Impact of WIVERN 94GHz brightness temperature observations on global NWP model forecasts using an OSSE framework

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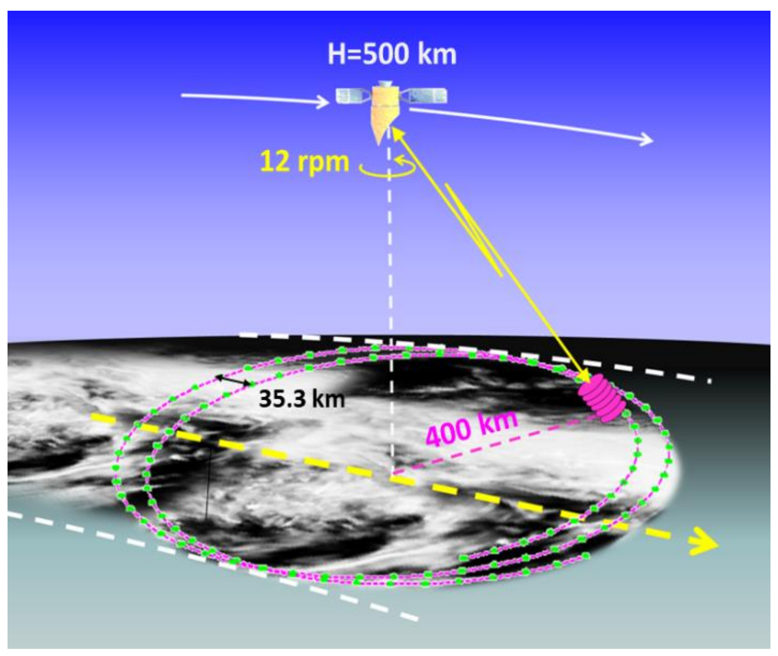
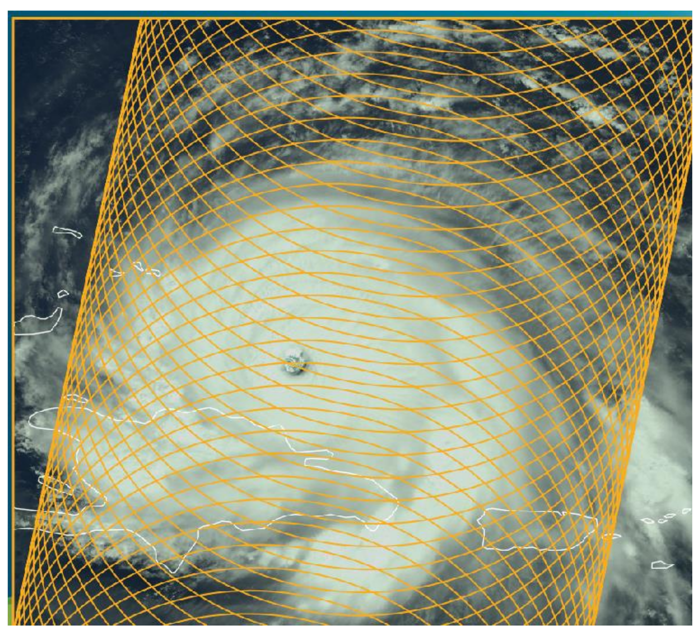
1. Introduction

As part of the Earth Explorer 11 program, ESA has selected the **WIVERN** (Illingworth et al. 2018) satellite mission concept to move into phase A in October 2023 and is now under study to enter phase B in July 2025. **WIVERN will be the first spaceborne dual-polarisation Doppler W-band radar** to also provide **94GHz brightness temperature in both polarizations** at a 1 km horizontal resolution.



