Validation of Aeolus winds using atmospheric radars in Arctic Sweden and in Antarctica and NWP modelling

EGU General Assembly 2020

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Structure

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- Introduction to Swedish Aeolus project
- Validation of Aeolus against ESRAD and MARA radars
- Aeolus studies using HARMONIE-AROME NWP model
- Conclusions and future plans

Swedish contribution to Aeolus Cal/Val project

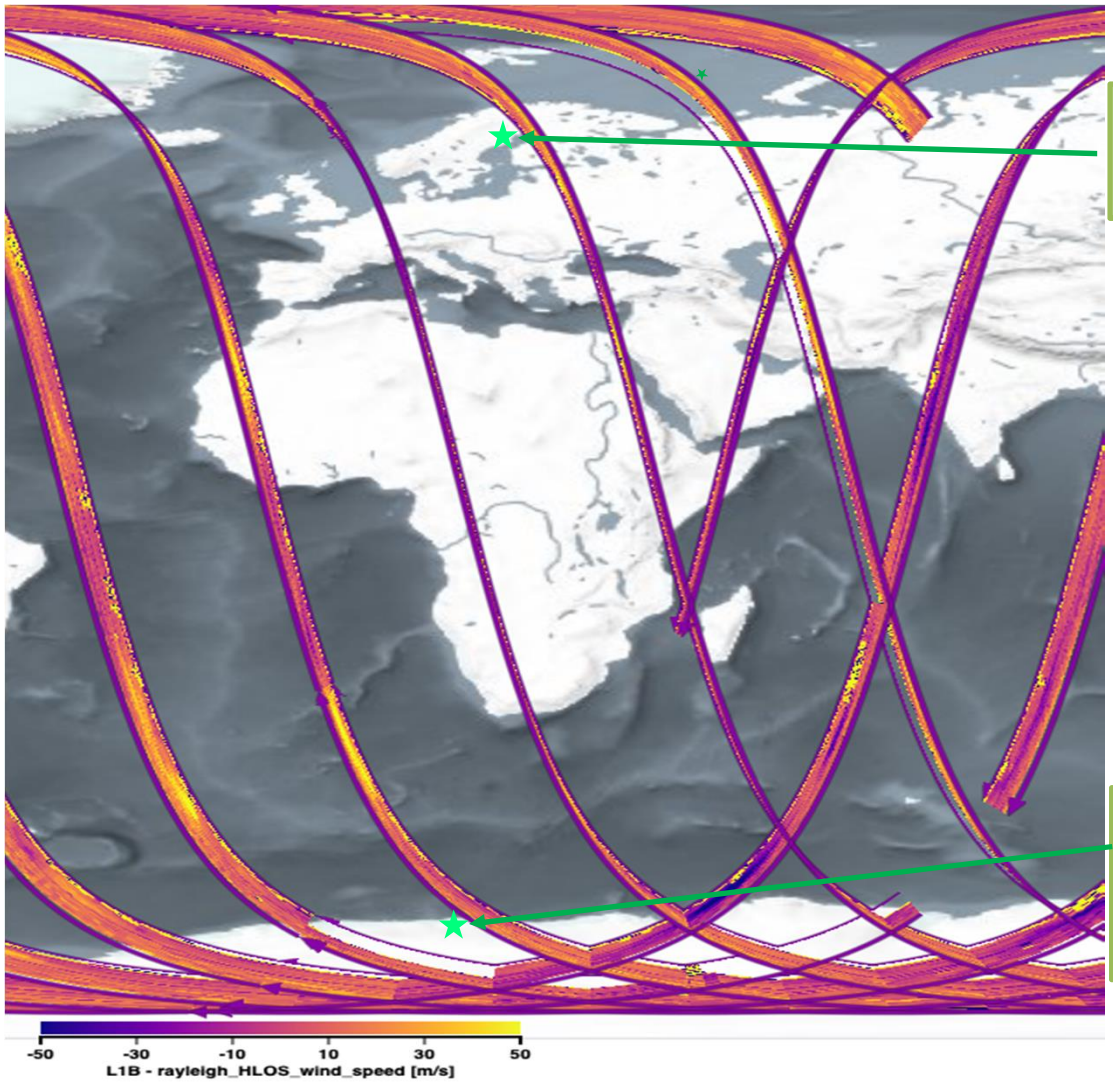
Validation of Aeolus winds using radar measurements in Arctic Sweden and Antarctica, and optimal use of wind data in numerical weather prediction.

- 2-year project financed by Swedish National Space Agency (Contract no: 125/18 (IRF), 279/18 (SMHI))
- PI: Evgenia Belova (IRF)

Goals:

- Compare Aeolus vs radars in Arctic Sweden and Antarctica
- Compare Aeolus vs high-resolution Numerical Weather Prediction
- Analysis of Aeolus winds for different atmospheric conditions (e.g. mountain waves, fronts and jets)
- Optimizing the usage of wind data in a convection-scale NWP system

Validation sites: Esrange (Northern Sweden) & Maitri (Antarctic)



SSC Esrange (68°N 21°E)

Indian Antarctic station Maitri (71°S 12°E)

Example of Aeolus L1B Rayleigh Horizontal Line-Of-Sight (HLOS) data. Plot produced with VirES Aeolus Portal-Virtual Environment for Scientists.

Wind profilers in Arctic (ESRAD) & in Antarctic (MARA)

The ESRAD radar at Esrange, Northern Sweden.

The ESRAD radar at Esrange:

- Joint project of SSC Esrange and IRF since 1996.
- Pulsed, Doppler, spaced antenna radar
- Frequency 52 MHz
- Altitude coverage:
  - 0.5-15 km all seasons;
  - 80-90 km May-Sept. ; 55-80 km occasionally
  - Altitude resolution: 75 m, 150 m, 600 m.

Webpage: www2.irf.se/program/paf/mst/?link=Data

The MARA radar at Maitri, Antarctica:

- In operation since 2006, initially IRF project, since 2017 owned and operated by Indian National Centre for Antarctic and Oceanic Research.
- Frequency 54.5 MHz
- Altitude range and resolution: the same as ESRAD.

The MARA radar at Maitri, Antarctica.

