

# The impact of Aeolus wind observations on the predictability of tropical cyclones

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## *Acknowledgement*

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Aeolus HLOS winds improve NWP forecasts: it has shown to improve forecasts of temperature, humidity and winds, particularly in the upper troposphere and lower stratosphere, with the largest signal seen in the tropics

**Scientific question:** *Is the positive impact on the typical large-scale verification metrics also translated into an improvement of the predictability of extreme weather events?*

**Project objectives:** to investigate if Aeolus wind data improve the predictability of strong storms in the extra-tropics and tropics. The focus was on:

- tropical cyclones
- European forecast busts
- extratropical storms, with a particular emphasis on Europe

} Poster session

# Impact Experiments

Observing System Experiments (OSEs) are the most reliable method to assess the forecast impact of a change to the data assimilation system.

## Observing System Experiments

- **Control (CTRL): “No Aeolus”:** Like the operational configuration with all operational observations used apart from Aeolus
- **Aeolus:** Like the *Control* experiment **plus** Aeolus data (*Rayleigh-clear + Mie-cloudy*).

**NWP System:** The pre-existing ECMWF Aeolus assimilation system (within IFS)

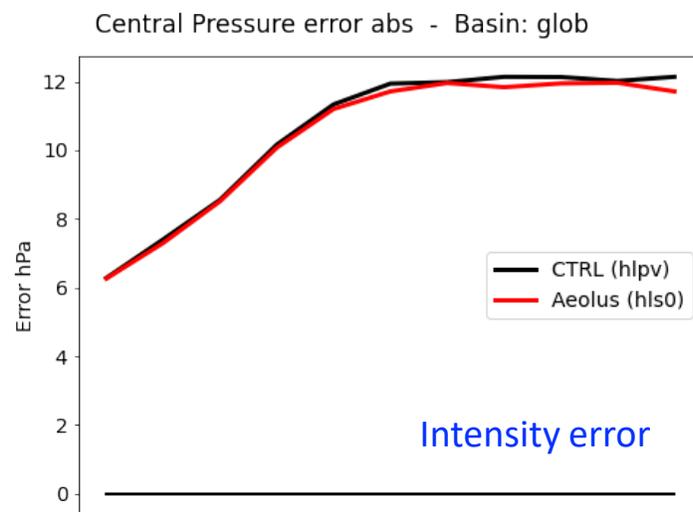
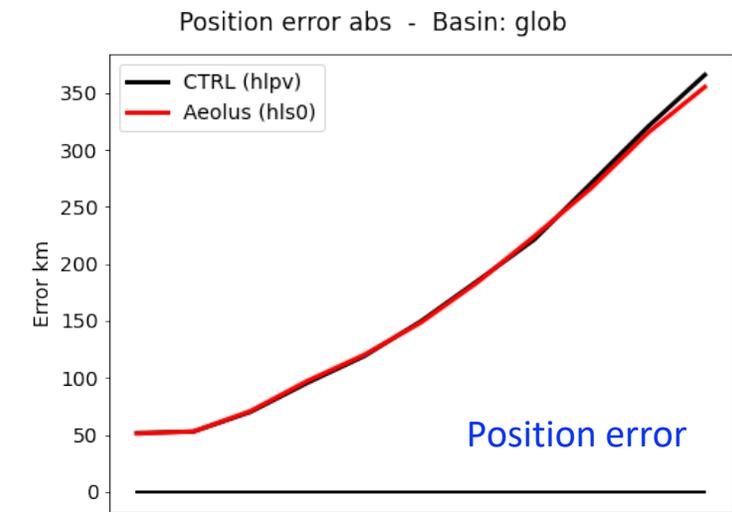
**Period:** from 29 June 2019 to 26 September 2021. To our knowledge, the longest Aeolus OSEs.

**Dataset:** **Second reprocessing campaign** dataset by the Aeolus DISC (Data, Innovation, and Science Cluster). FM-B dataset (baseline 11) from 29 June 2019 to 10 October 2020. This was combined to operational data from October 2020 to September 2021.

**Resolution:** **Tco639 ~18 km** (producing global forecast out to day-10). This is a much higher resolution than previous Aeolus OSEs.