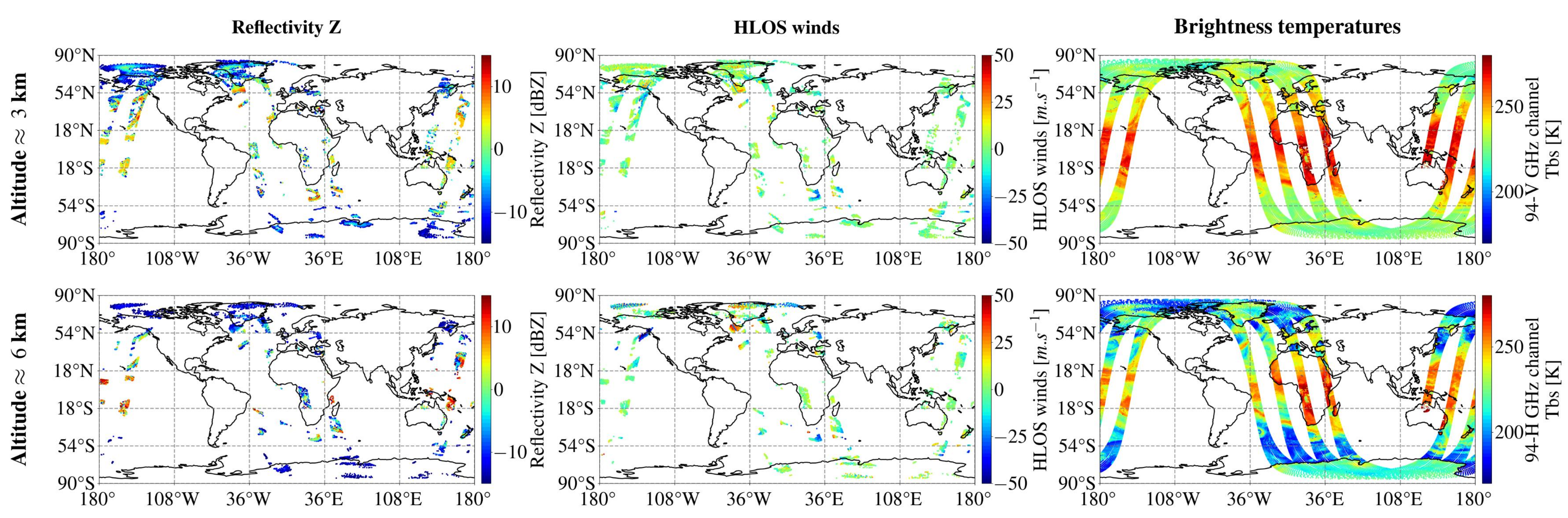


Recent studies conducted at Météo-France have already shown the benefits of assimilating WIVERN in-cloud HLOS wind profiles to improve short-range global NWP forecasts using the Ensemble of Data Assimilation method of ECMWF (Sasso et al. 2025).

=> Here, the impact of the HLOS winds and 94 GHz observations is evaluated using the Observing System Simulation Experiment (OSSE) approach which has been previously developed at Météo-France (Rivoire et al. 2024).

2. WIVERN observations

- **Reflectivity and dual-polarization variables** at 1km every 500m in the vertical.
  => simulated using RTTOV-SCATT (Mangla et al. 2025)
- **Horizontal Line-of-Sight (HLOS) winds** at a horizontal resolution of 20 km every 500 m.
  ⇒ $HLOS = -u\,sin(\alpha)$ - vcos (α), with u and v the zonal and meridional winds, and α the azimuth angle (see Sasso et al. 2025)
- **94 GHz Brightness temperature observations at H and V polarizations**