Validation of Aeolus against the radars

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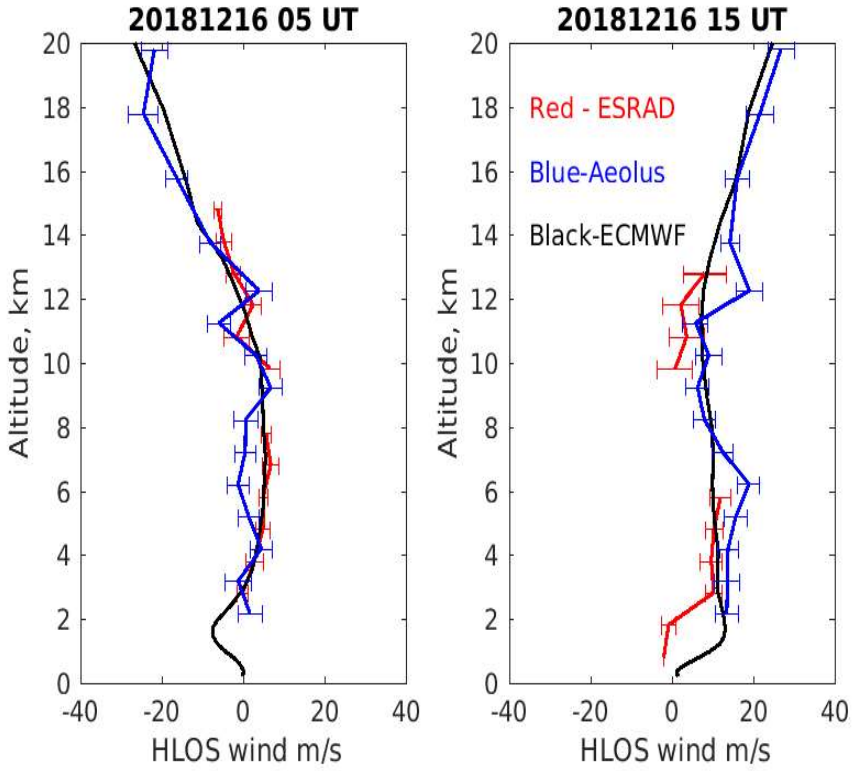
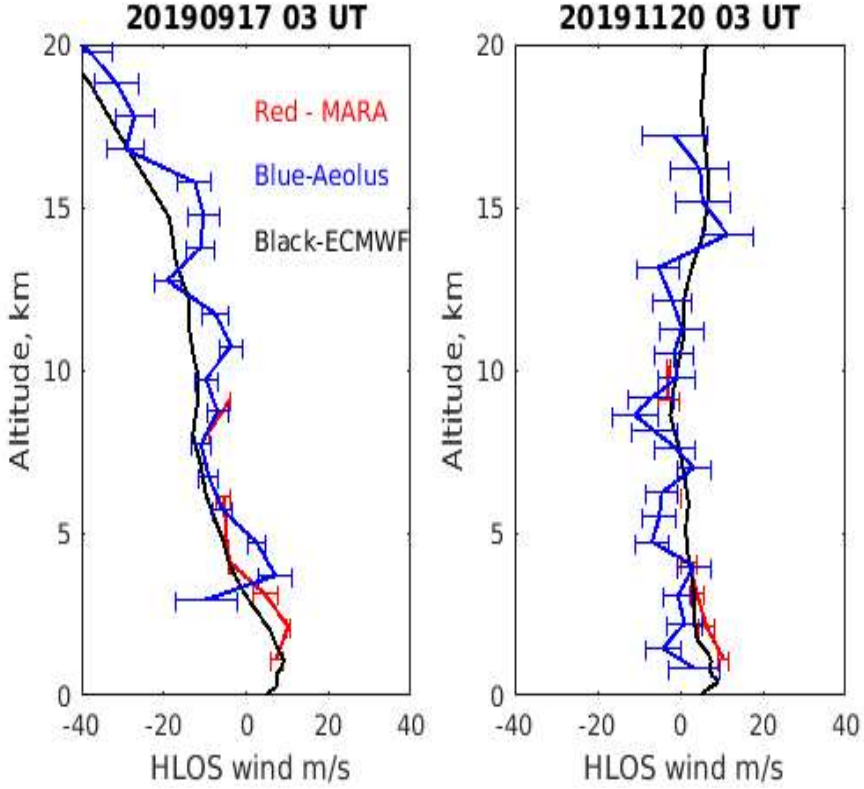
Arctic, ESRAD



Antarctica, MARA



Examples of the HLOS wind profiles as derived from ESRAD/MARA, Aeolus observations (the Rayleigh channel) and from the ECMWF Interim/ERA5 reanalysis.

Validation of Aeolus in Arctic, Esrange

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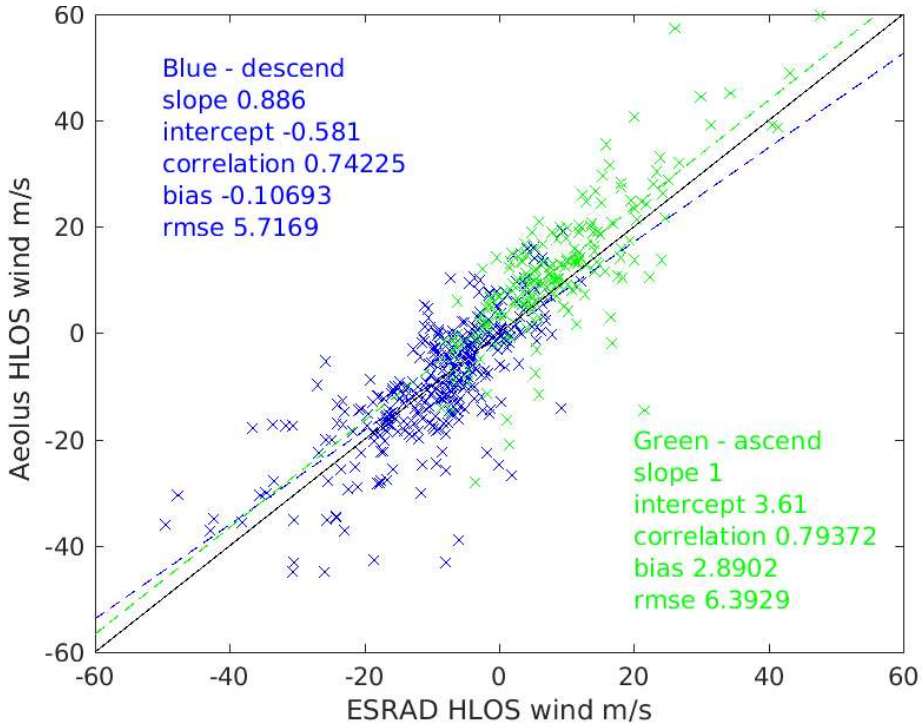
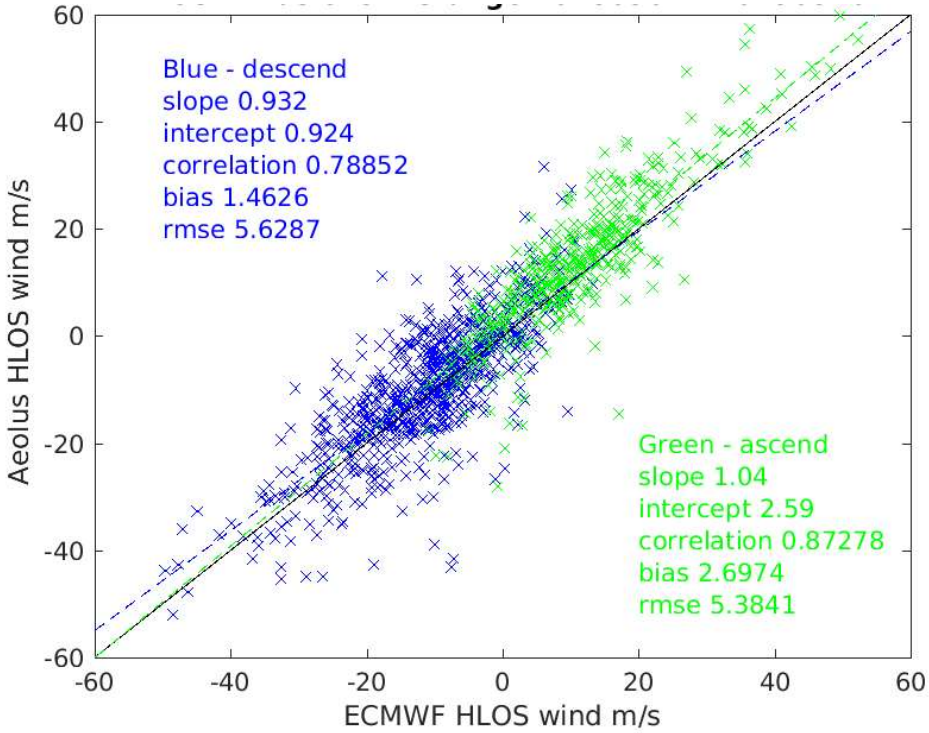
Aeolus Rayleigh vs ESRAD HLOS winds



Aeolus Rayleigh vs ECMWF HLOS winds



Period 20180904 – 20190526 (laser A). ESRAD and ECMWF winds are 1-hour averaged and interpolated to the Aeolus altitudes. The Aeolus data with errors > 8 m/s are removed.

