Separate the contributions from the Rayleigh and Mie channels of the AEOLUS HLOS winds in the Météo France global NWP model.

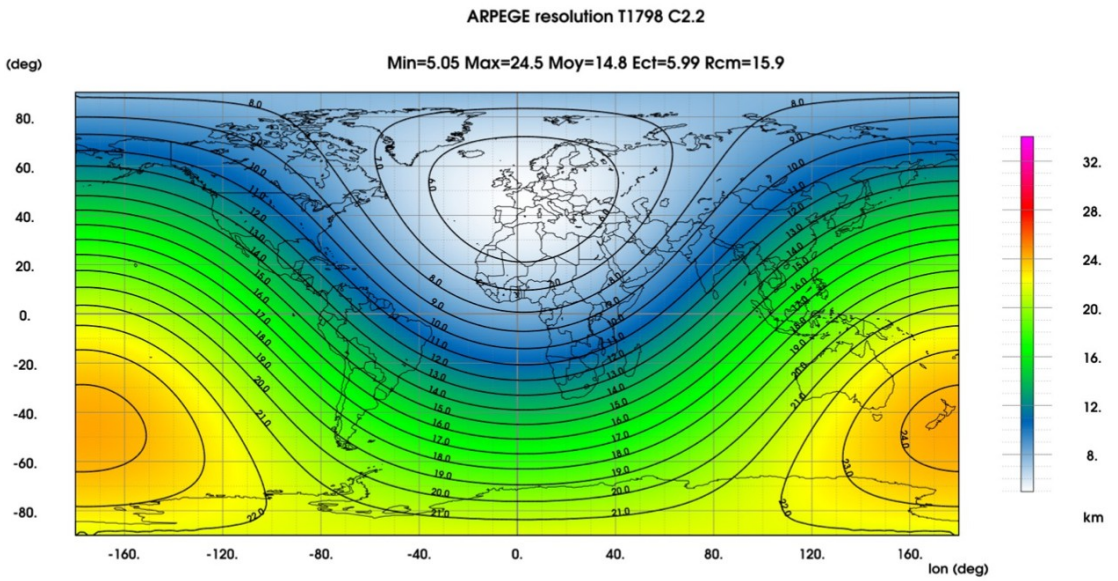
J.-F. Mahfouf, V. Pourret, I. Seck, D. Raspaud, H. Benichou

CNRM/GMAP (Toulouse, France)

Outline

- Current global NWP system and observation usage
- Overview of AEOLUS HLOS wind assimilation in operations
- Distinct contributions of Rayleigh and Mie channels of the first reprocessed dataset in NWP impacts
- Conclusion / future activities

Global model ARPEGE (high resolution)



Spectral model with variable resolution:
T_L1798c2.2L105

Δx from **5** to 25 km
105 vertical levels
from 10 m to 0.1 hPa

Incremental 4D-Var assimilation (6-h window and 30 min time-slots) :

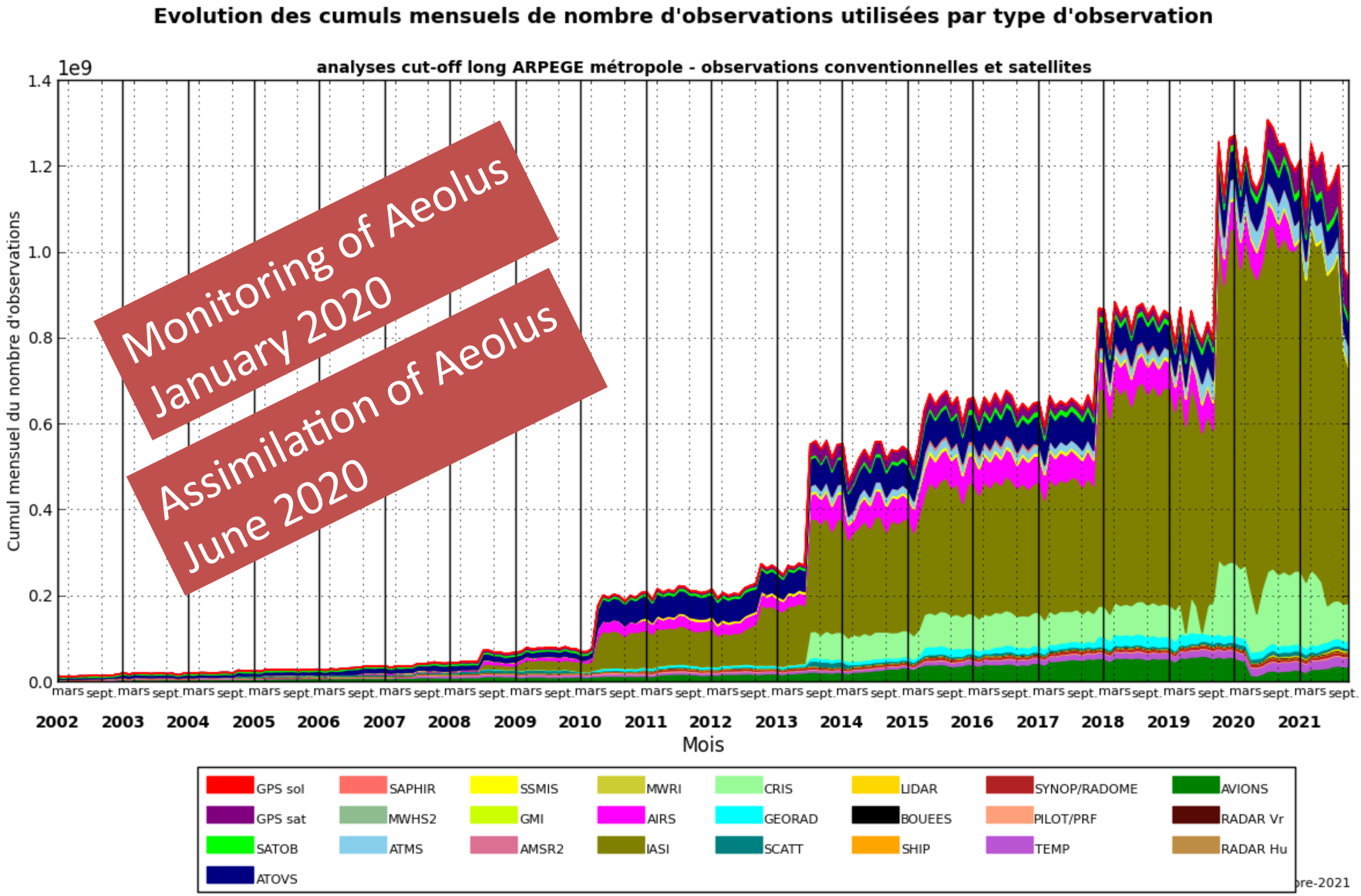
- 2 loops of minimization: T_L224c1L105 (40 iterations) + T_L499c1L105 (40 iterations)
- Background error variances and correlation lengths from an EDA system (4D-Var at lower resolution: T_L499/T_L224) with 50 members (**AEARP**)

Forecasts (cut-off and ranges):
00 UTC (1h10/54h), 00 UTC (2h15/102h),
06 UTC (3h/72h), 12 UTC (1h50/114h), 18 UTC (3h/60h)