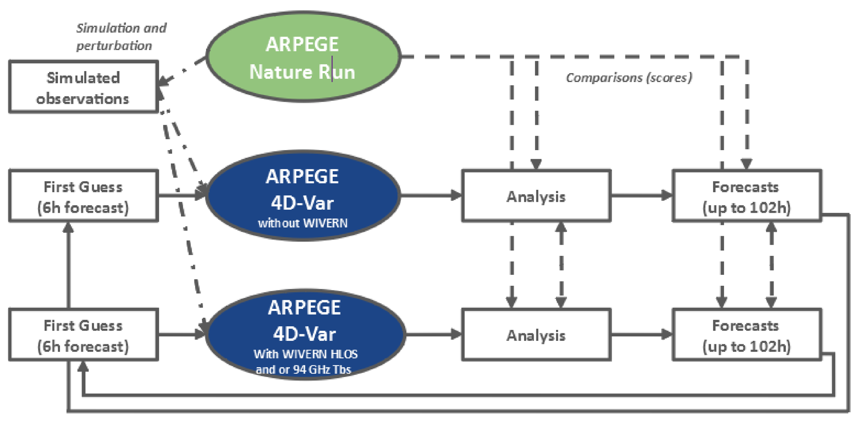


3. The OSSE framework

An OSSE mimics a real NWP system with simulated data by providing forecasts with realistic errors compared with a known truth. All the different components of the NWP system are fully simulated. In particular, existing observations as well as the new satellite observations (e.g. WIVERN), are simulated, thus deriving the impact of such new measurements on the quality of the forecasts.

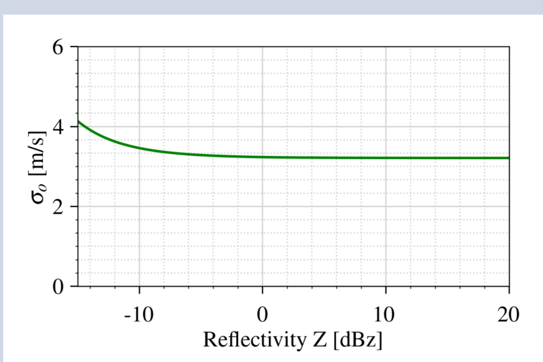
=> The framework used for WIVERN HLOS winds and brightness temperature observations is the same as the one to assess the impact of EPS-STERNA, CMIM, IASI-NG observations in the global model ARPEGE and is further described in Rivoire et al. (2024).

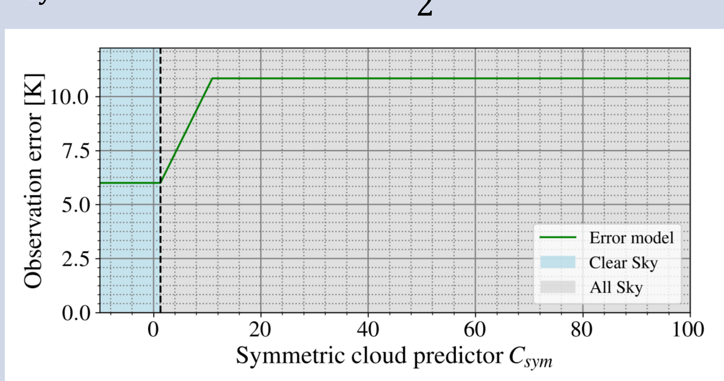
Parameters of the model	Nature run	Data assimilation and forecasting system
Truncation	TL1798	TL798
Resolution over Europe	About 5 km	About 10 km
Resolution over New-Zealand	About 24 km	About 61 km
Physics package	Tiedtke convection scheme	Bougeault convection scheme
Period of study	July to October and November to February (one month of spin-up)	August to October and December to February



4. DA setup for WIVERN observations

	HLOS winds	94-V GHZ
Thinning	~70 km	~70 km
Assimilation route	Same as Aeolus	Allsky (Geer et al. 2011)
Observation error	Depends on the SNR	$C_{sym} = \frac{\lvert Tb_{clear} - Tb_{Guess}\rvert + \lvert Tb_{clear} - Tb_{94H}\rvert}{2}$