- Some differences for the descend / ascend orbits.
- Correlation is slightly higher for the ascend orbits than for descend ones.
- Possible explanation: Swath distance to ESRAD is 5 km for ascending while 35/97 km for the descending orbits.

Validation of Aeolus in Antarctic, Maitri: laser A

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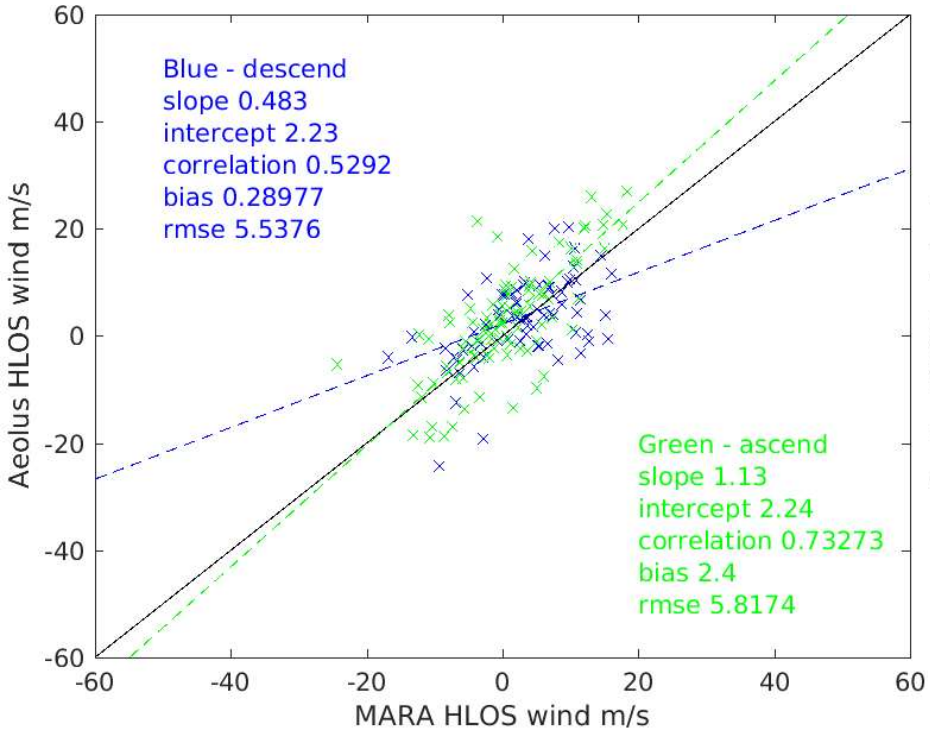
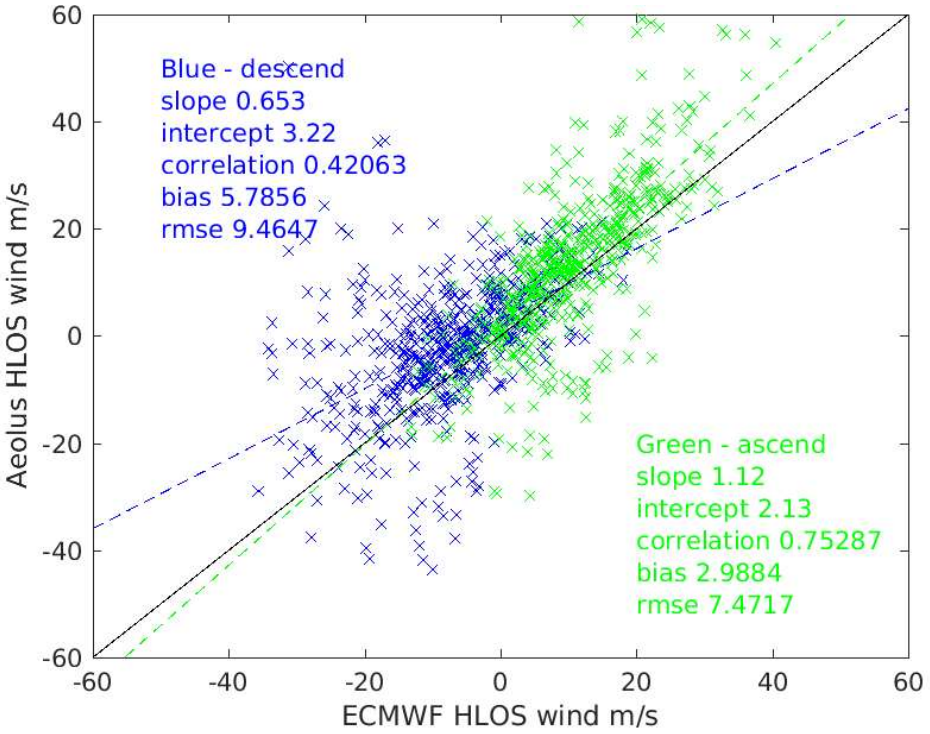
Aeolus Rayleigh vs MARA HLOS winds



Aeolus Rayleigh vs ECMWF HLOS winds



Period 20180904 – 20190526 (laser A). MARA and ECMWF winds are 1-hour averaged and interpolated to the Aeolus altitudes. The Aeolus data with errors > 8 m/s are removed.

- Large differences for the descend / ascend orbits.
- Correlation is slightly higher for the ascend orbits than for descend ones.
- Large RMSE for comparison of Aeolus with MARA/ECMWF.
- Possible explanation: Poor statistics because not enough MARA data in period.