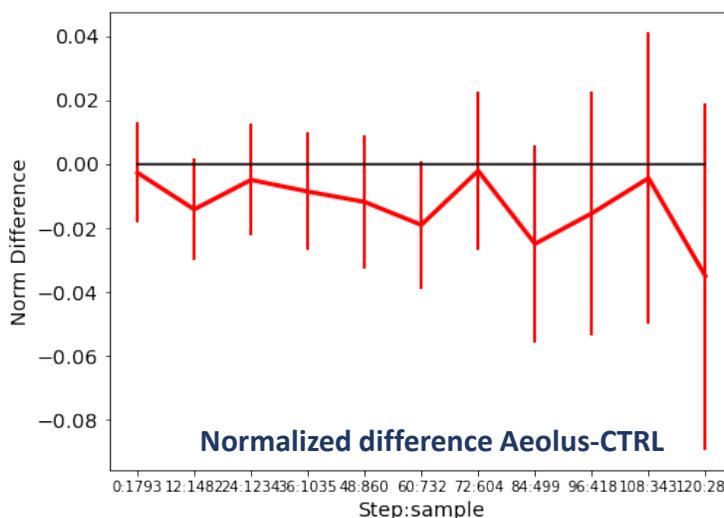
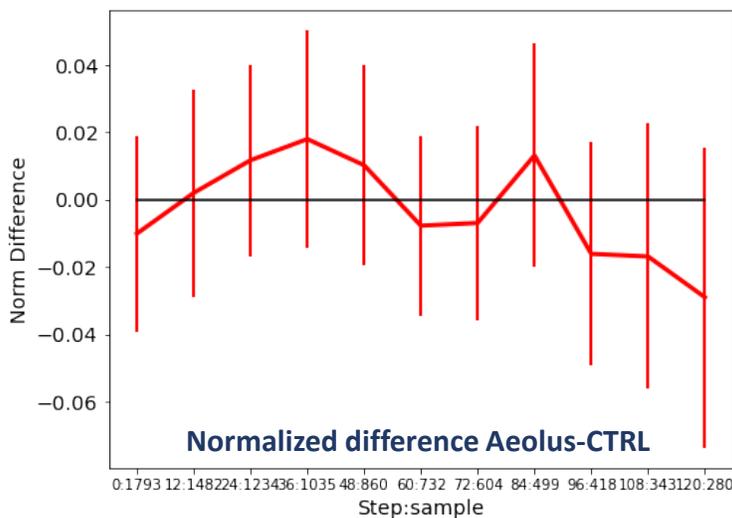
# Tropical Cyclones

Impact of Aeolus on the TC position and intensity errors for the **CTRL** and **Aeolus** experiments (Tco639 ~ 18 km)



**Global statistics**  
**29 June 2019 – 26 September 2021**

- Aeolus impact on position error is neutral
- Impact on intensity error is positive/neutral