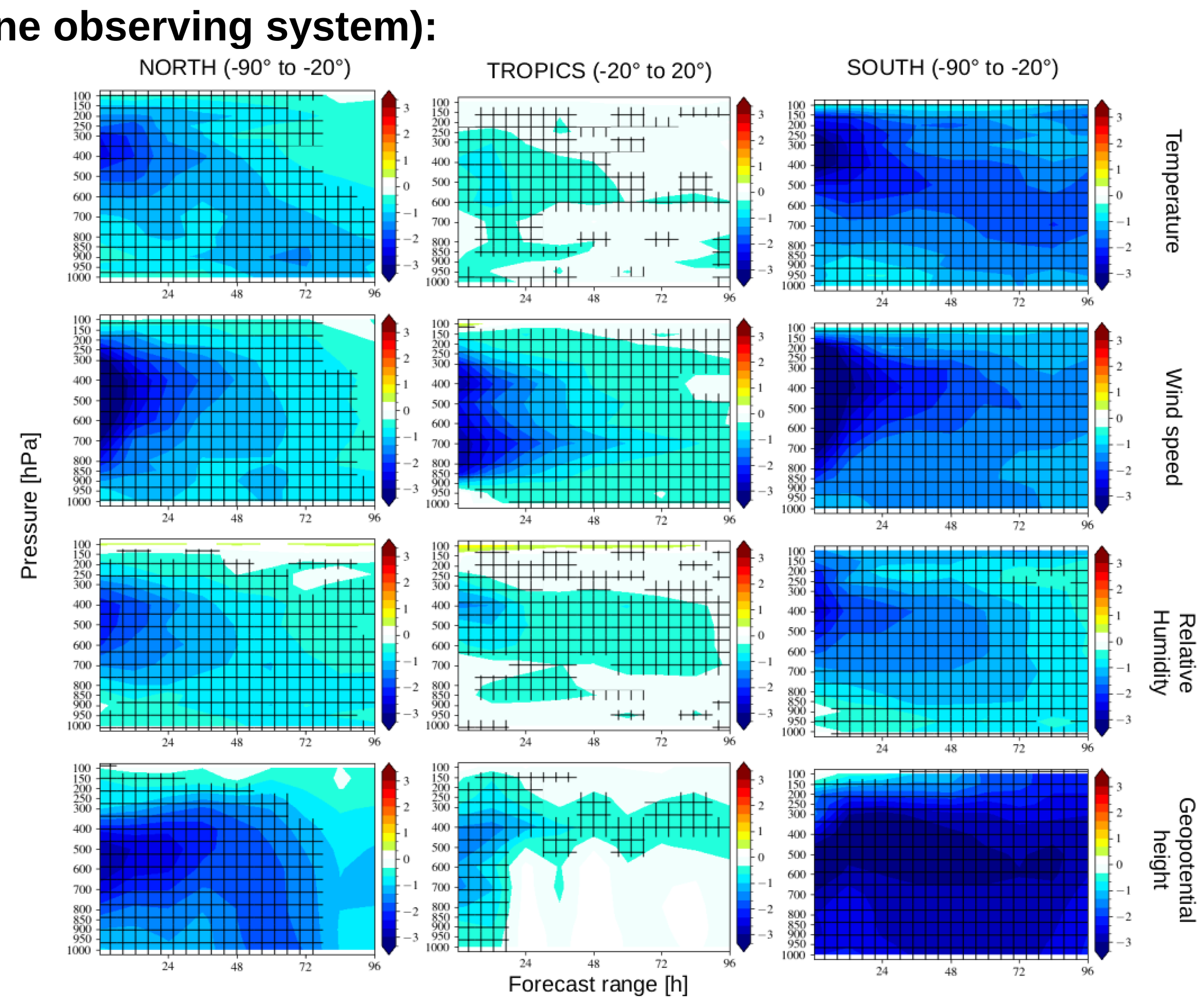




5. Impact of the HLOS winds

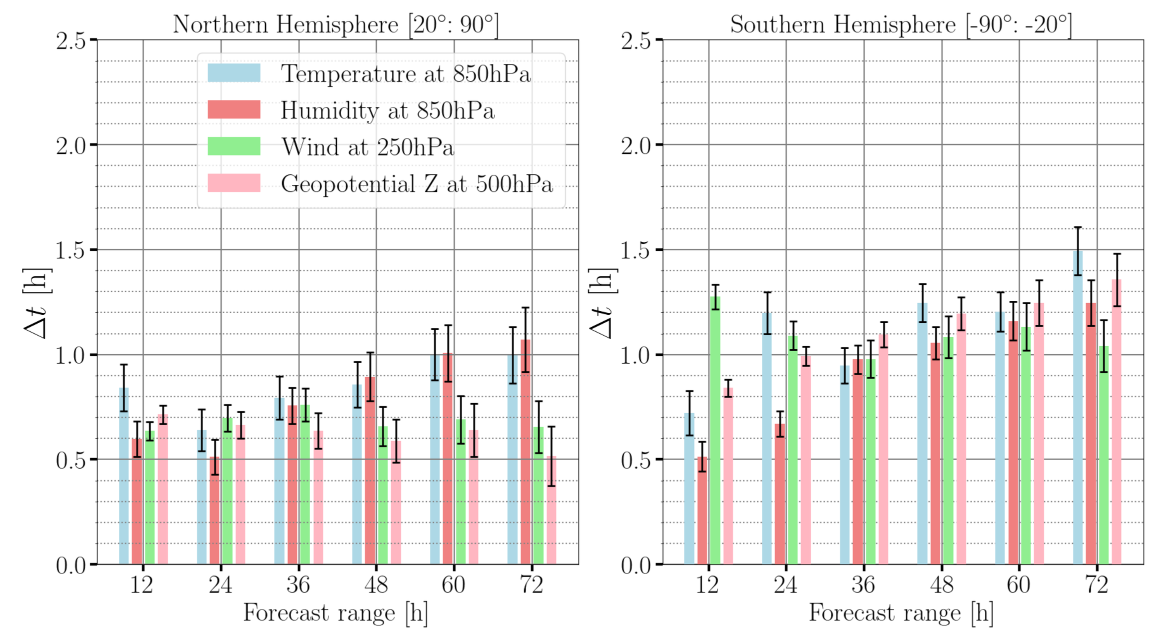
Differences of standard deviation of forecast errors over two 3-month periods (HLOS winds versus baseline observing system):

- **Large beneficial impact on the winds at all latitudes**
- **Large beneficial impact on temperature and humidity variables in the midlatitudes, consistent with the strong link between winds and mass variables in the mid-latitudes.**
- **Significant impact up to 4 days ahead.**
- **Larger impact over the polar areas.**