Validation of Aeolus in Antarctic, Maitri: laser B

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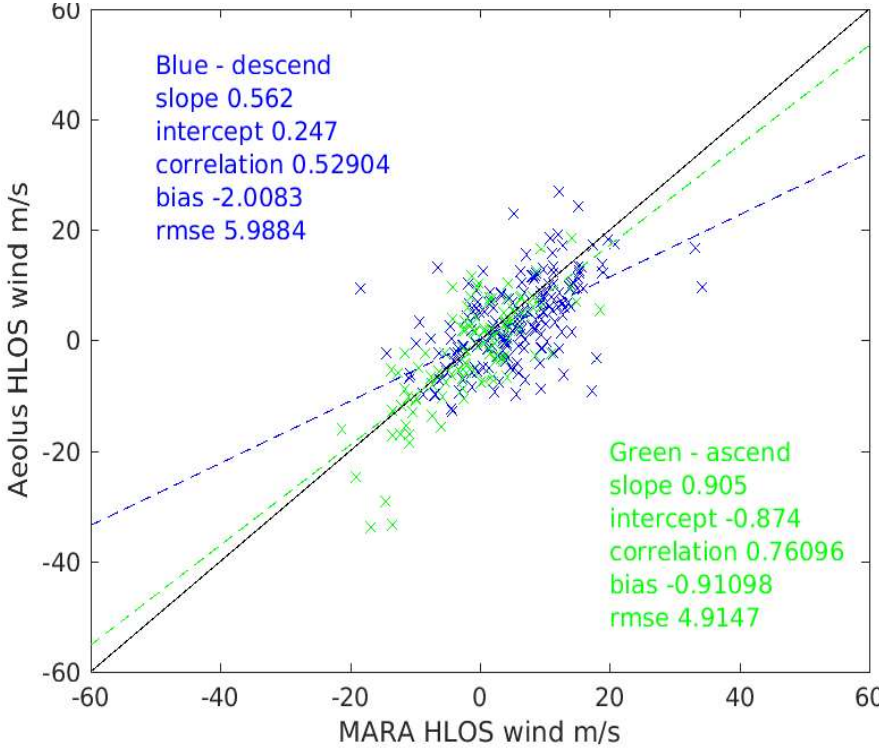
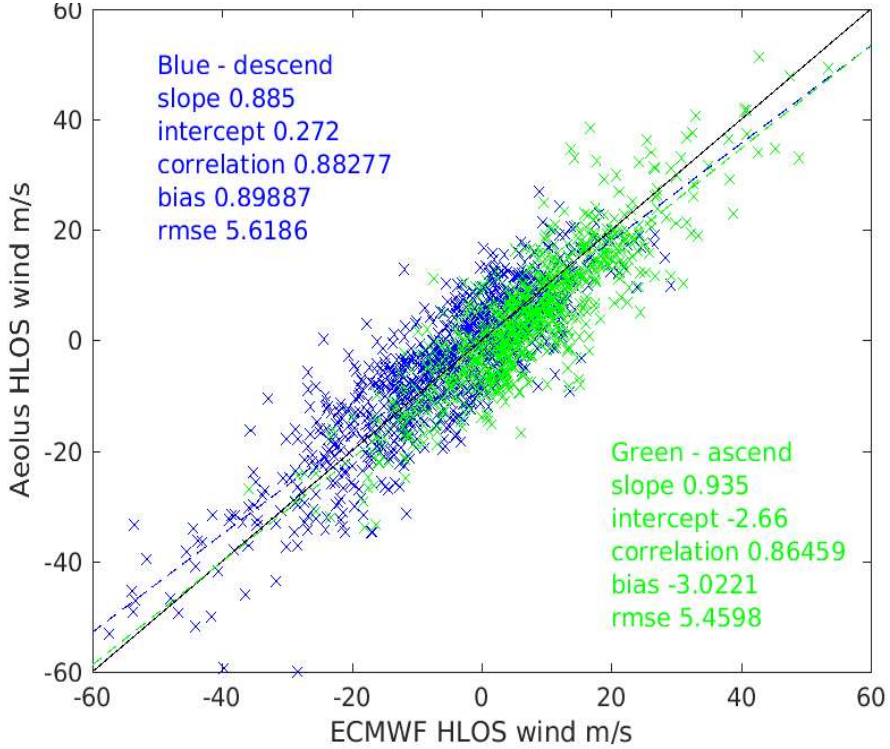
Aeolus vs MARA winds



Aeolus vs ECMWF winds

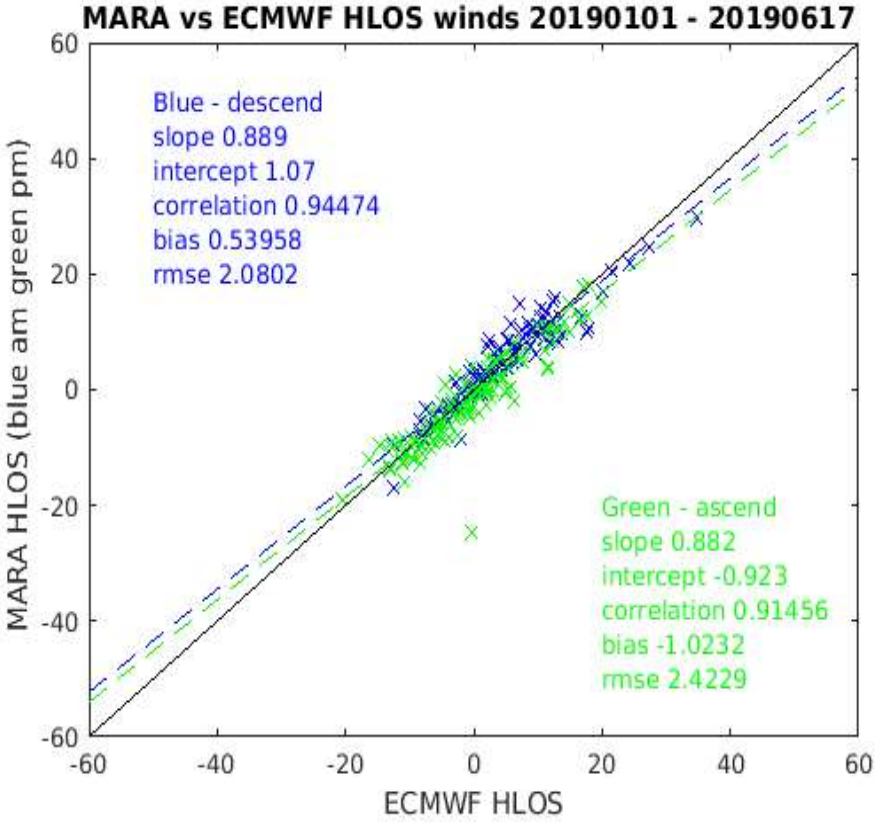


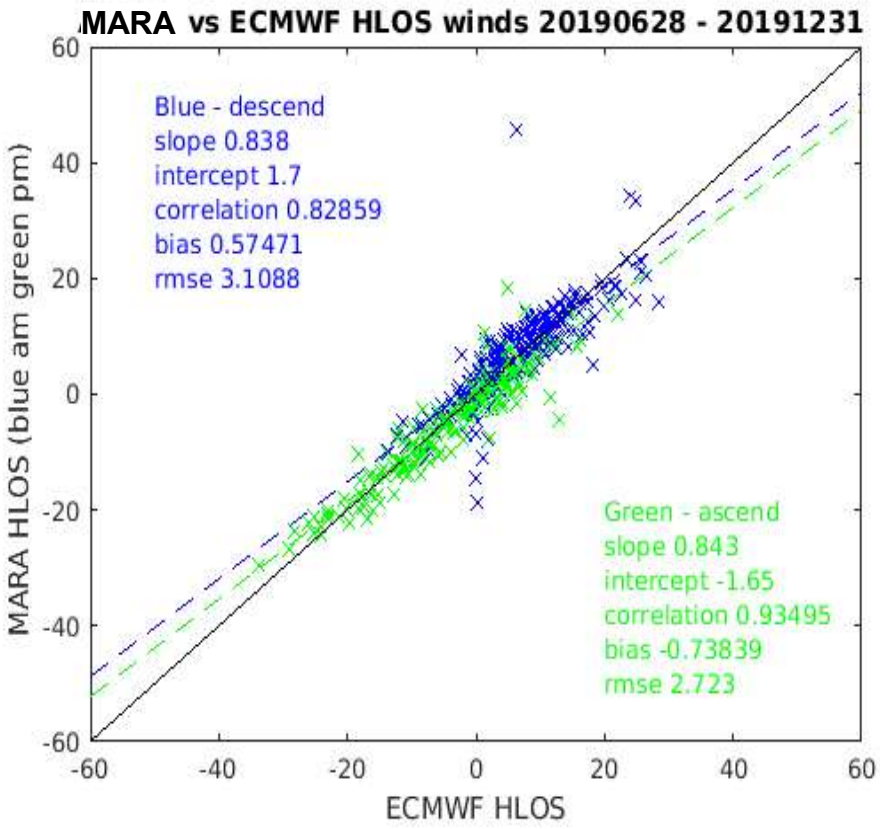
Period 20190628 – 20191231 (laser B).