CTRL (no Aeolus)  
 Aeolus

# TC 6-month period statistics

## Position error

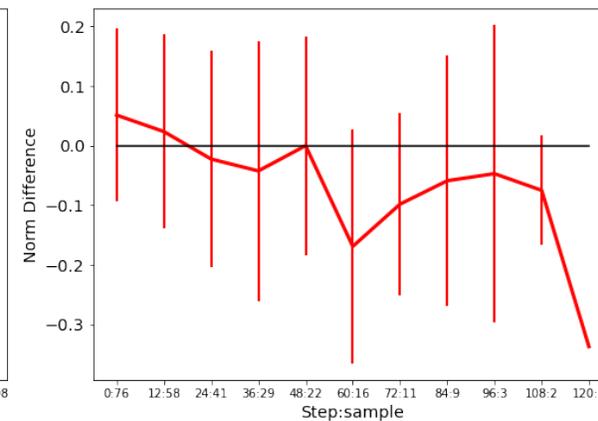
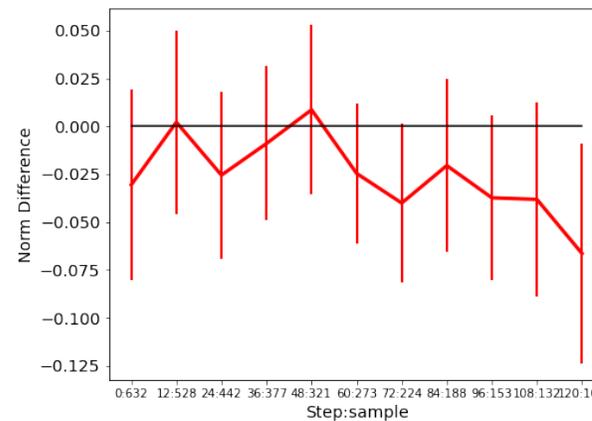
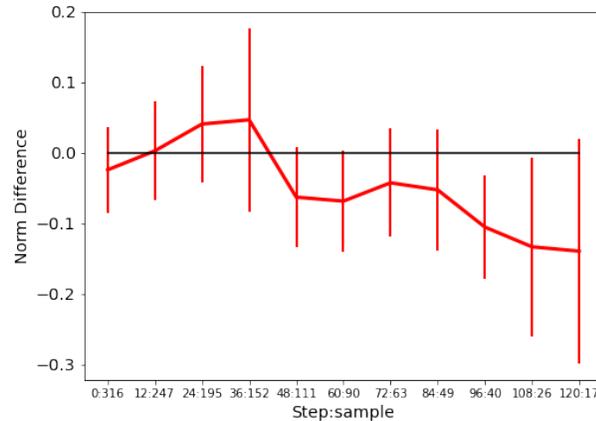
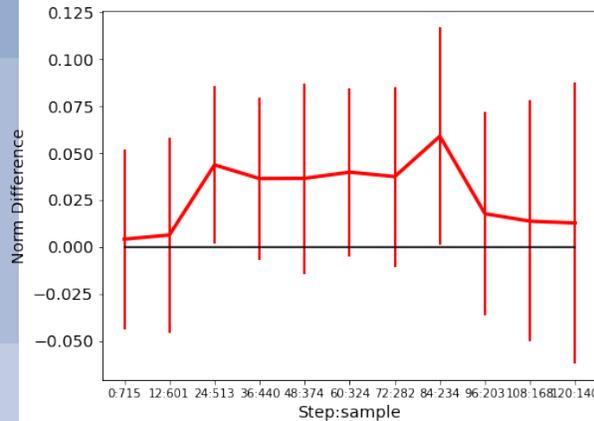
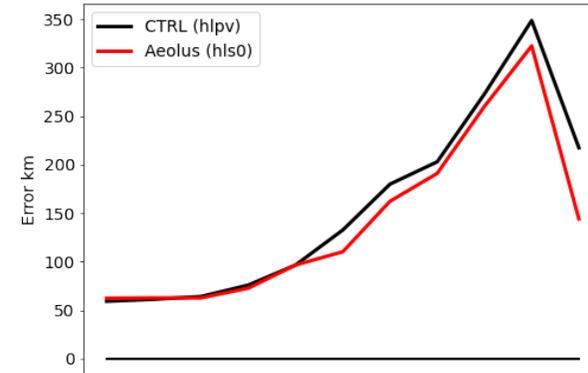
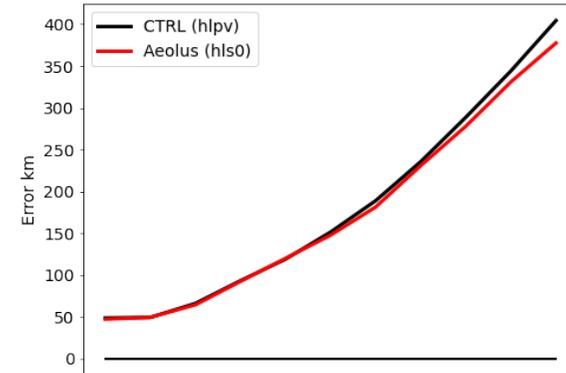
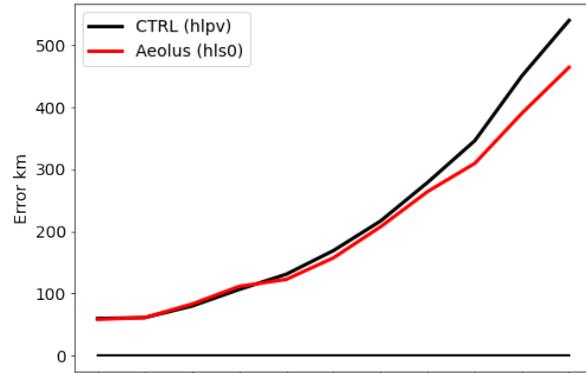
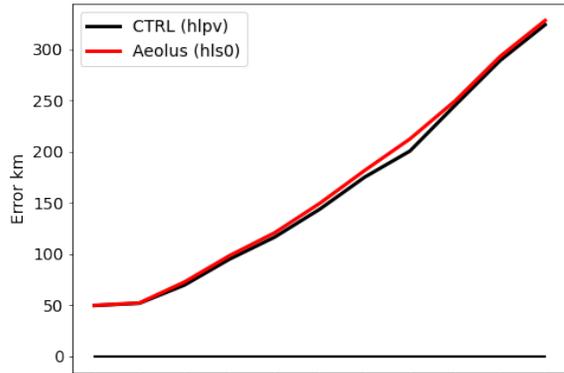
### July – December 2019