Since 07/2019

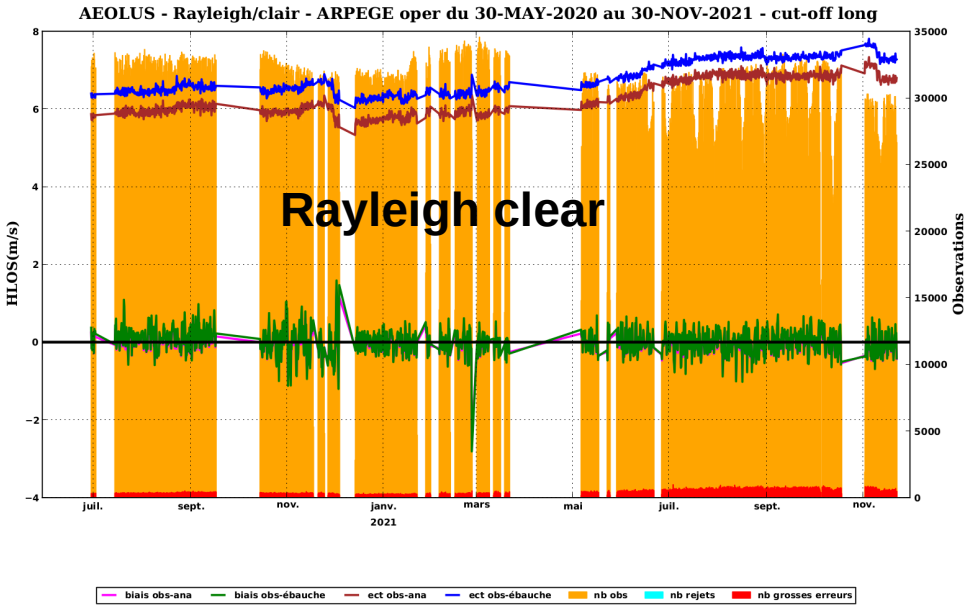
METEO FRANCE

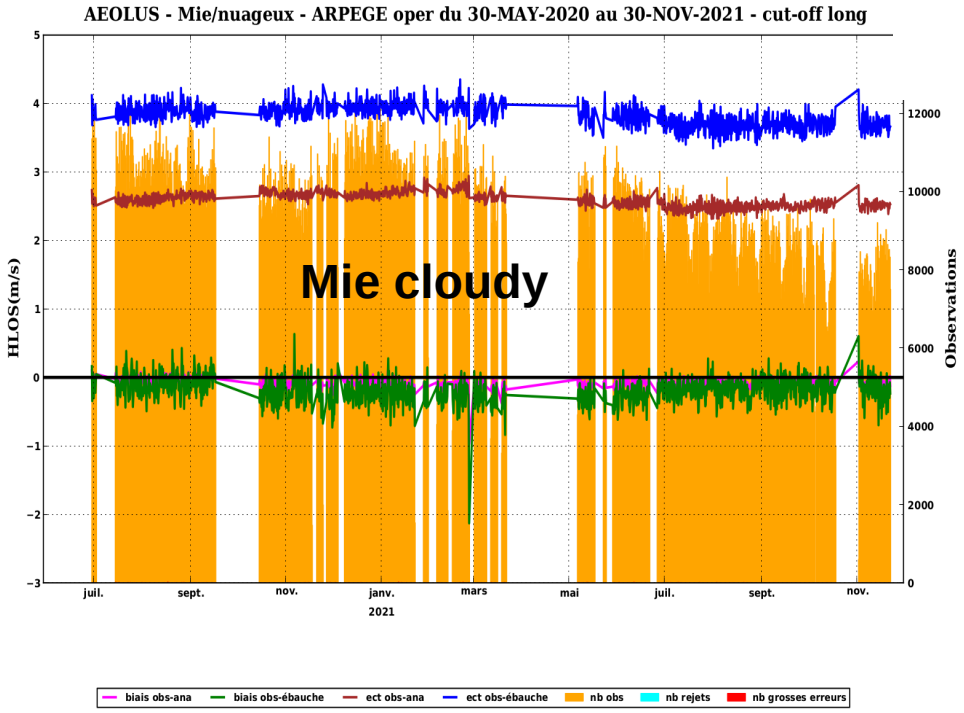
Observation evolution in ARPEGE



Monitoring: June 2020 - November 2021
HLOS winds bias corrected from M1 temperature gradient

Slow increase of SD(OmB) from ~6.5 m/s to ~7.5 m/s especially since this summer



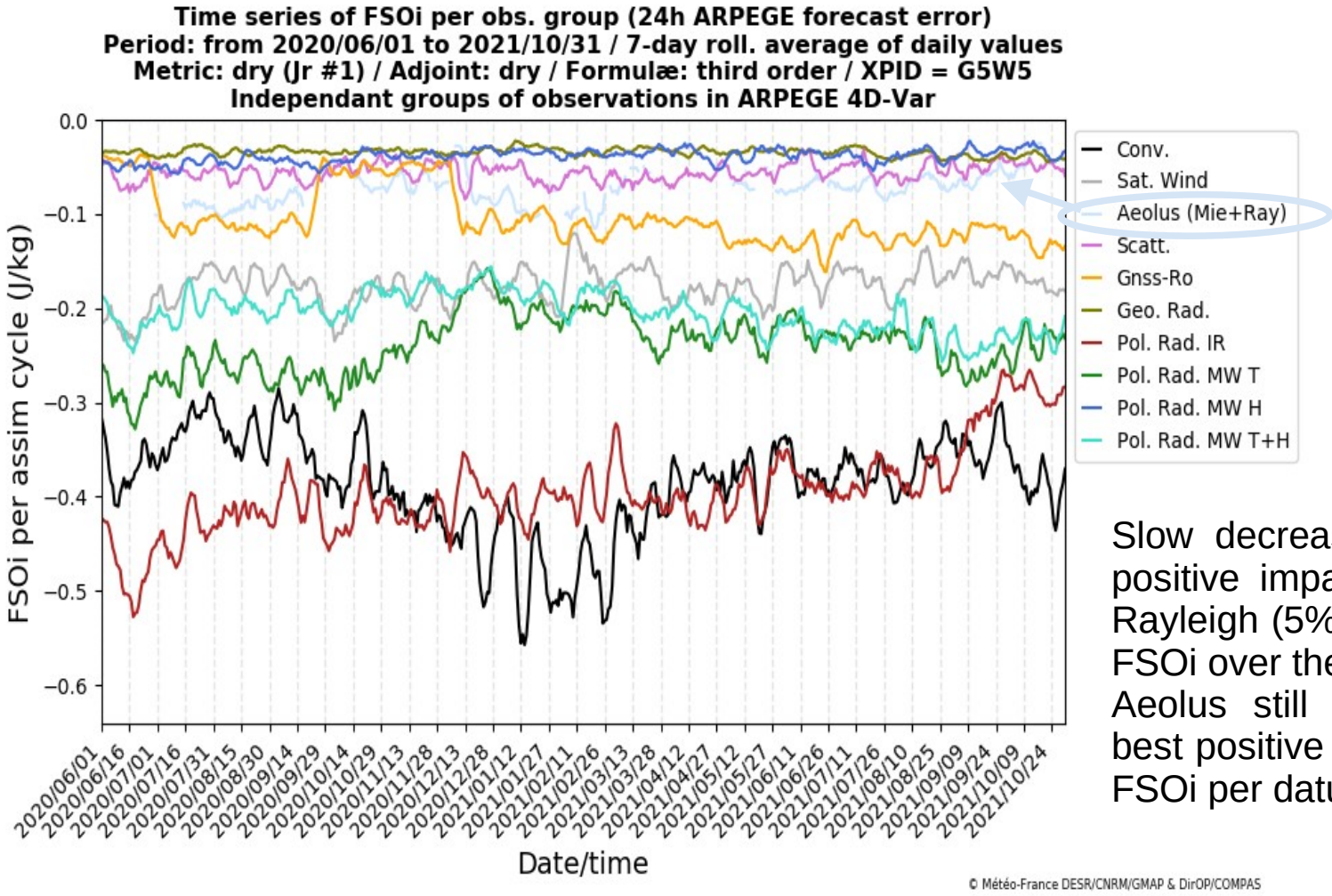


Stable signals for Mie
Negative bias till July 2021
but with decreasing data counts

Blue : SD(OmB)
Red : SD(OmA)
Green : mean(OmB)
Pink : mean(OmA)
Orange : obs number

METEO FRANCE

FSOi : June 2020 – October 2021
HLOS winds bias corrected from M1 temperature gradient



Slow decrease of the relative positive impact especially for Rayleigh (5% to 4% of the total FSOi over the period).
Aeolus still have one of the best positive impact in terms of FSOi per datum.

Experiments with reprocessed unbiased HLOSW

Test period: 4 July 2019 – 31 October 2019 (FM-B laser) with first reprocessed dataset

OSE1: Assimilation of Rayleigh + Mie channels

OSE2: Assimilation of Rayleigh channel

OSE3: Assimilation of Mie channel

σ_0 scaled as a function of prescribed HLOS L2B errors (based on one year of operational assimilation dataset)

Quality controls:

HLOS winds restricted to Rayleigh/clear and Mie/cloudy

- Rayleigh/clear above 850 hPa
- Rayleigh winds kept when $2 \text{ m/s} < \sigma_0 < 8 \text{ m/s}$
- Mie winds kept when $0.5 \text{ m/s} < \sigma_0 < 3 \text{ m/s}$
- Background check to reject winds too far from model (5σ)

METEO FRANCE

Reminder : first experiments with unbiased HLOSW

Test period: 1 July 2019 – 31 August 2019 (FM-B laser) according to the guidance for AEOLUS NWP impact XP

OSE1 bis: Météo-France bias correction based on temporal and spatial statistical comparison between good quality *Mie/cloudy* and *Rayleigh/cloudy* to bias correct Rayleigh/clear data (Rayleigh products share similar systematic error properties / small biases for Mie/cloudy)

OSE1 ter: ECMWF bias correction (OmB) running mean

σ_0 scaled as a function of latitude (R/C) using prescribed HLOS L2B errors (with statistics over the test period)

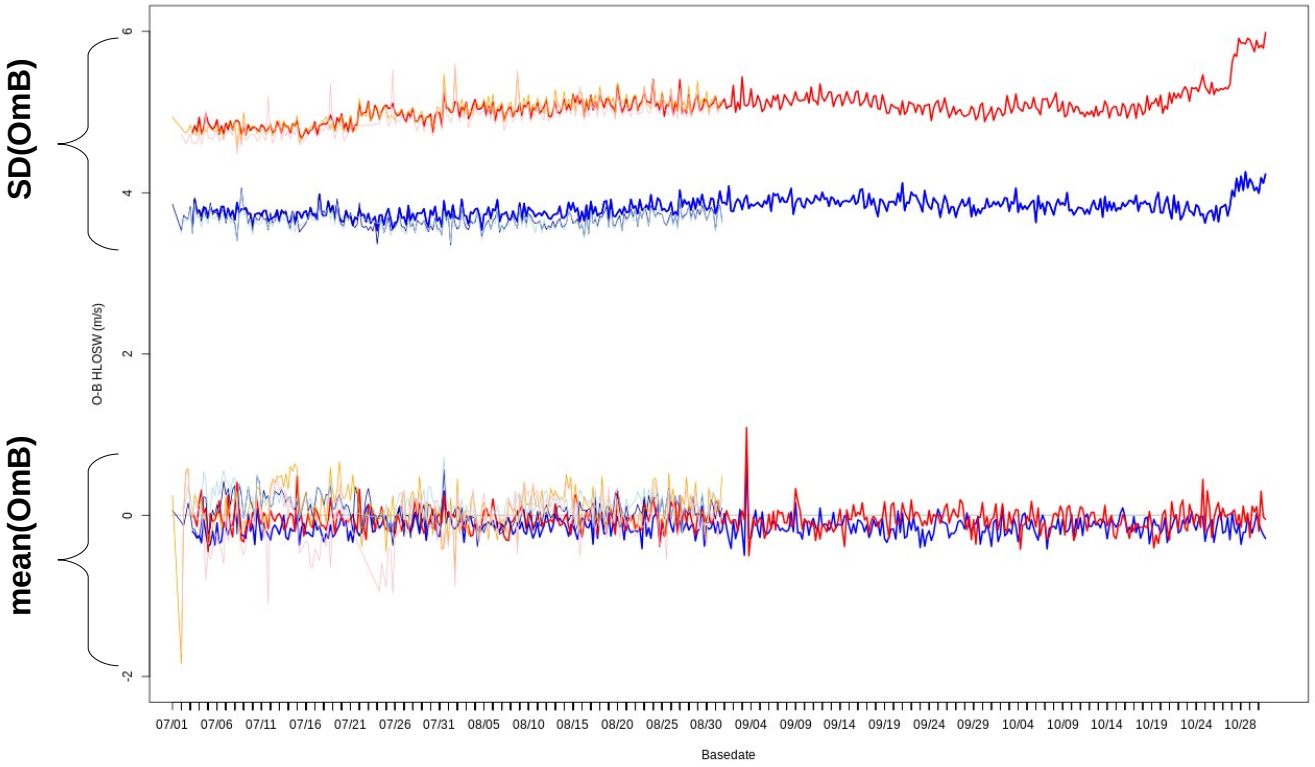
Quality controls (adapted from ECMWF guidelines):