- Large differences for the descend / ascend orbits and for laser A (previous slide) / laser B.
- Correlation is higher for the ascend orbits than for descend ones, as for laser A.
- Average swath distance to the MARA site is similar for the ascending (36 km and 69 km) and for the descending orbits (21 km and 84 km). Another reason to explain differences between the ascend and descend paths?
- More available MARA data and better performance of laser B are possible reasons for the smaller RMSE and higher correlation compared to the previous period (laser A).

Validation of MARA against ECMWF

The MARA and ECMWF (ERA5) HLOS winds for Aeolus paths over Maitri for period 20190101 – 20191231 (laser A & B).





- MARA and ECMWF HLOS winds agree much better for both ascending and descending orbits than in comparison with the Aeolus winds (2 previous slides).

Summary for validation using the radars

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Aeolus Rayleigh HLOS wind observations have been evaluated against the winds observed with two atmospheric radars and ECMWF model.

Antarctica

	MARA, laser A since Mar 2019 Ascend/Descend	ERA5, laser A since Jan 2019 Ascend/Descend	MARA, laser B until Jan 2020 Ascend/Descend	ERA5, laser B until Jan 2020 Ascend/Descend
Correlation	0.73 / 0.53	0.75 / 0.42	0.76 / 0.53	0.86 / 0.88
Slope of linear fit	1.1 / 0.5	1.1 / 0.7	0.9 / 0.6	0.9 / 0.9
Bias, m/s	2.4 / 0.3	3.0 / 5.8	-0.9 / -2.0	-3.0 / 0.9
RMSE, m/s	5.8 / 5.5	7.5 / 9.5	4.9 / 6.0	5.5 / 5.6

Arctic

	ESRAD, laser A Ascend/Descend	Interim, laser A Ascend/Descend
Correlation	0.79 / 0.74	0.87 / 0.79
Slope of linear fit	1.0 / 0.89	1.0 / 0.9
Bias, m/s	2.9 / -0.1	2.7 /1.5
RMSE, m/s	6.4 / 5.7	5.4 / 5.6

Aeolus studies using HARMONIE-AROME NWP model

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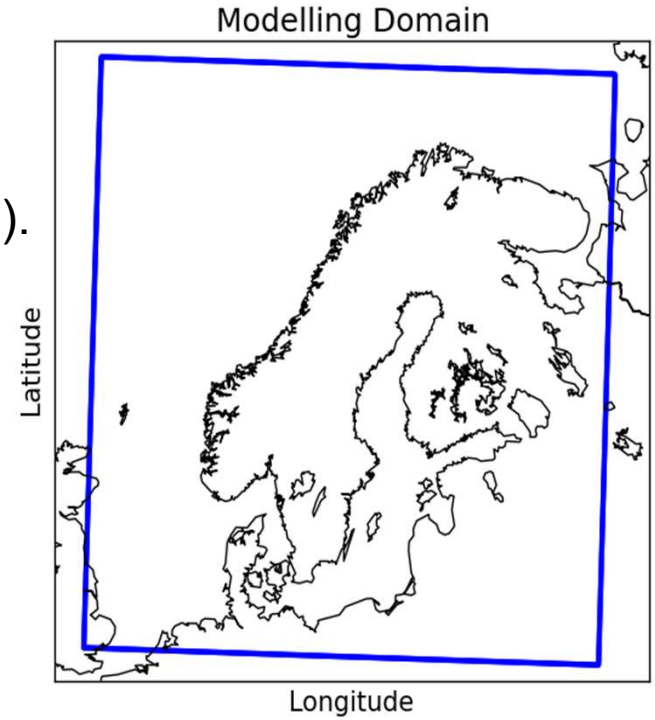
HARMONIE-AROME NWP configuration

- Non-hydrostatic forecast model.
- 2.5 km hor. grid-distance and 65 vertical levels.
- MetCoOp modelling domain (960 x 900 x 65 points).
- 3D-Var data assimilation with 3h DA cycle.
  - Assimilated obs: Conventional obs., AMSU-/MHS sat. radiances and Aeolus HLOS obs.



Experiments

- In co-operation with MET Norway
- Period: 14 SEP. 2018 to 14 OCT. 2018

CRL	REF	DES2	MIE	RAY
Control	Control + Aeolus	Tuned control + Aeolus	Control + Aeolus Mie only	Control + Aeolus Rayleigh only

Comparison of Aeolus HLOS with other data sources

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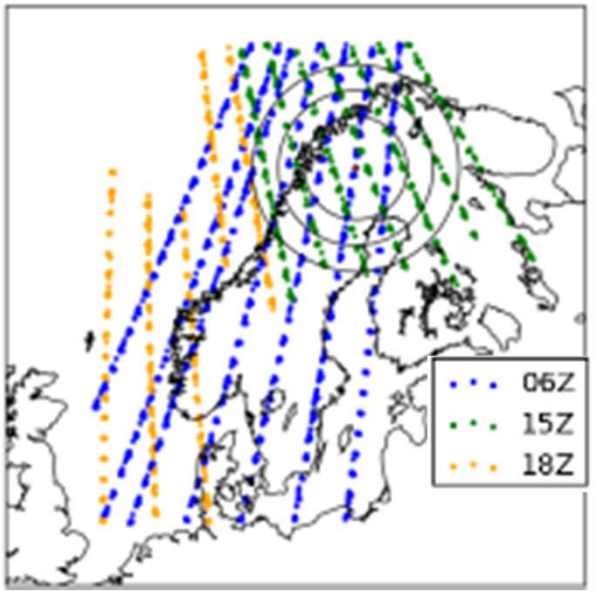
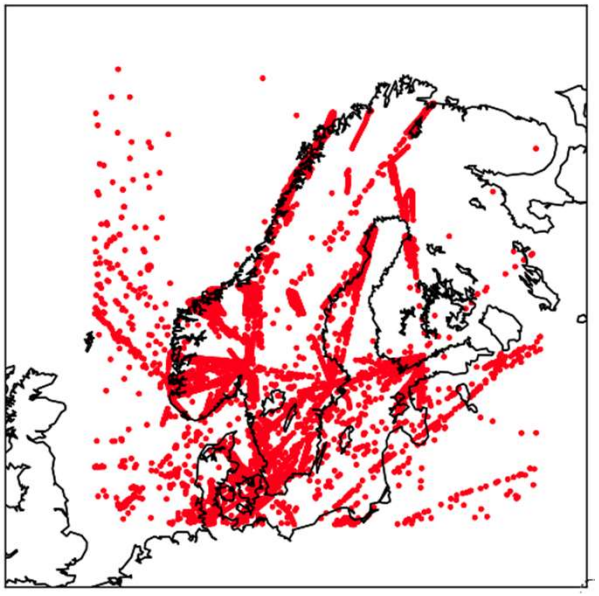
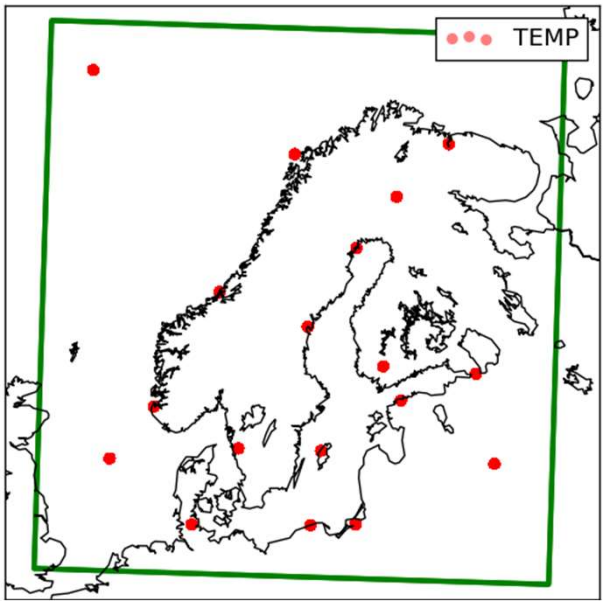
AEOLUS HLOS