Impact on the lead time gain Δt

Δt calculated over two 3-month period by comparing the forecast range at which a given forecast error is reached in the WIVERN, and the CONTROL experiments.



⇒ WIVERN HLOS winds allows to provide more accurate forecasts ~1h30 (resp. 45 min) earlier in the Southern Hemisphere (resp. Northern Hemisphere), compared to a forecast which only includes the baseline observing system in its initial state.

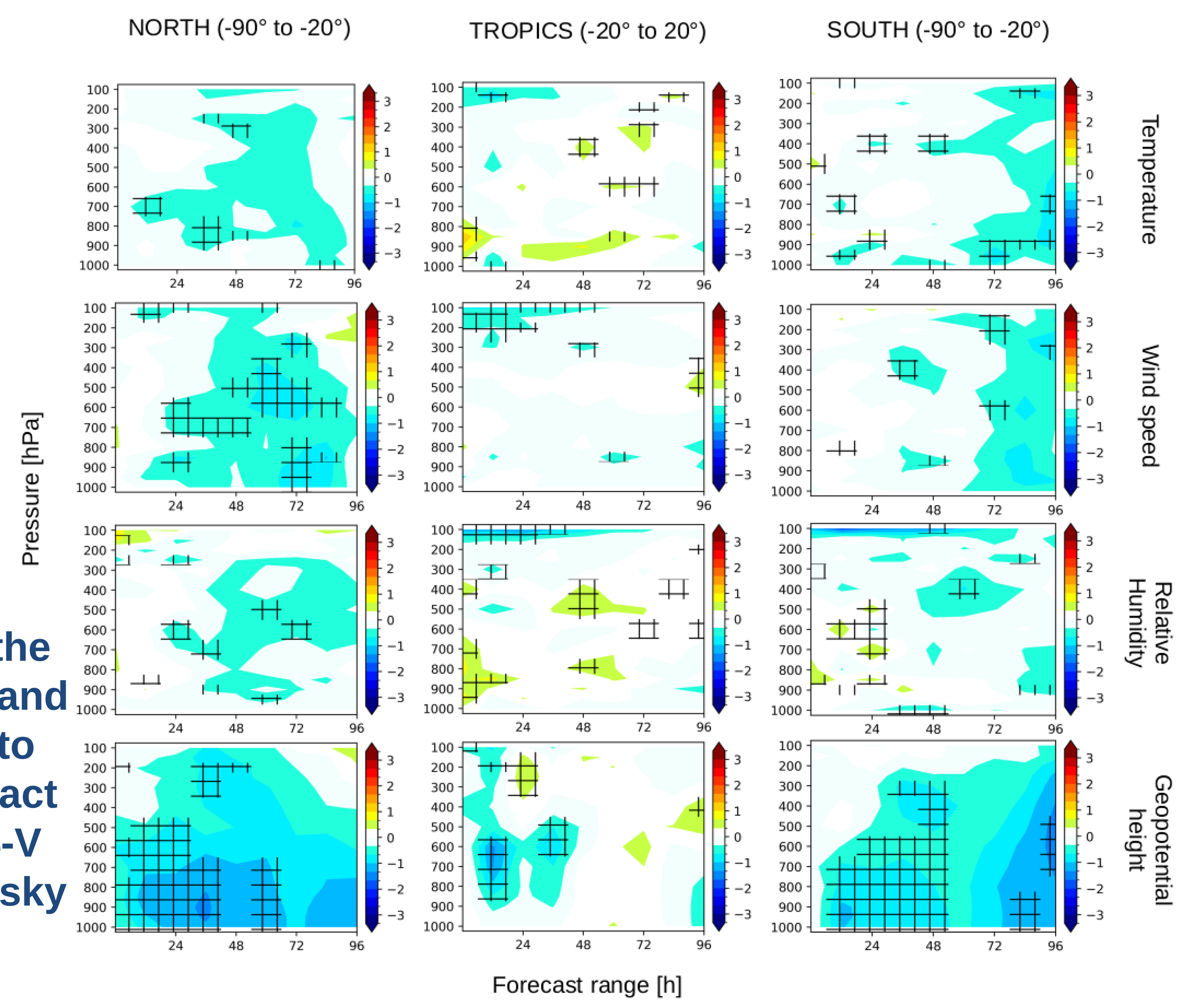
⇒ This 1-h improvement is of paramount importance for making alert decisions in case of extreme events.