HLOS winds restricted to Rayleigh/clear and Mie/cloudy

- Mie integration length > 5 km
- Rayleigh/clear above 850 hPa
- Rayleigh winds kept when 2 m/s < σ_0 < 8 m/s
- Mie winds kept when 0.5 m/s < σ_0 < 3 m/s
- Background check to reject winds too far from model (5σ)

OSEs HLOS wind (OmB) statistics

1 Jul 2019
31 Oct 2019



OSE1: Rayleigh, Mie

OSE2: Rayleigh (not shown)

OSE3: Mie (not shown)

OSE1bis: Rayleigh, Mie

OSE1ter: Rayleigh, Mie

σ (O–B) mean(O-B)	OSE1 bis	OSE1 ter	OSE1	OSE2	OSE3
Rayleigh Clear	5.01 m/s 0.1 m/s	4.93m/s -0.05 m/s	5.07 m/s -0.05 m/s	5.07 m/s -0.05 m/s	
Mie cloudy	3.68 m/s 0.05 m/s	3.66 m/s 0.15 m/s	3.81 m/s -0.14 m/s		3.82 m/s -0.14 m/s

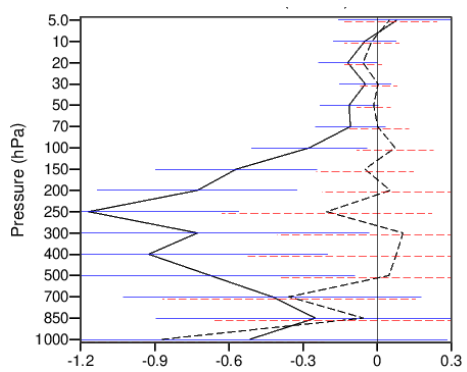
- Rayleigh clear HLOSW SD(OmB) very close for all OSE
- Mie cloudy HLOSW SD(OmB) slightly higher for OSE1 and OSE3 (cf. OSE1 bis and ter QC)
- Mie cloudy HLOSW mean(OmB) slightly negative for OSE 1 and 3
- HLOSW mean(OmB) for OSE1bis and OSE1ter noisier than OSE1, OSE2 and OSE3.

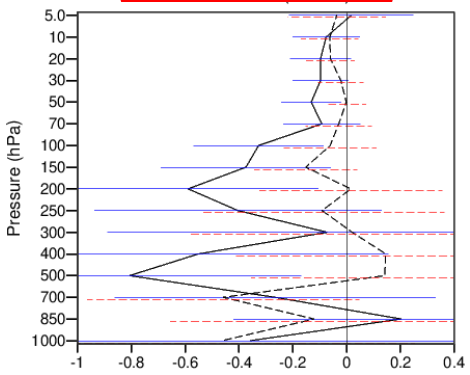
RS u wind (OmB) statistics for OSE1, OSE2 and OSE3

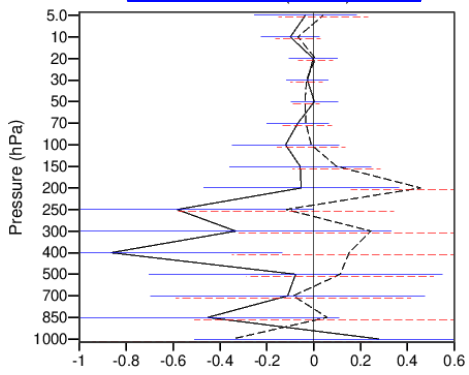
OSE1 (R+M) | **OSE2 (R)** | **OSE3 (M)**

Relative (%) $SD(OmB)_{XP}$ -$SD(OmB)_{ref}$

NH

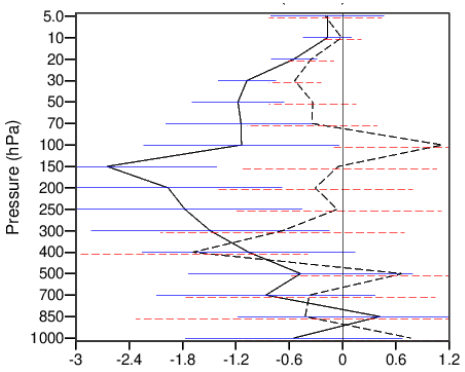


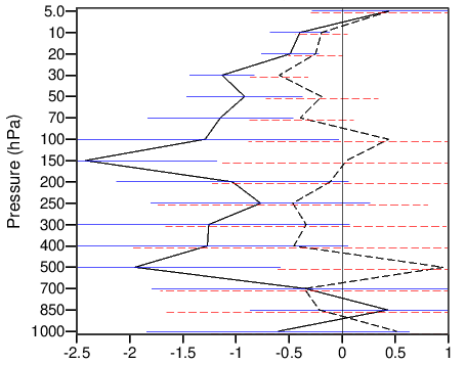


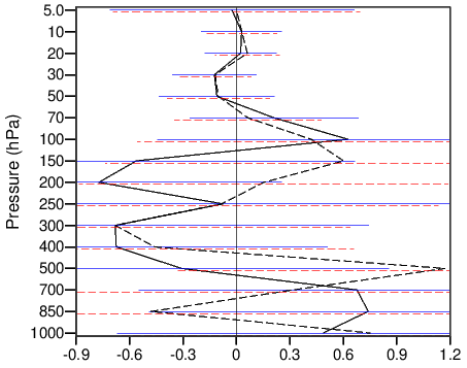


Negative = better with AEOLUS

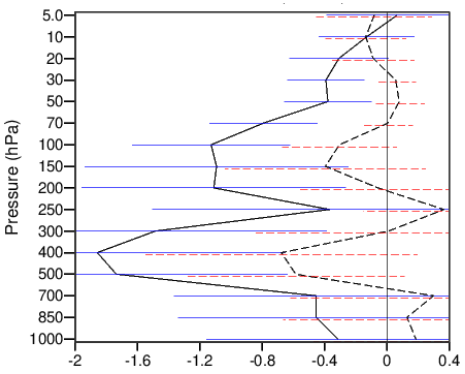
Tropics

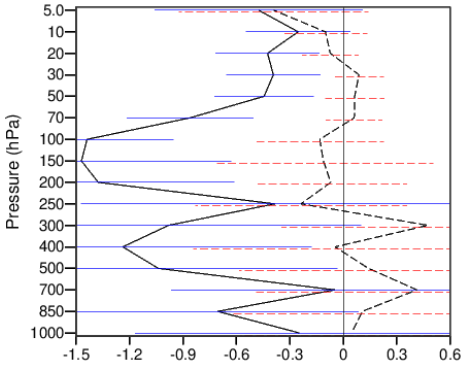


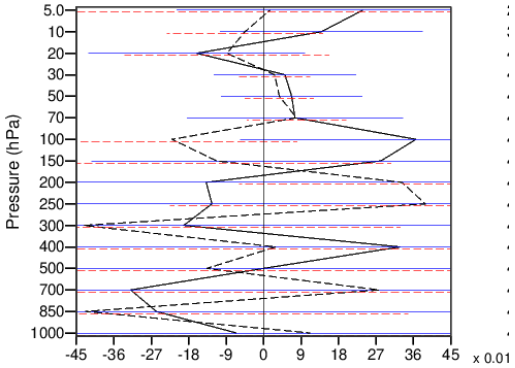




SH







METEO FRANCE

(OmB) statistics between OSE1, OSE2 and OSE3

- Like in earlier OSEs: Aeolus improves wind, temperature and humidity background fits against other observing system (except for polar and tropical AMVs)
- As expected, AEOLUS impacts are the largest in tropical UTLS
- Rayleigh clear data have much more positive impacts on short range forecasts than Mie cloudy (main positive impacts in troposphere, in Antarctic)

METEO FRANCE

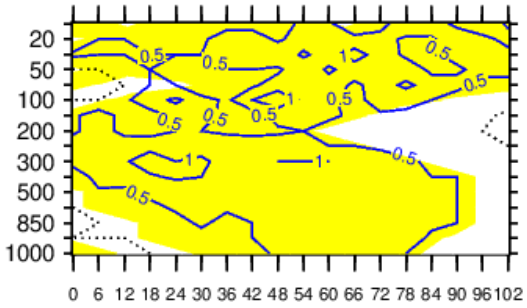
July-October 2019

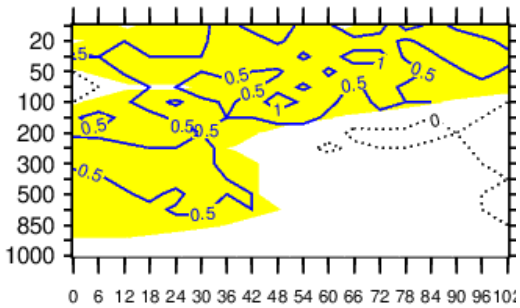
Forecast scores (winds)

