1 Orbits of WIVERN over a 6h assimilation time.



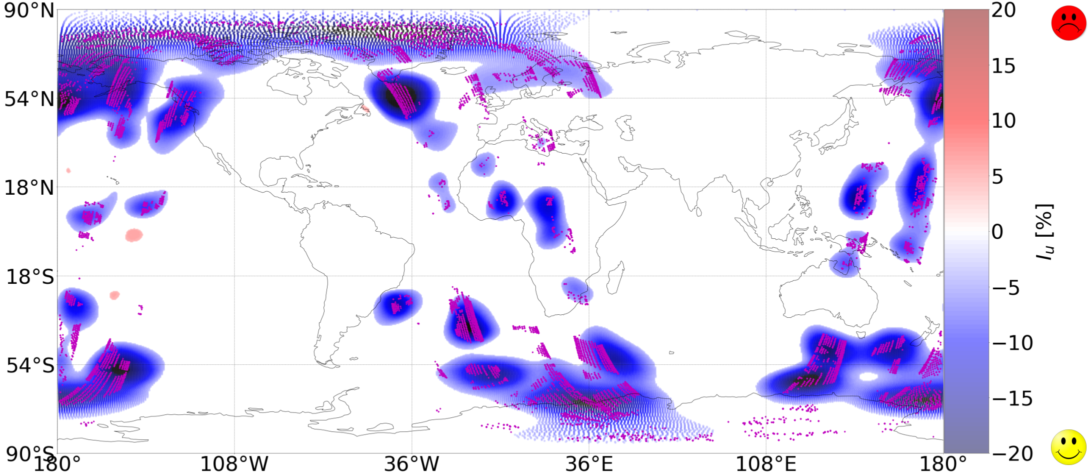
Results: first assimilation time.

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



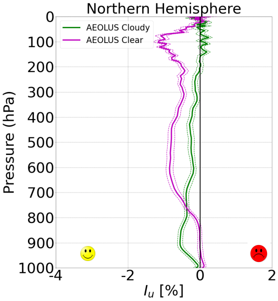
Results: first assimilation time.

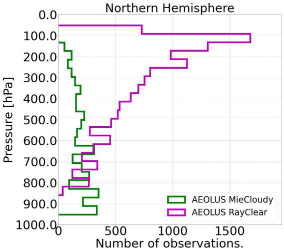
3 2D field of spread ratio at an altitude of 644 hPa.



Results over a 25 days period

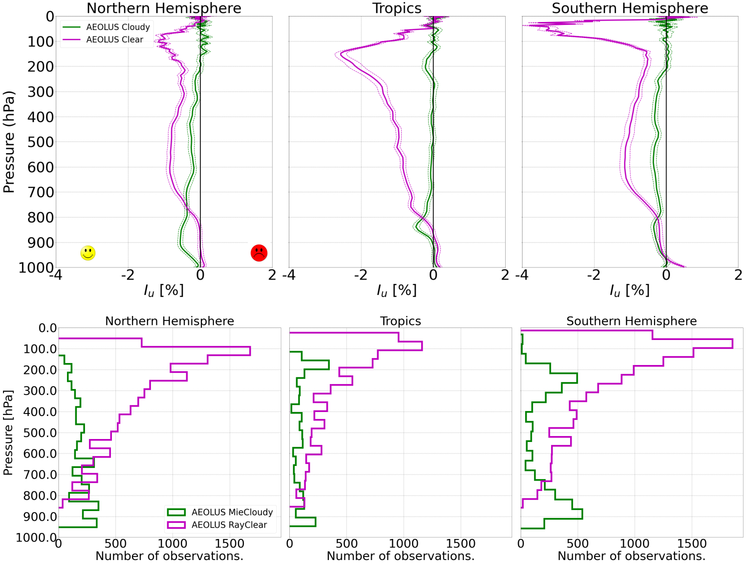
- Impact of AEOLUS Clear greater than AEOLUS Cloudy, consistent with the work of *Pourret et al.(2021)*