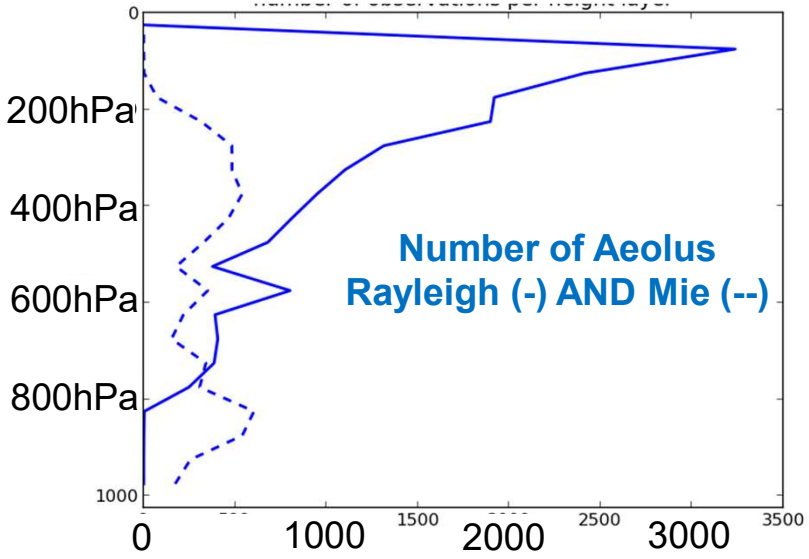


AIRCRAFT

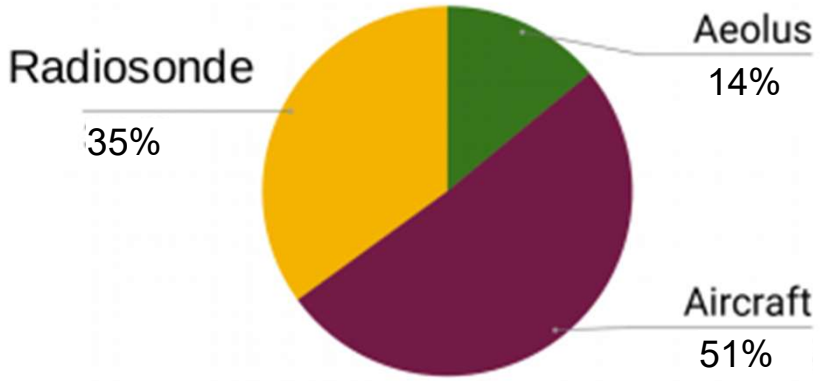


RADIOSONDE





RELATIVE AMOUNT OF WIND DATA



(From Roohollah Azad)

Comparison of observed and forecasted wind

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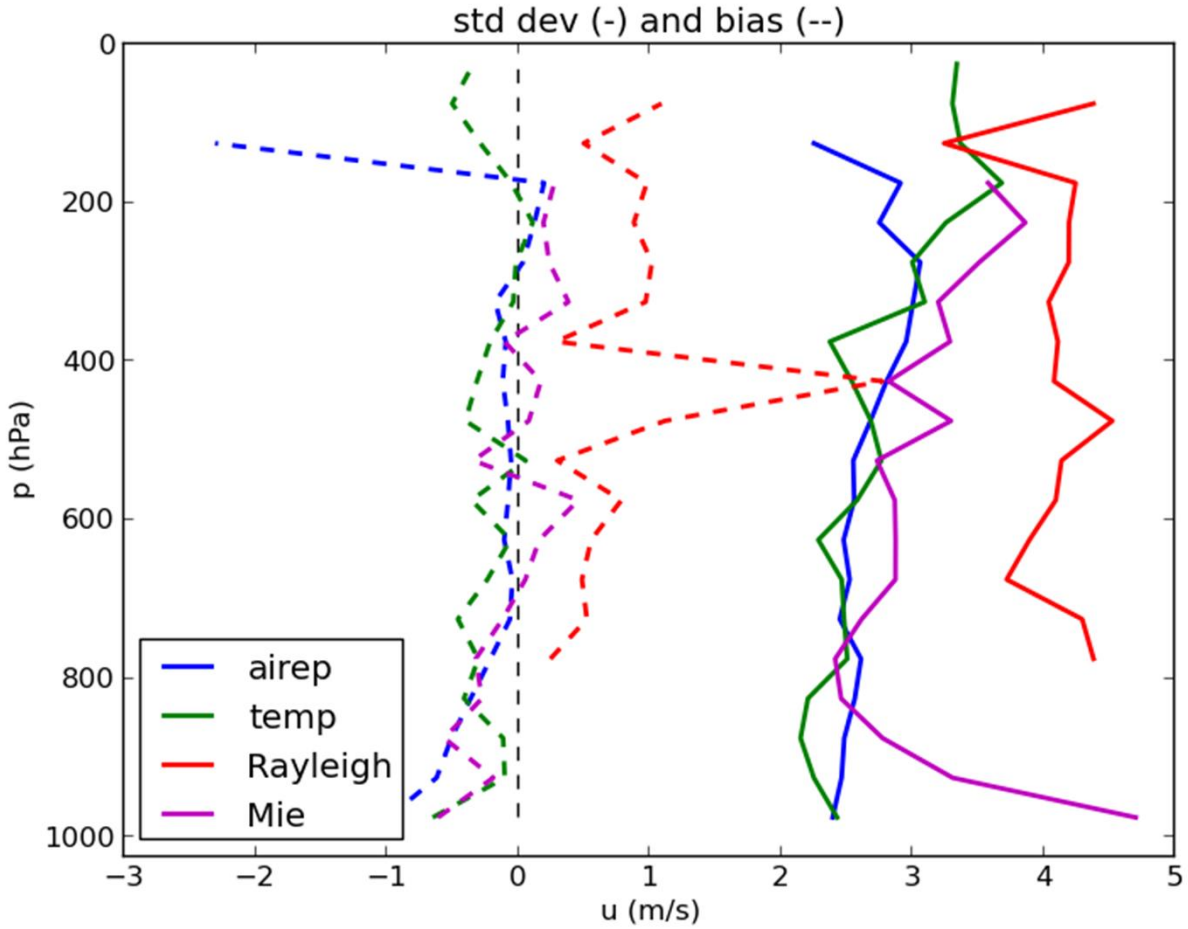
Standard deviation and bias for OB-FG (observed minus forecasted wind)



For:
AIREP (wind u-comp)
TEMP (wind u-comp)
AEOLUS Rayleigh (HLOS)
AEOLUS Mie (HLOS)