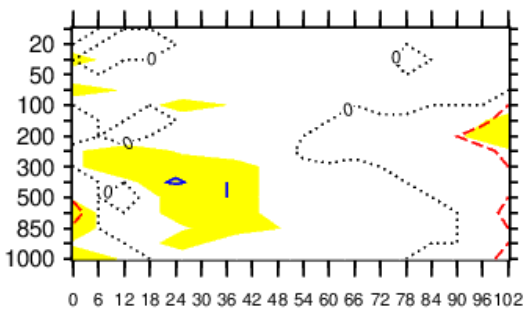
Normalized RMS(O-F)
Differences REF – EXP
REF : ARPEGE oper
O : ECMWF analyses

OSE1 (R+M) | **OSE2 (R)** | **OSE3 (M)**

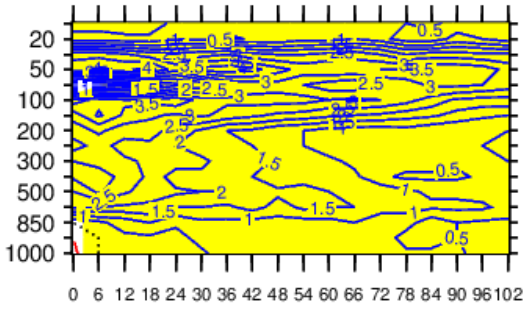
NH

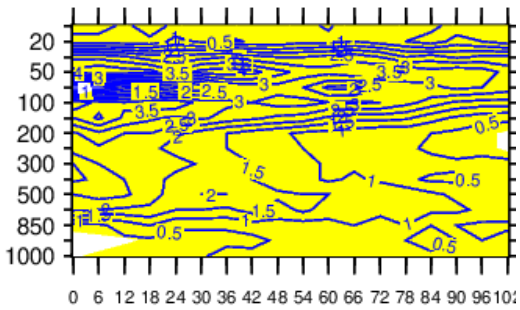


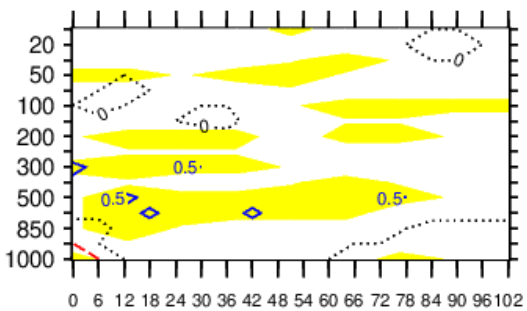




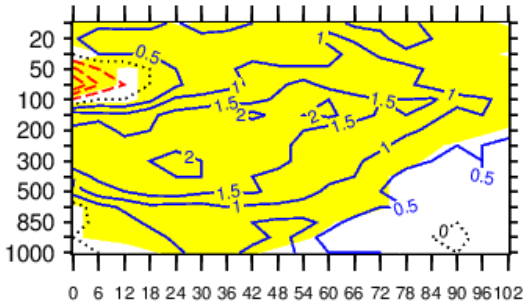
Tropics

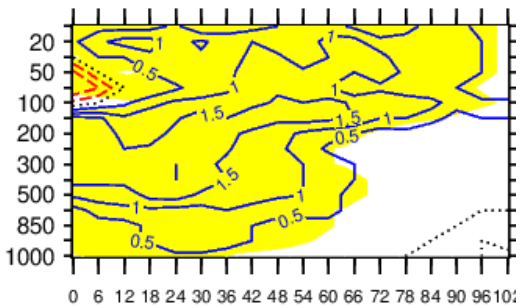


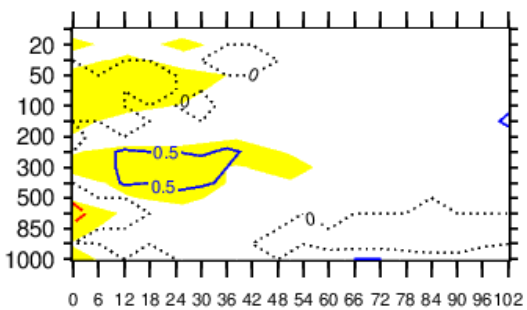




SH







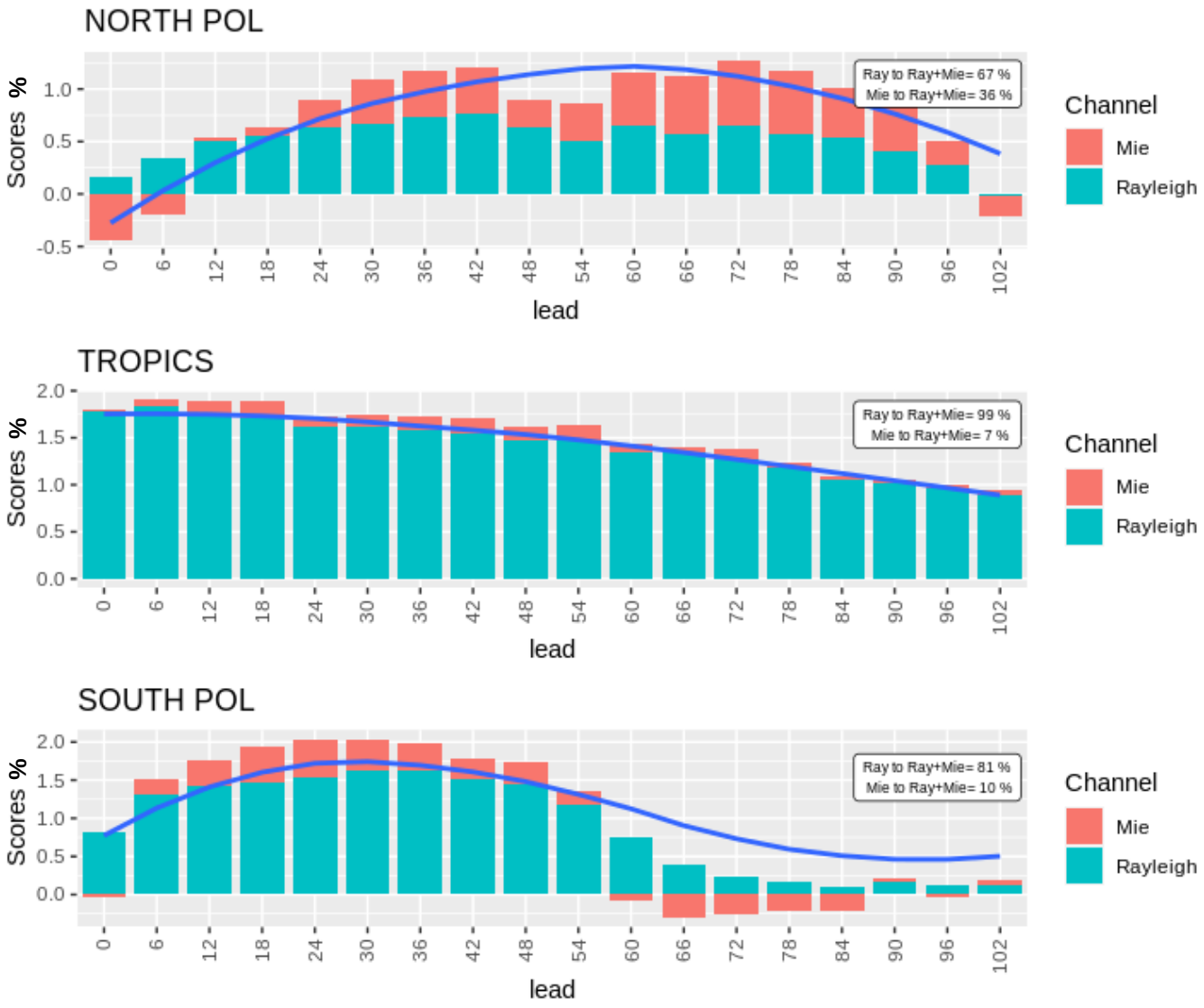
significant

METEO FRANCE

Forecast scores vertical means (winds)

July-October 2019

Normalized RMS(O-F)
Differences REF – EXP
REF : ARPEGE oper
O : ECMWF analyses



METEO FRANCE

Conclusions and future activities

- Operational monitoring in ARPEGE since January 2020
- Operational assimilation since June 2020
- Operational FSOI shows that Aeolus still provides positive impact till october this year (even with the slow increase of Rayleigh winds observation error)
- Assimilation of the first reprocessed dataset leads to positive impacts statistically significant and of good magnitude on wind, temperature and humidity forecasts especially in tropical UTLS and in polar region (up to 4 days).
- Similar to previous OSEs (July-August 2019 using NRT data with two different unbiasing methods) – but with larger positive impact on forecats scores (0.5-1%)
- Much larger positive impacts of Rayleigh channel on ARPEGE forecast up to 4 days compared to the Mie channel (limited to troposhere, poles and first ranges - 36 % max in mean of the R+M XP scores for wind over North Pole)