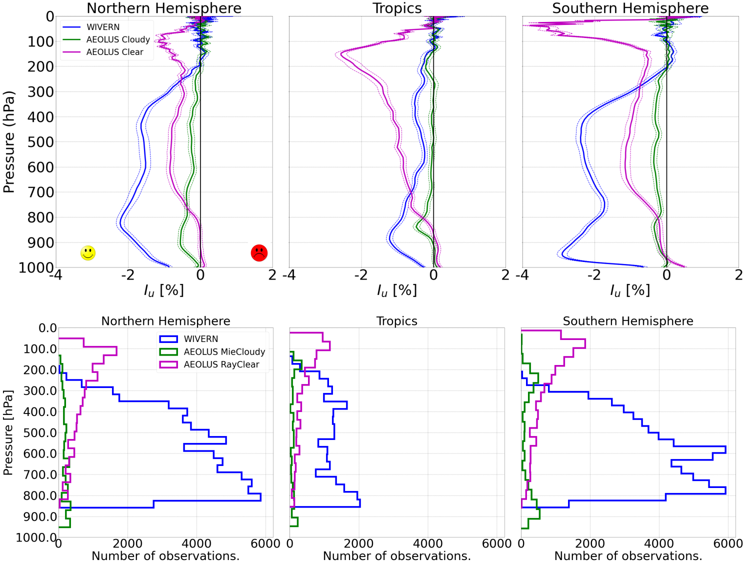
Results over a 25 days period

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



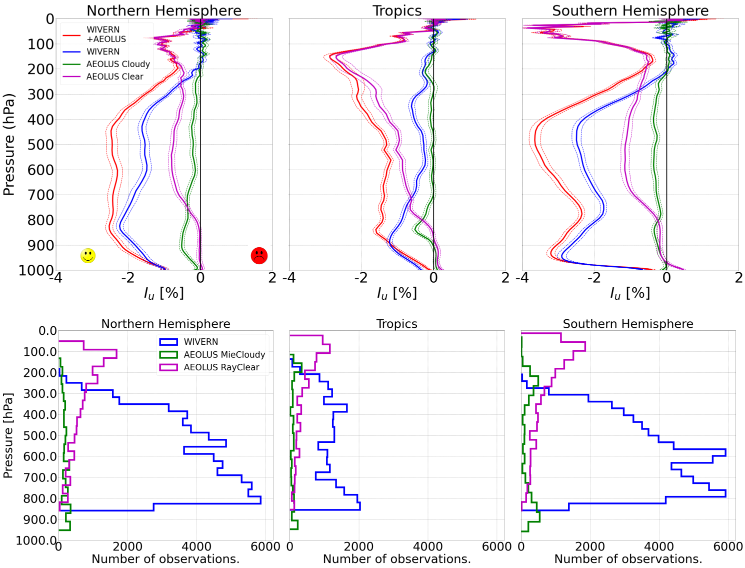
Results over a 25 days period

- 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).

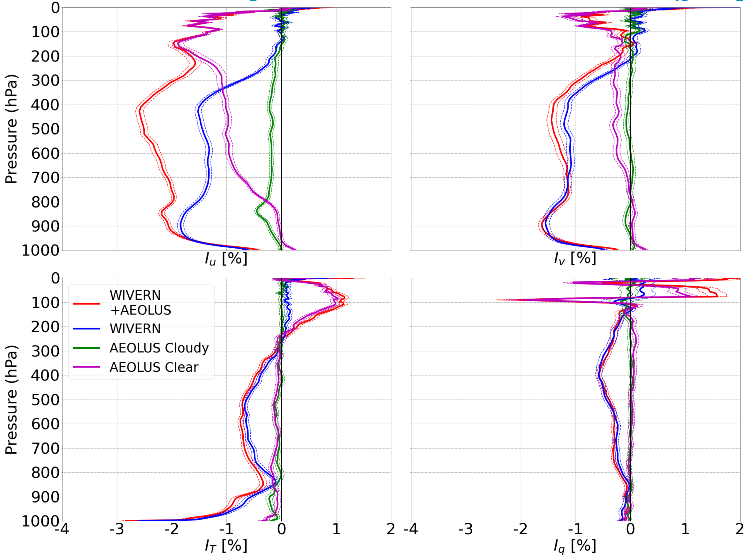


Results over a 25 days period

- 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).