### January – June 2020

### July – December 2020

### January – June 2021

Position error abs - Basin: glob



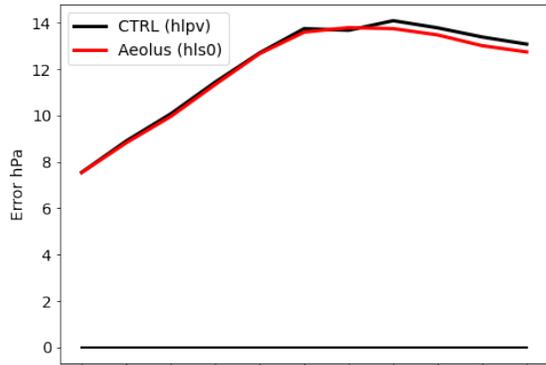
Worst impact in July-December 2019

# TC 6-month period statistics

## Intensity Error

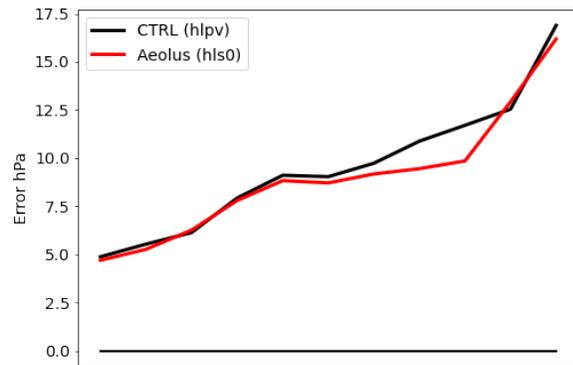
### July – December 2019

Central Pressure error abs - Basin: glob



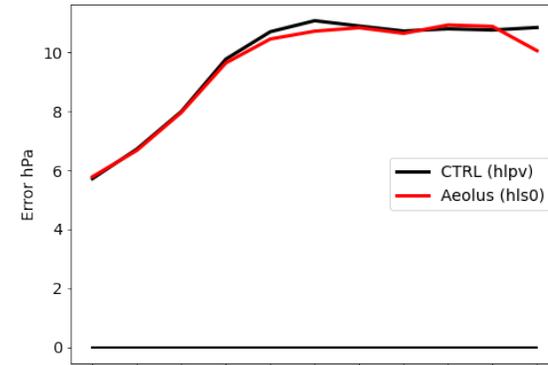
### January – June 2020

Central Pressure error abs - Basin: glob



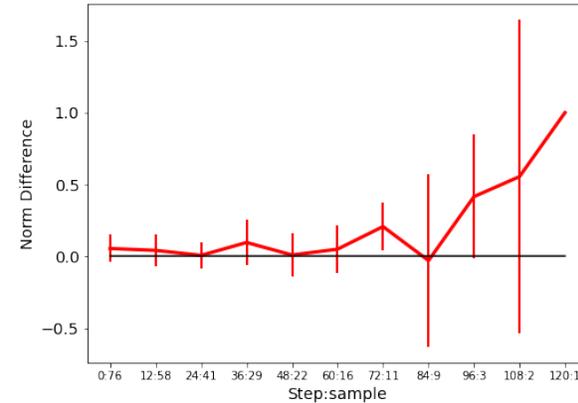