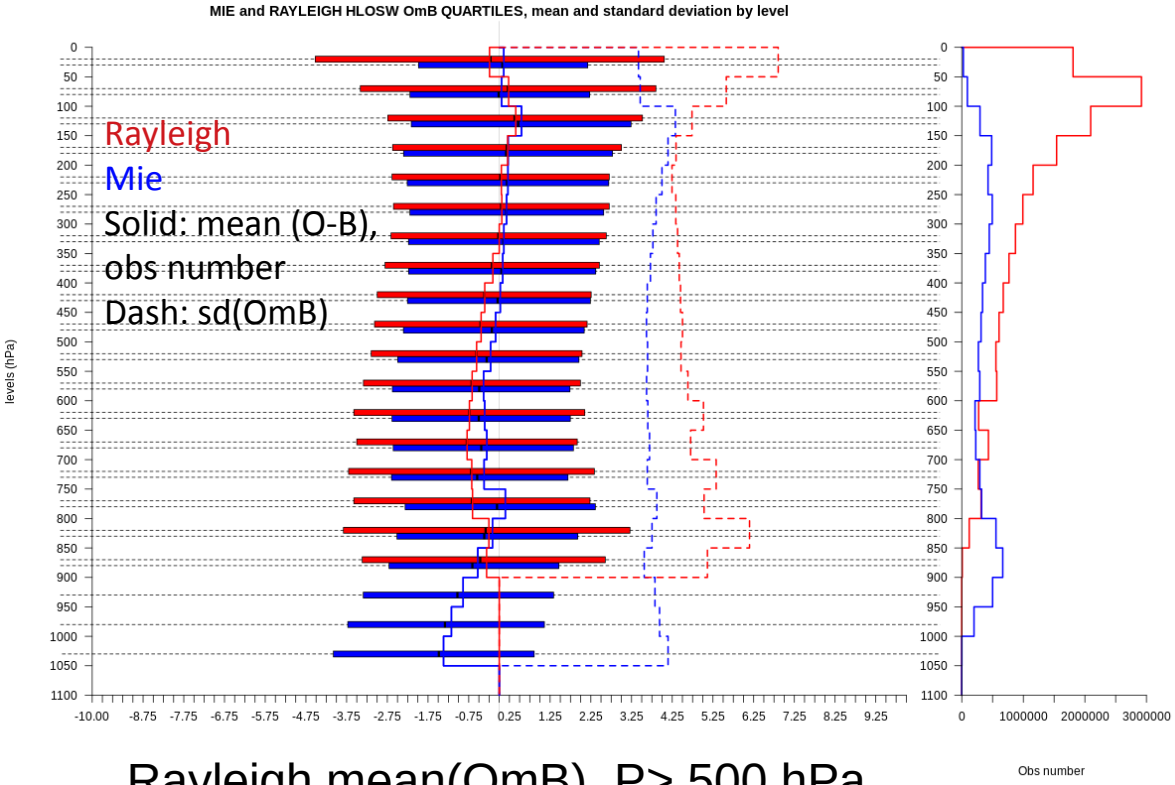
- Planned activities : consolidate statistics over the period of the whole first reprocessed dataset, statistical and case studies (tropical storms)

METEO FRANCE

Thank you for your attention !

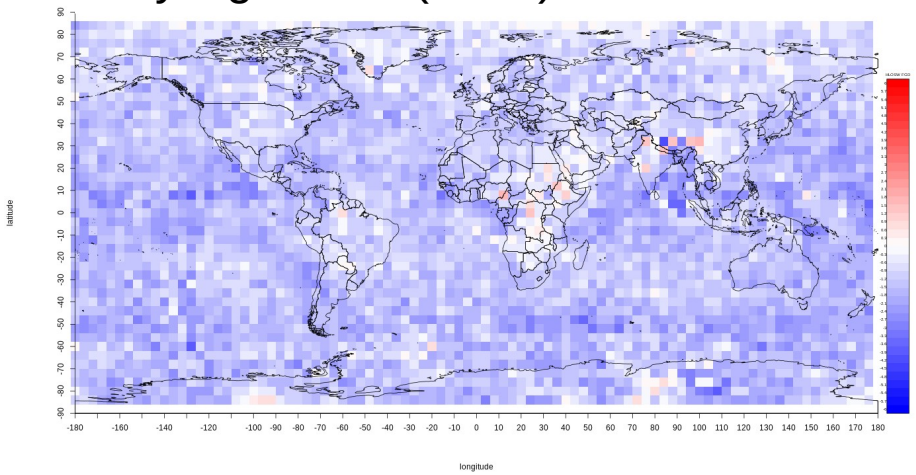
OSE1 profiles of HLOS wind (OmB) statistics

1 Jul 2019
31 Oct 2019



- Mie cloudy HLOSW mean(OmB) increasing with altitude (negative to slightly positive bias)
- Rayleigh clear HLOSW mean(OmB) sligthly negative in low levels and widespread