Statistics for all data in domain assimilated.
Period:
14 Sep 2018 - 14 Oct 2018

- **Rayleigh positive bias of about 1 m/s and large standard-deviation.**
- **Mie of quality comparable with AIREP and TEMP, except below 900 hPa.**

3 cases with collocated HLOS wind data over Esrange

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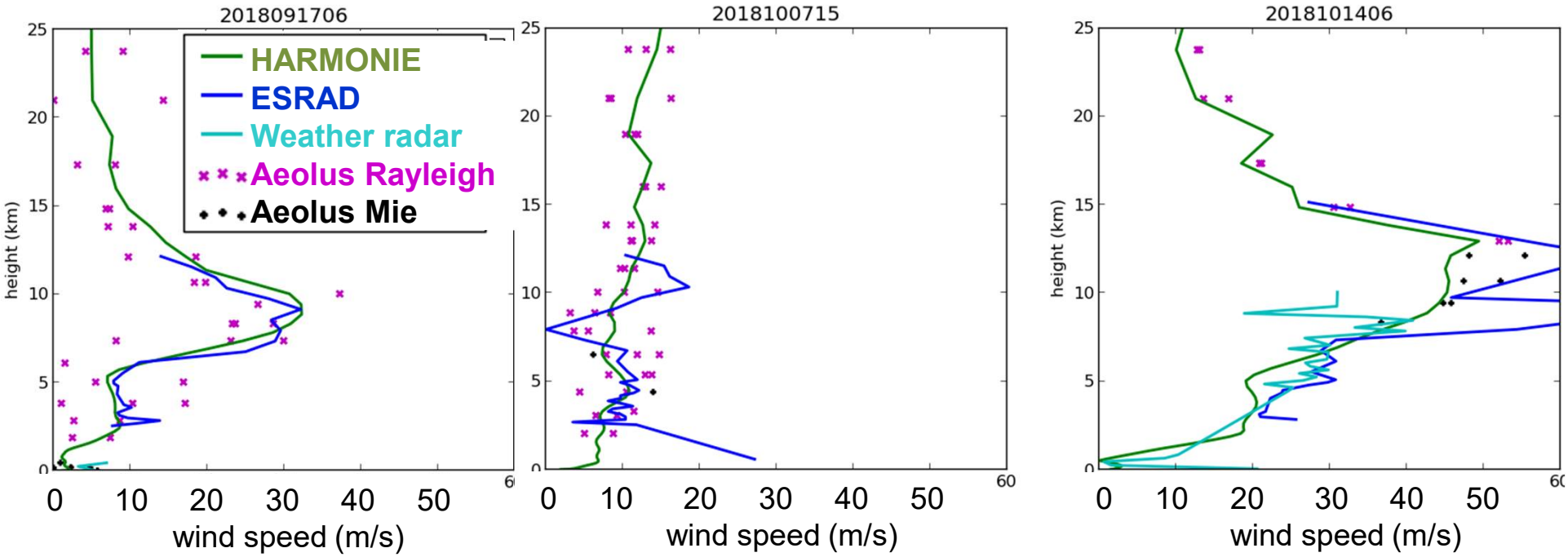
All Aeolus data within one degree from ESRAD location and during NWP exp.



- Overall, good agreement between the model and observations.
- Similar RMSE values (3-5 m/s) against model for ESRAD and weather radar.

Provided Aeolus obs error (OE) and NWP background error (BE)

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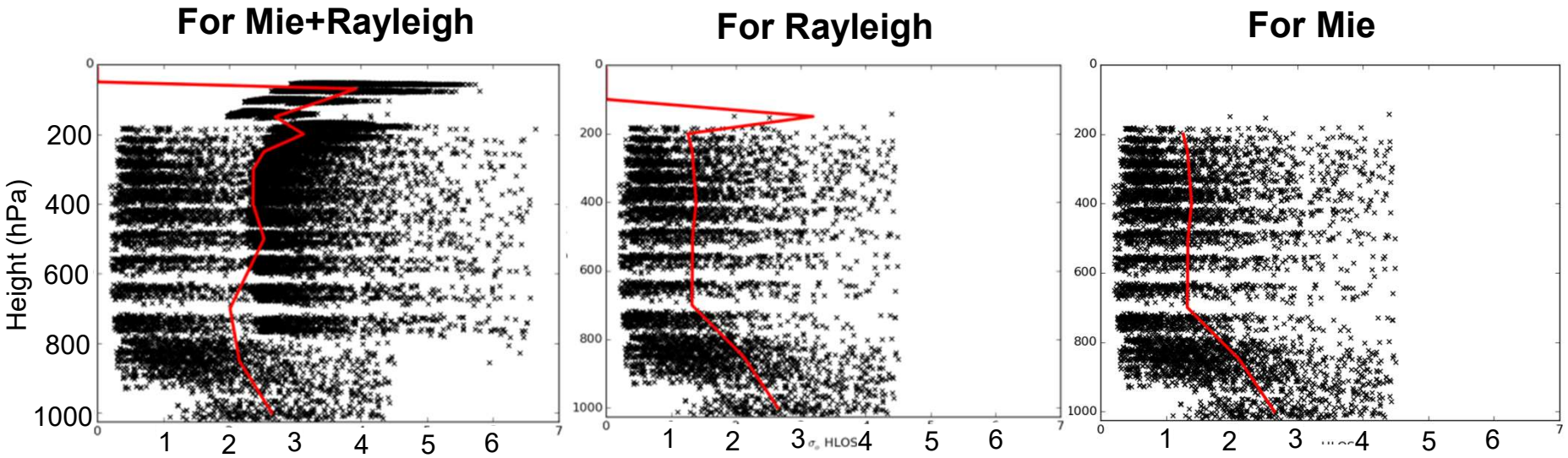
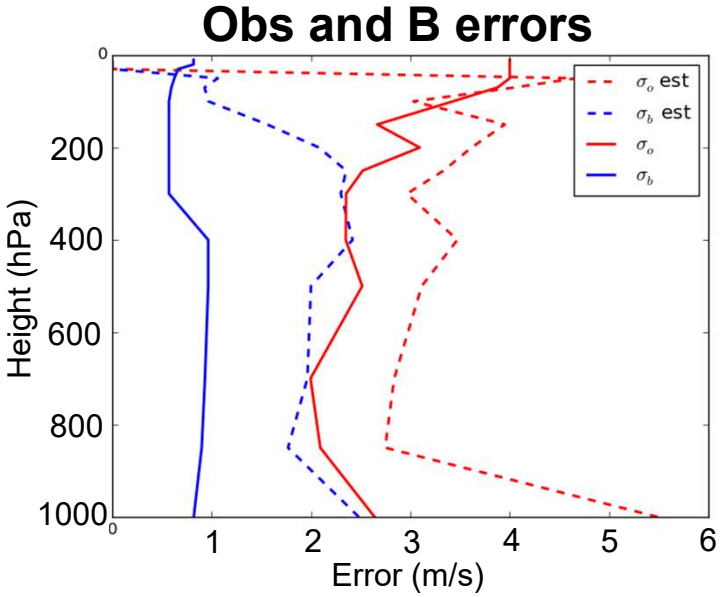


HLOS error in m/s. Black crosses: all data from one month period. Red curve: mean value.

Solid lines:
Mean Aeolus HLOS obs error std and
Corresponding Background error std
used in experiment **REF**.

Dashed lines:
Estimated observational and background errors from Desroziers diagnostic used for experiment **DES2** with slightly larger weight to observations.