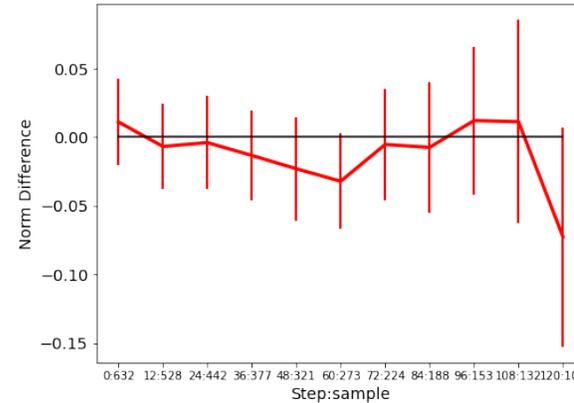
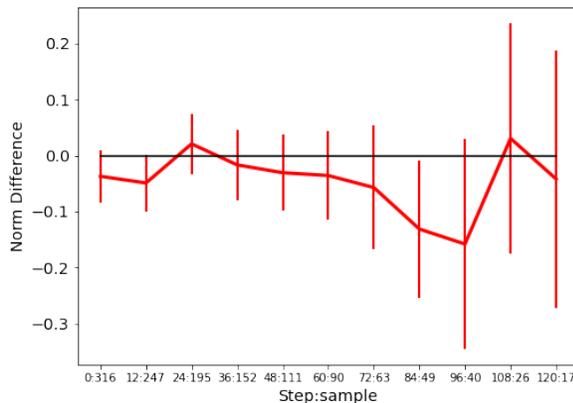
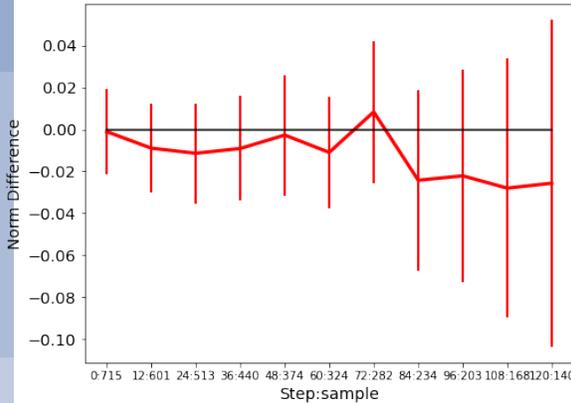
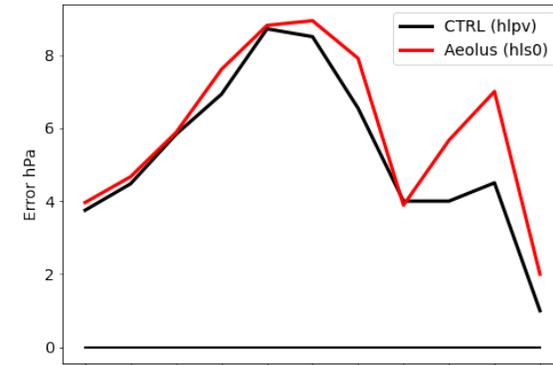
### July – December 2020

Central Pressure error abs - Basin: glob



### January – June 2021

Central Pressure error abs - Basin: glob



Impact consistent over time  
Slightly worse impact in Jan-Jun 2021

# Comparison to other papers

We tried to replicate *Garret et. al (2022)* and *Marinescu et al. (2022)* results but we did not reach the same outcome. Why?