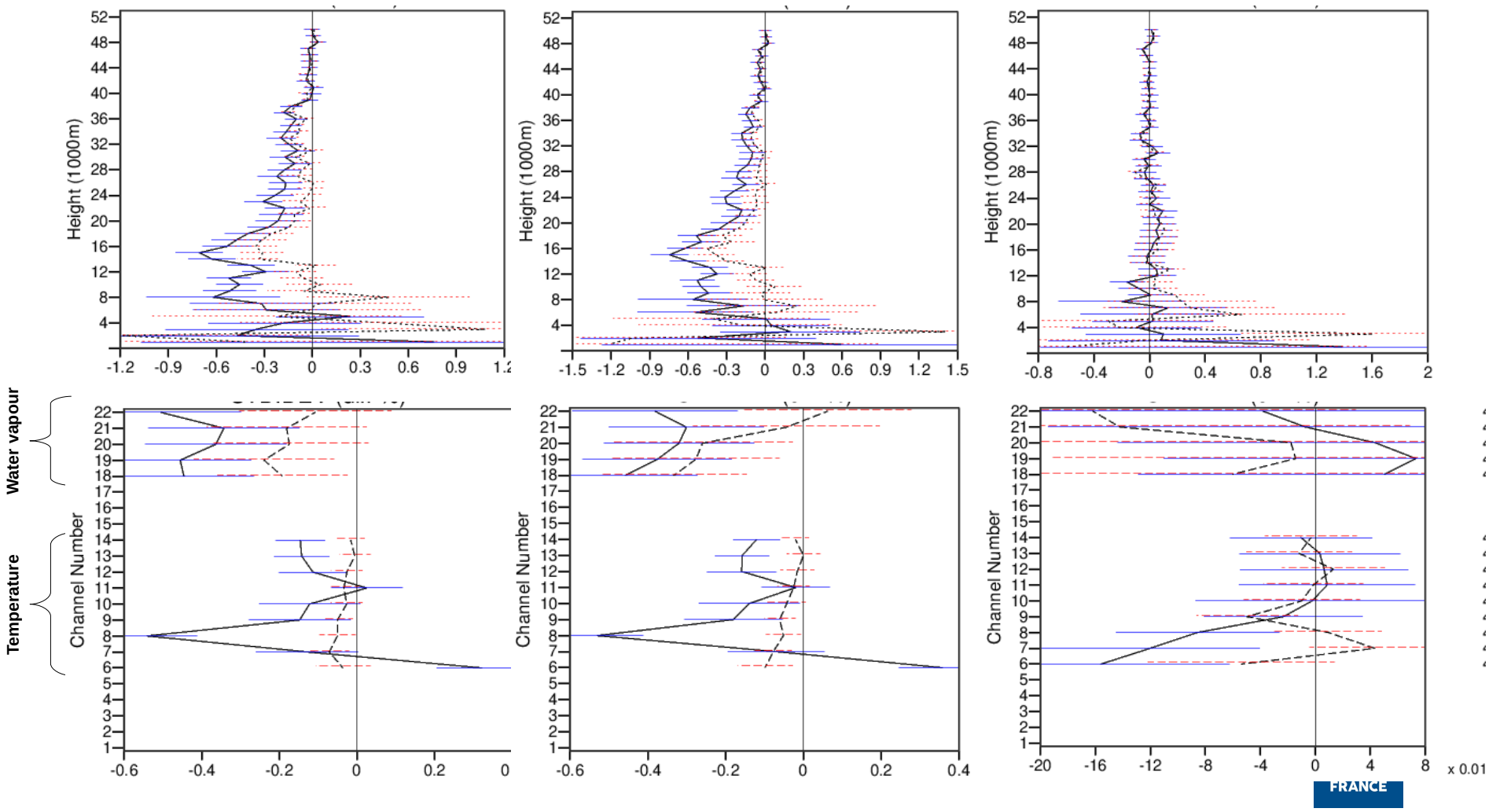
Rayleigh mean(OmB), P> 500 hPa



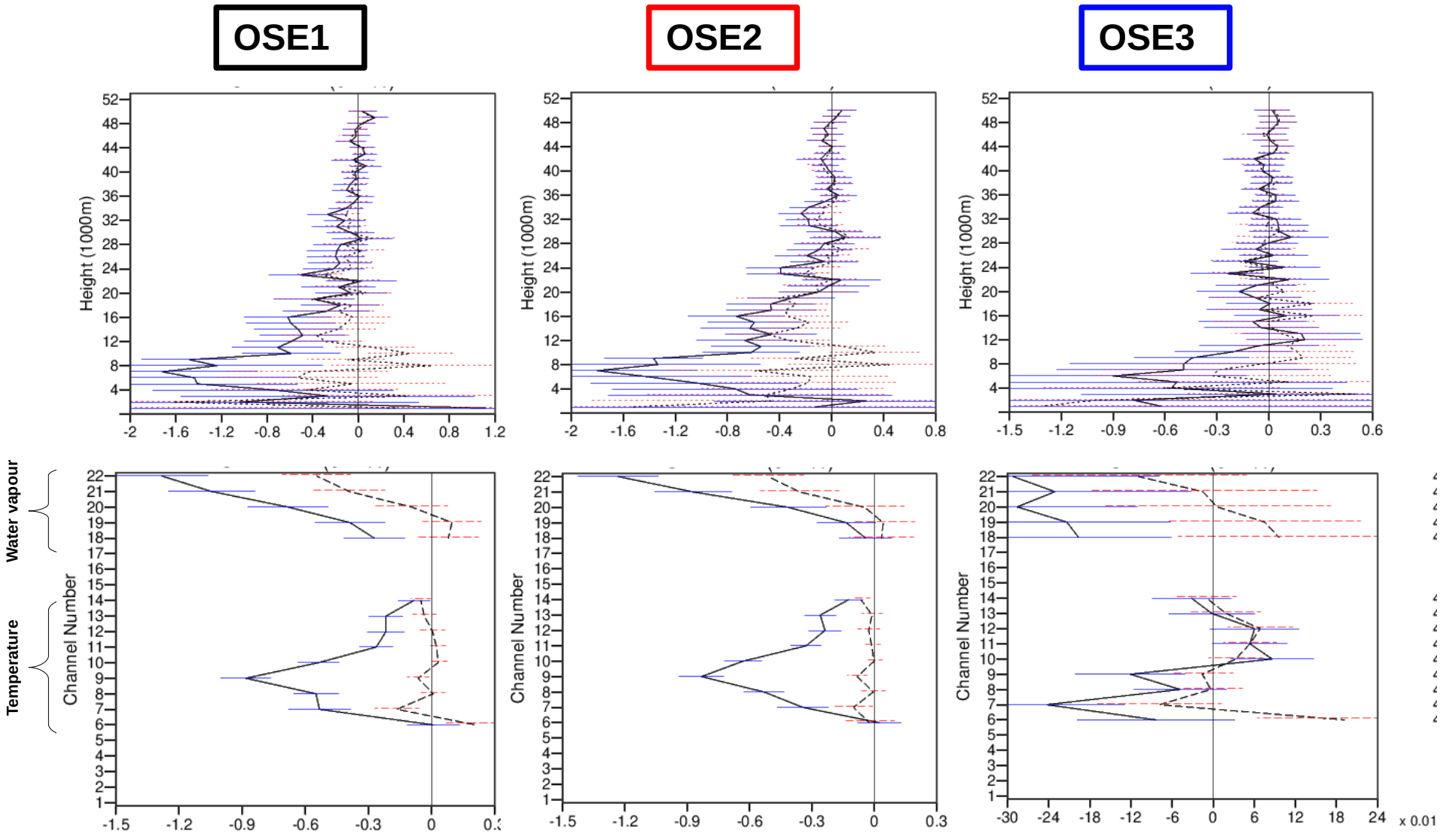
Global GNSSRO and ATMS tropics (OmB) statistics for OSE1, OSE2 and OSE3

Negative = better with AEOLUS

OSE1 **OSE2** **OSE3**



Antarctic GNSSRO and ATMS (OmB) statistics for OSE1, OSE2 and OSE3



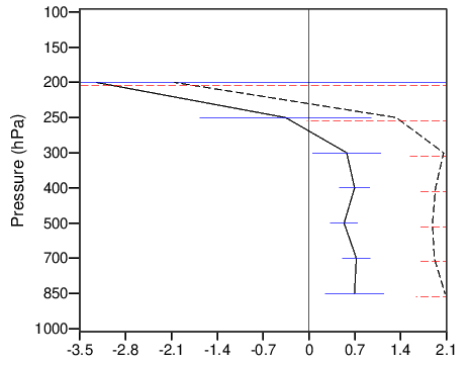
Negative = better with AEOLUS

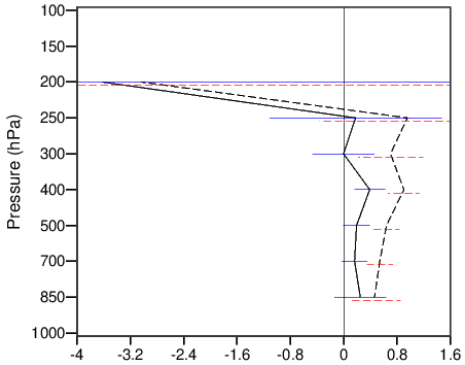
AMV u wind (OmB) statistics for OSE1, OSE2 and OSE3

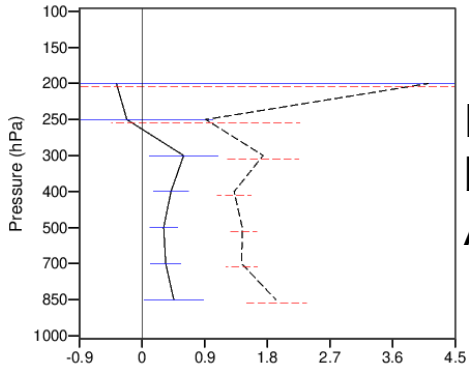
OSE1 (R+M) | **OSE2 (R)** | **OSE3 (M)**

Relative (%) $SD(OmB)_{XP}$ -$SD(OmB)_{ref}$

Arctic

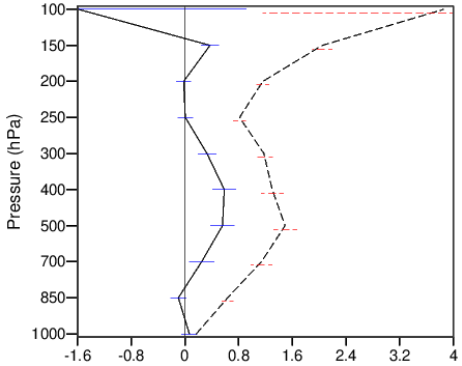


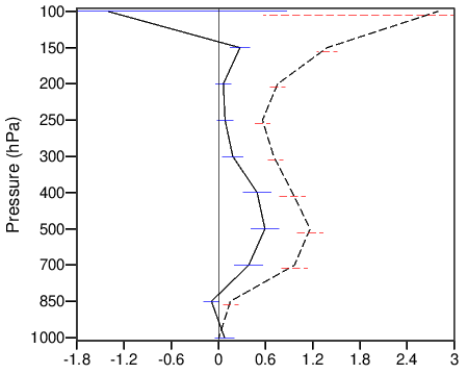


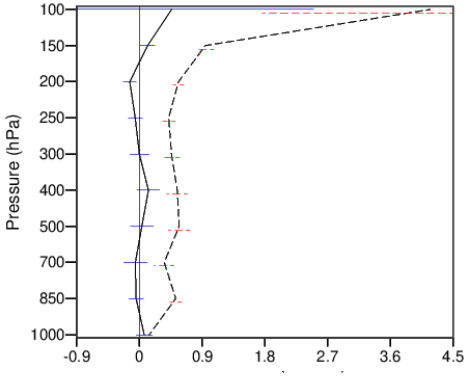


Negative = better with AEOLUS

Tropics

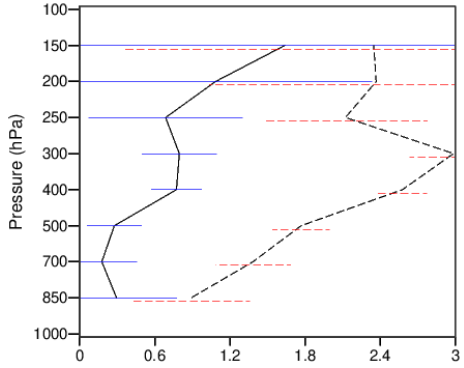


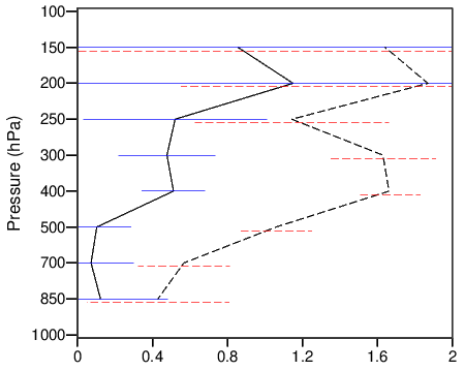


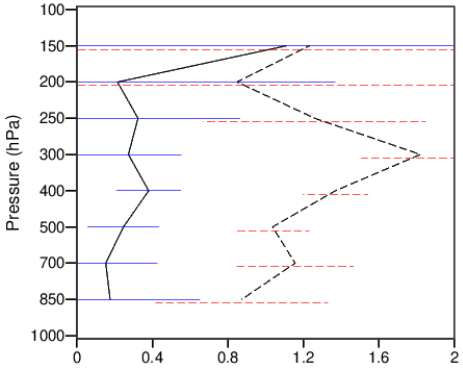


Degradation of the background fits for AMVs In Tropics and polar region for all OSE except for Mie XP in tropics.