Verification of 12h wind forecasts against Radiosondes

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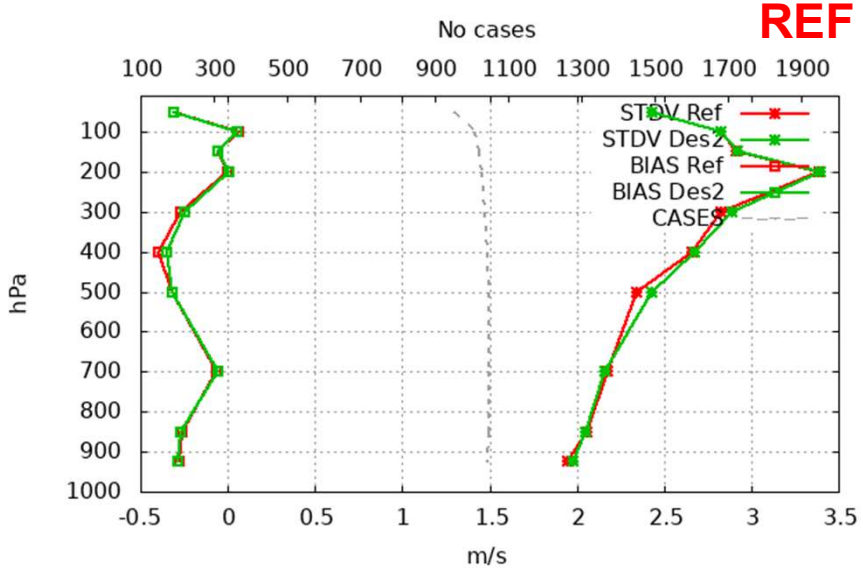
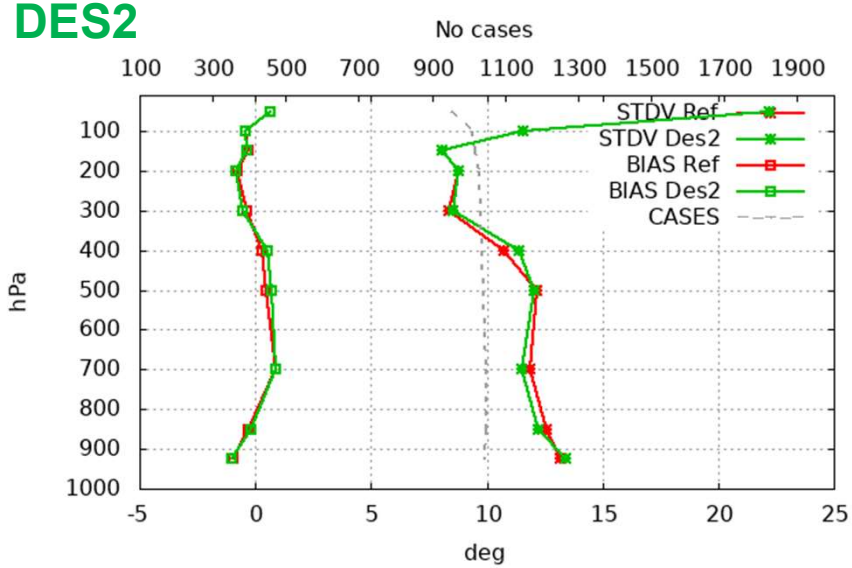
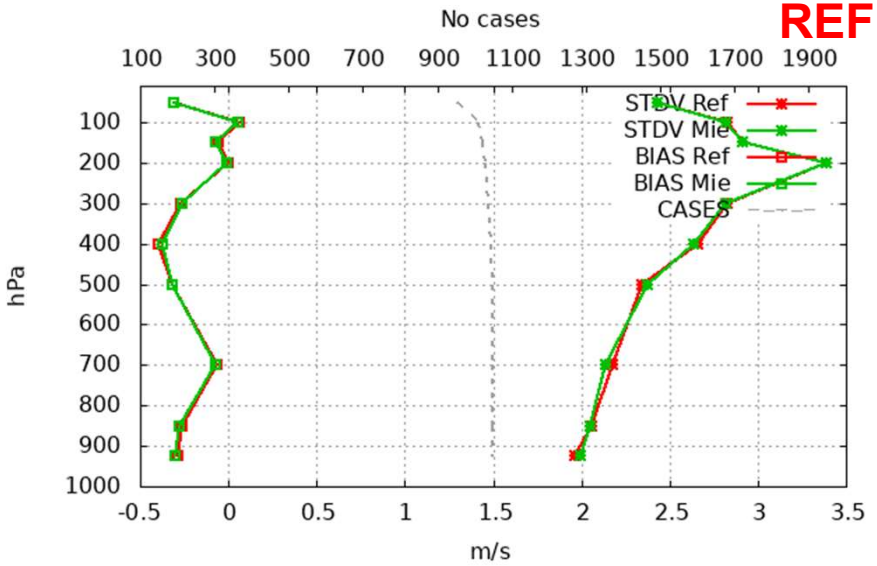
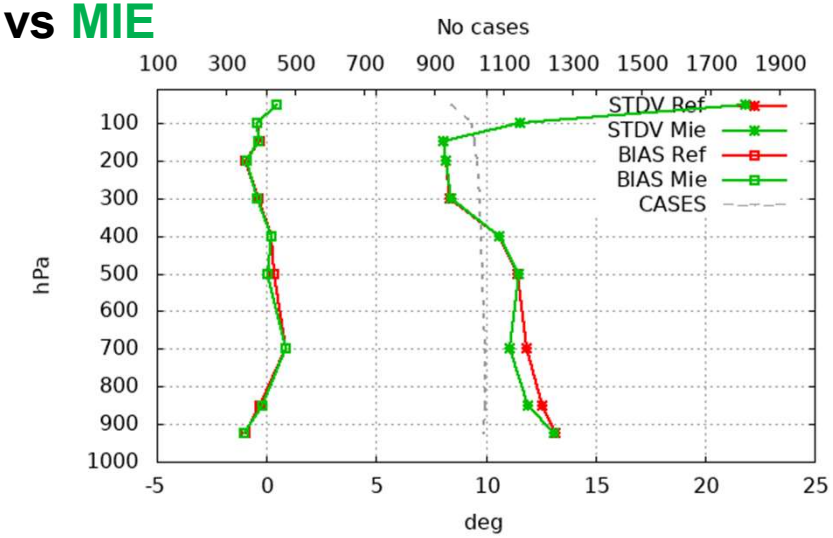
REF vs DES2





REF vs MIE





Period: 15 Sep 2018 to 14 Oct 2018. 12h-forecast started at 00 and 12 UTC. 21 stations.


Picture by ArianeSpace

Conclusions and future plans

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Conclusions:

- **Aeolus Rayleigh HLOS winds have been evaluated by comparison with the winds observed with two atmospheric radars: ESRAD in Swedish Arctic and MARA in Antarctica.**
- **Larger differences between Aeolus HLOS wind statistics for ascending and descending orbits obtained from the radar in Antarctica than from the radar in Arctic were found.**
- **Aeolus HLOS wind observations have been evaluated and assimilated during a one month period using HARMONIE-AROME km scale NWP model.**
- **Mie winds of better quality than Rayleigh winds.**
- **Assimilation experiment revealed neutral to slightly positive impact of HARMONIE_AROME forecast of assimilation of Mie winds.**

Future plans:

- **Validation with ESRAD for laser B**
- **Validation statistics as a function of altitude**
- **Case studies for special conditions such as strong GWs**
- **NWP experiments with laser B**