- **Different assimilation system?**
- **Different dataset used?**
- **Different resolution?**

**Are the results depending on the dataset used?**

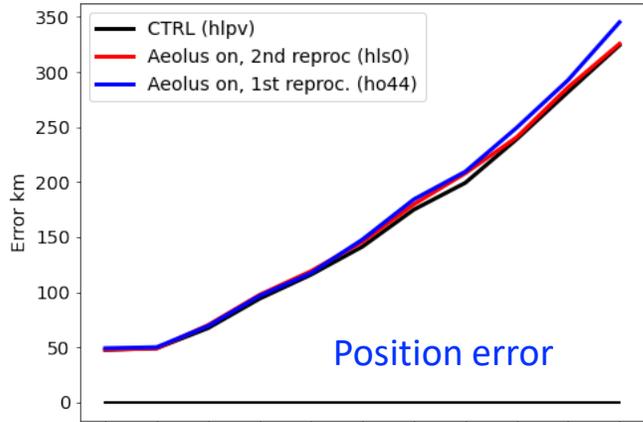
# TC statistics: dataset impact?

29 June – 31 December 2019

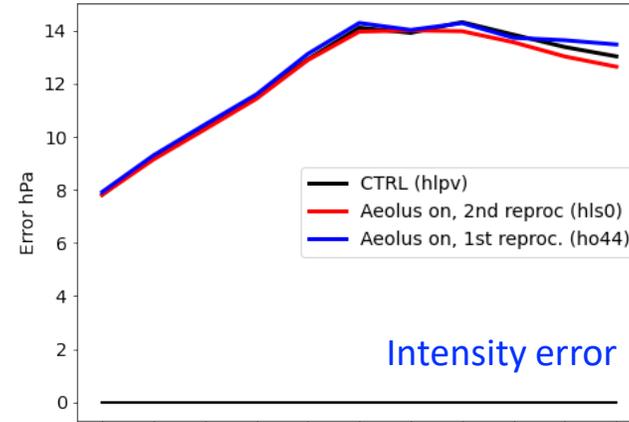
1<sup>st</sup> & 2<sup>nd</sup> reprocessed dataset OSEs (both at Tco639)

CTRL (No Aeolus)  
2<sup>nd</sup> reproc Tco639  
1<sup>st</sup> reproc Tco 639

Position error abs - Basin: glob

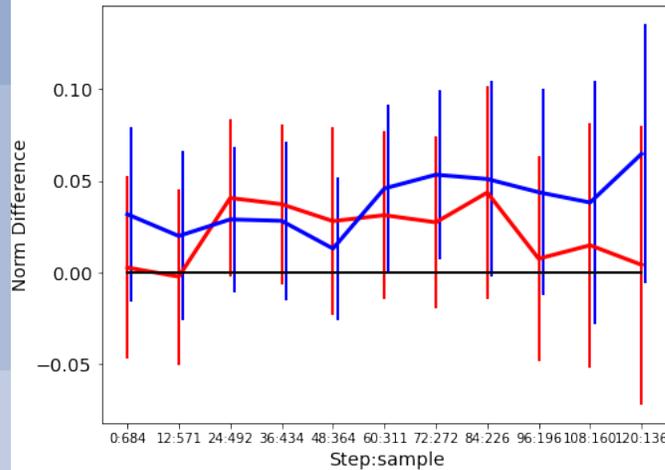


Central Pressure error abs - Basin: glob

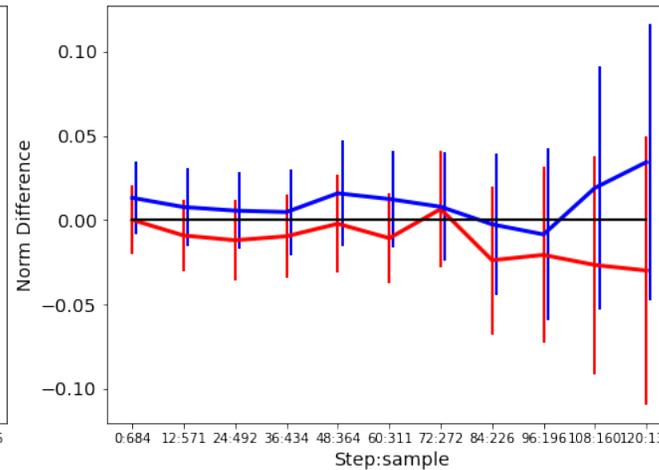


Indication that 2<sup>nd</sup> reprocessed dataset slightly better than 1<sup>st</sup> one on TC (not statistically significant)