Antarctic



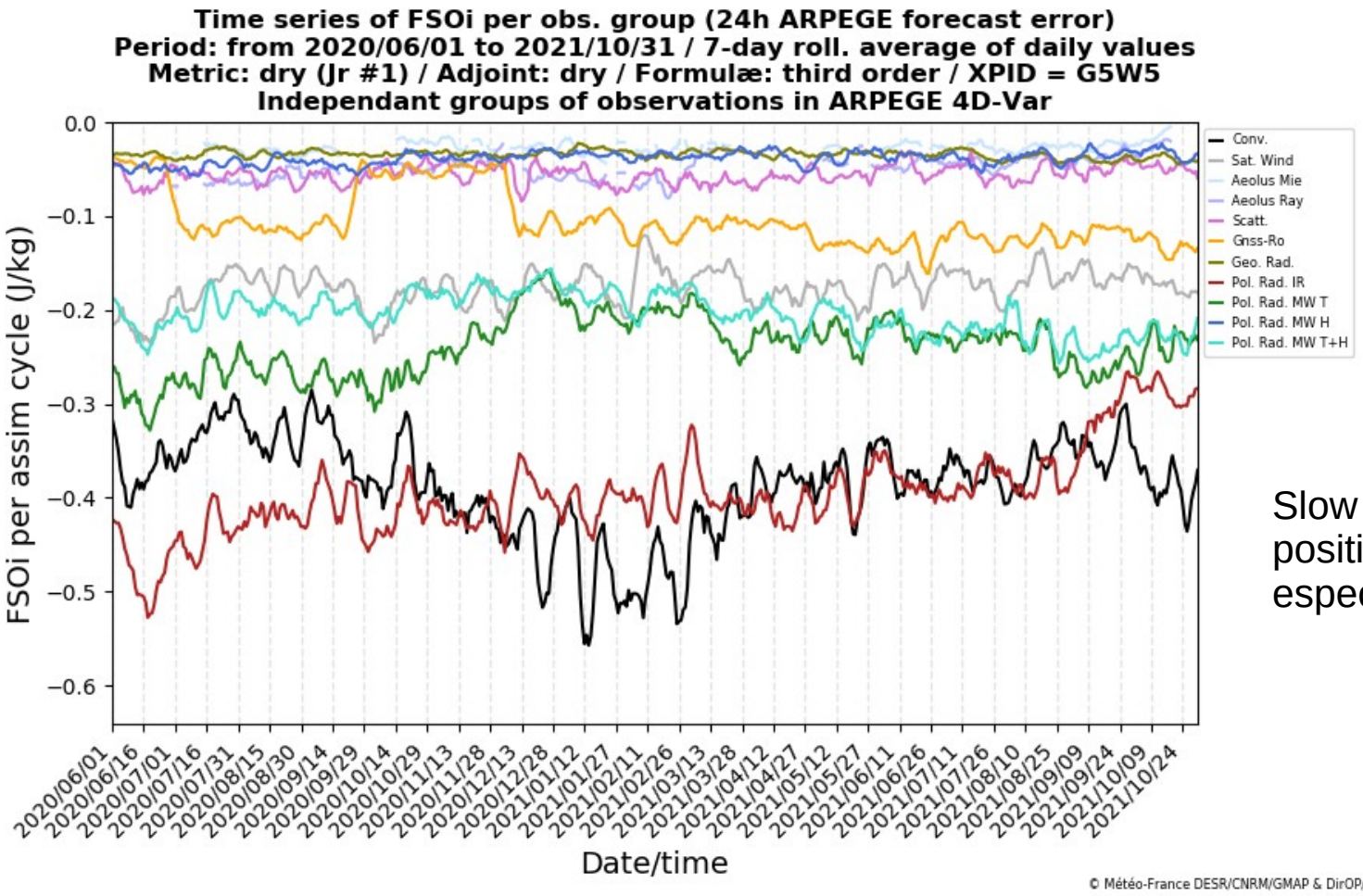




METEO FRANCE

FSO – since June 2020

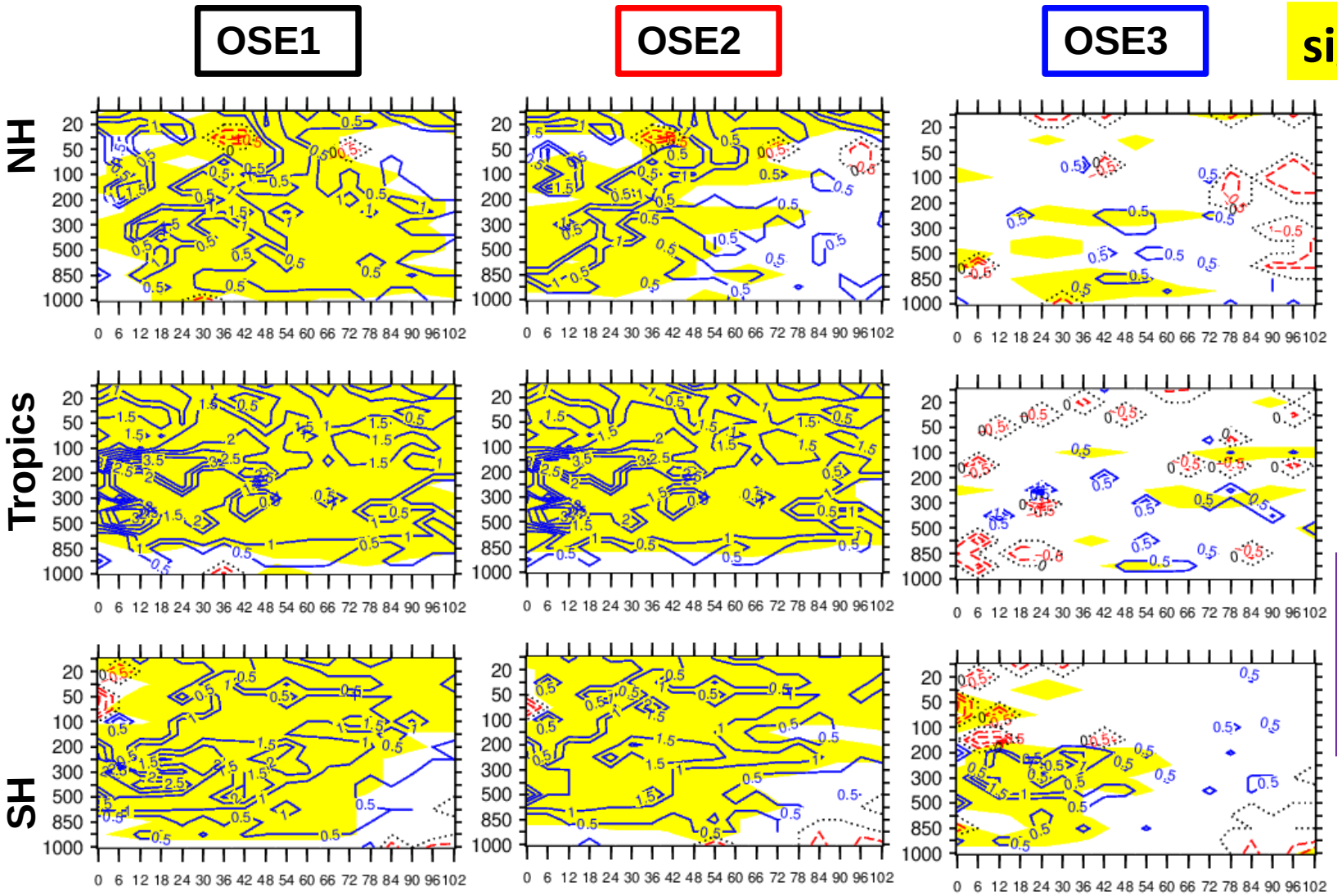
HLOS winds bias corrected from M1 temperature gradient



Slow decrease of the positive impact especially for rayleigh

Forecast scores (Temperature)

Normalized RMS(O-F)
Differences REF – EXP
REF : ARPEGE oper
O : ECMWF analyses



Close to wind scores

July-October 2019

Forecast scores (winds) over poles

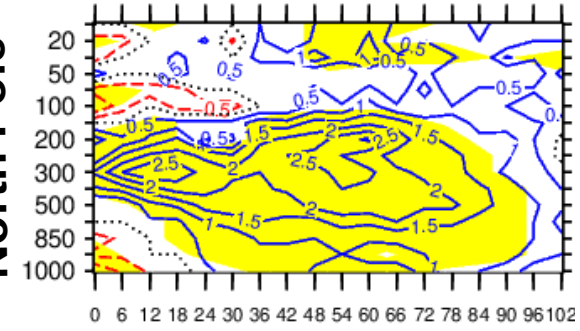
Normalized RMS(O-F)
Differences REF – EXP
REF : ARPEGE oper
O : ECMWF analyses