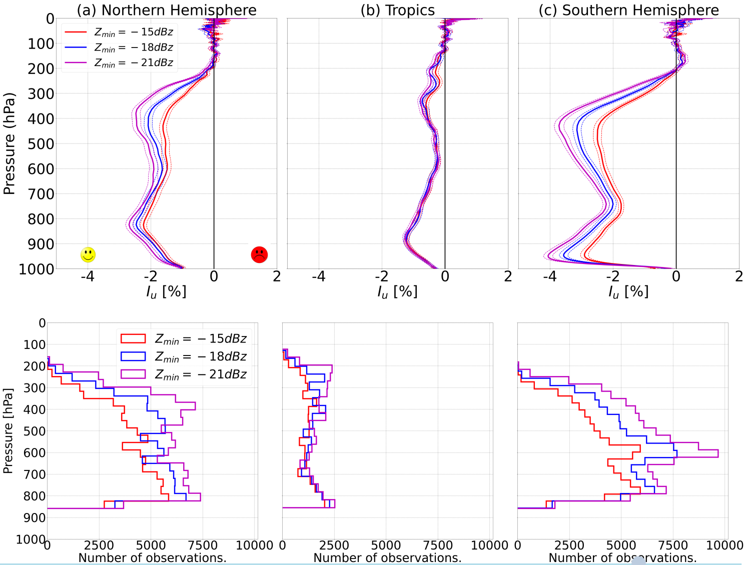


Global vertical profiles over a 25 days period



Effect of radar sensitivity Z_{min}, 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.

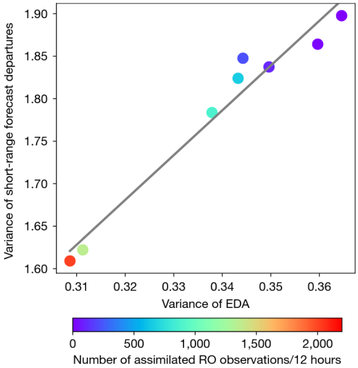
Perspectives

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

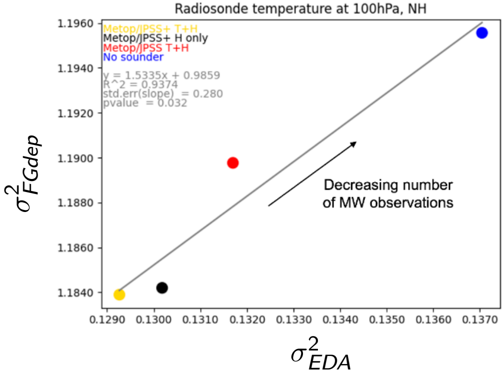
Thank you for your attention

The EDA method

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

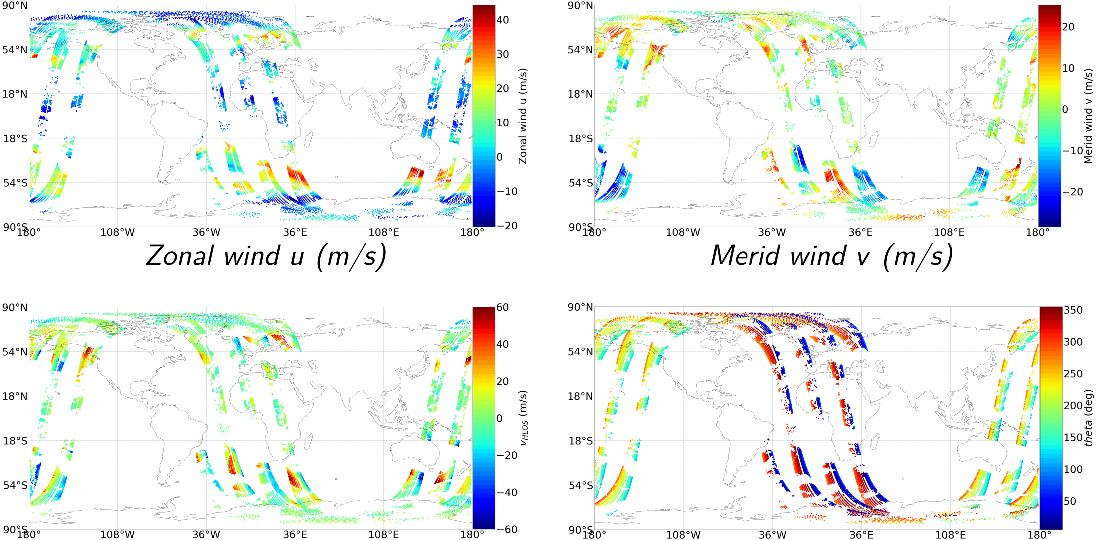


Bormann et al., 2023



Lean et al., 2022

Simulated WIVERN observations :



Zonal wind u (m/s)

Merid wind v (m/s)

HLOS wind (m/s)

Azimuth angle θ (°)