6. Impact of the 94-V GHz brightness temperature

First time that a single window channel is assimilated -> different DA settings have been tested and are intercompared (e.g. clear-sky versus allsky here).

Here we show the impact of assimilating WIVERN 94-V GHz observations in **clear-sky conditions only**, compared with an experiment in which they are also **assimilated in allsky conditions** (calculated for a 3-weeks period)

=> Without any other observational constrains, the assimilation of the cloudy and precipitating areas seems to degrade the beneficial impact obtained when WIVERN 94-V GHz is assimilated in clearsky areas only



7. Conclusions

Impact of the HLOS winds:

- Large beneficial impact on all variables (consistent with the EDA study, see Sasso et al. 2025).
- Comparable impact to the impact of EPS-STERNA with 6 satellites (Rivoire et al. 2024).
- This positive impact is also observed on the 24h rainfall accumulated rainfall forecast.
- Because of the uniqueness of WIVERN in-cloud HLOS winds, small sensitivity of the impact to the prescribed observation error (not shown here).

Impact of the 94-V GHz brightness temperature observations:

- Slight positive impact if it is assimilated in clear-sky conditions only, which is degraded by ~0.5% if it is also assimilated in cloudy conditions (on-going work).
- Will also provide valuable information on the fresh snow on the ground (Bremen University).
- Potential synergy with the reflectivity to infer microphysical properties.

8. References

- *Rivoire, L. , et al. "A global observing-system simulation experiment for the EPS–Sterna microwave constellation." QJRMS 150.762 (2024): 2991-3012.*
- *Illingworth, A. J., et al. "WIVERN: A new satellite concept to provide global in-cloud winds, precipitation, and cloud properties." BAMS 99.8 (2018): 1669-1687.*
- *Sasso, N. et al. "Impact of WIVERN wind observations on ARPEGE Numerical Weather Prediction model forecasts using an Ensemble of Data Assimilation method", QJRMS, 10.1002/qj.4991 (2025)*
- *Mangla, R., et al. "Assessment and application of melting layer simulations for spaceborne radars within the RTTOV-SCATT v13. 1 model." AMTD 2024 (2024)*

9. Acknowledgements

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