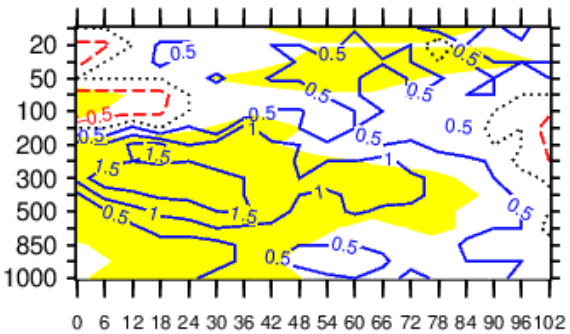
July-October 2019

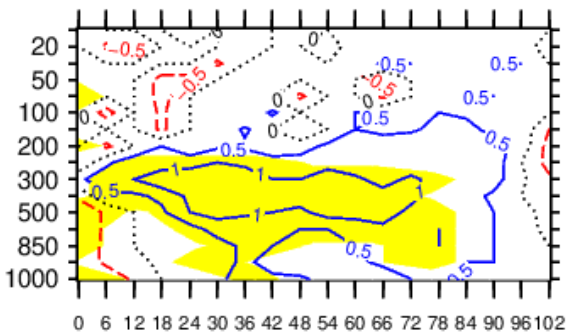
significant ☺ ☹

OSE1 **OSE2** **OSE3**

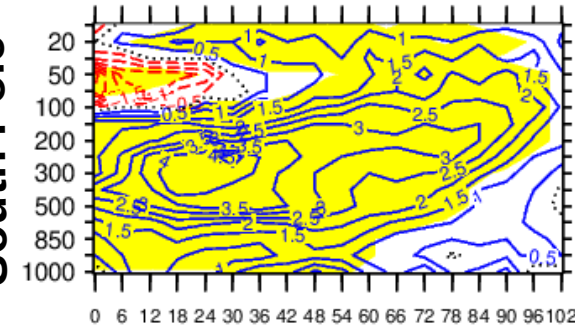
North Pole

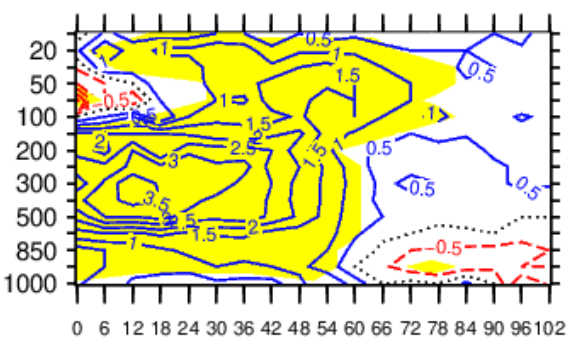


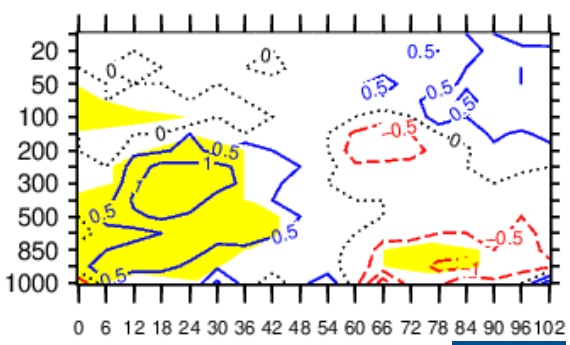




South Pole







METEO FRANCE

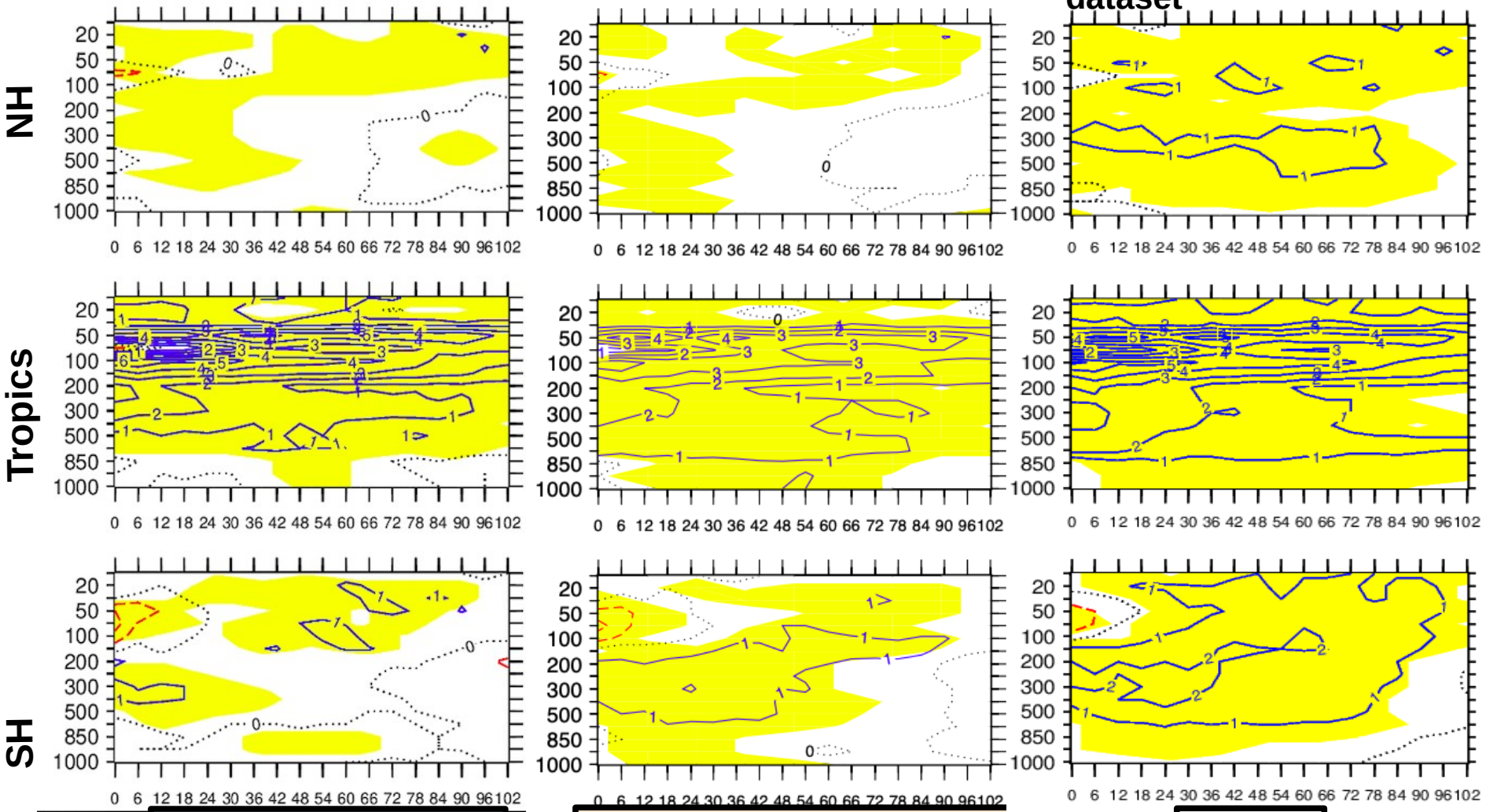
Forecast scores (winds)

July-August 2019

Normalized RMS(O-F)
Differences REF – EXP
REF : ARPEGE oper
O : ECMWF analyses

significant ☺ ☹

0.5 - 1 % improvement With 1st reprocessed dataset



OSE1 bis : MF BC

OSE1 ter : ECMWF BC

OSE1

Forecast scores (winds) – Pre oper XP (B9) vs OSE1

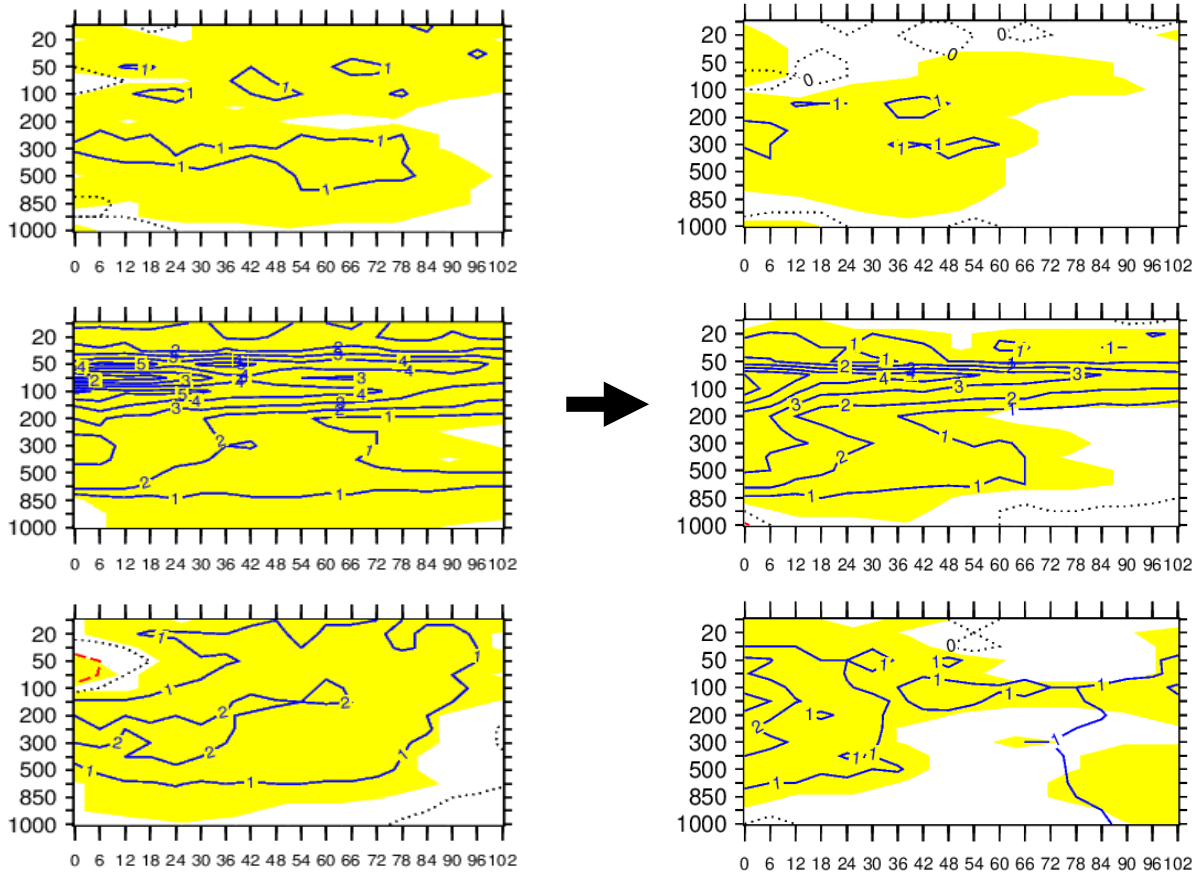
2019→2020 After 10 months ~1 % of positive impact lost
Rayleigh obs error 4.3 m/s → 6 m/s

OSE1 | **Pre oper XP**

NH

Tropics

SH



Normalized RMS(O-F)
Differences REF – EXP
REF : ARPEGE oper
O : ECMWF analyses

☺ ☹

significant

July-August 2019

April-May 2020

METEO FRANCE