Position error

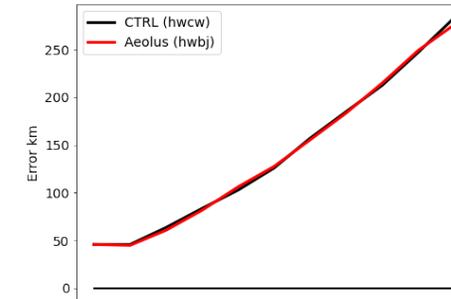


Intensity error

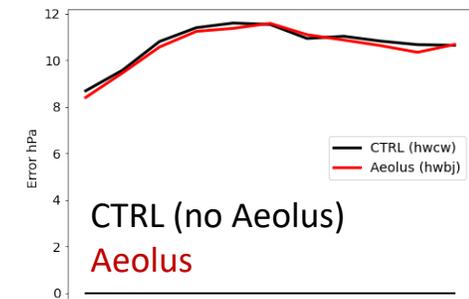


## 3<sup>rd</sup> reprocessed dataset Tco 639 (4 Sep 2018 – 5 June 2019)

Position error abs - Basin: Glob

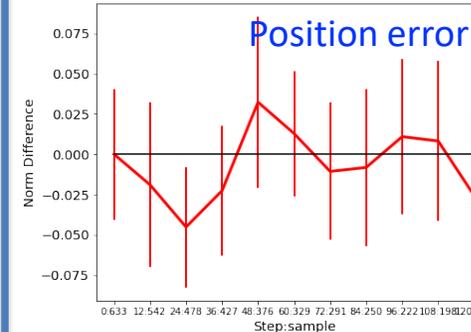


Central Pressure error abs - Basin: Glob

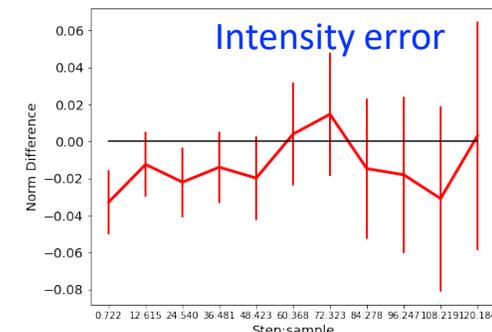


CTRL (no Aeolus)  
Aeolus

Position error



Intensity error



## Are the results depending on the OSEs resolution?

With increased resolution (from Tco399 to Tco639) using the **first reprocessed dataset**:

- 5% improvement on the position
- 16% improvement on the intensity

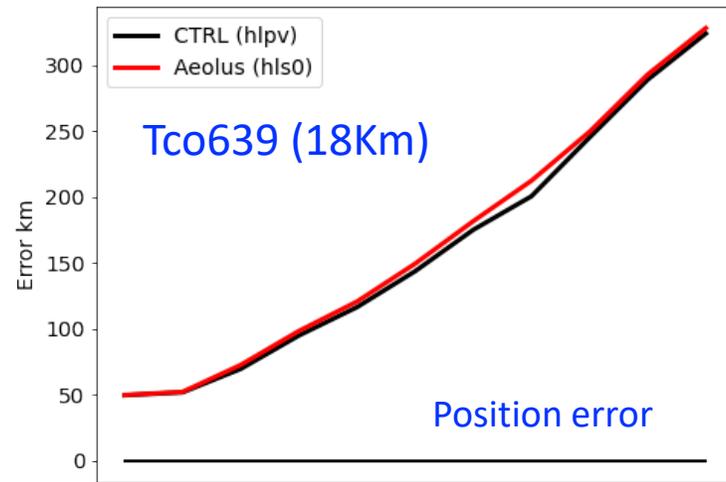
# TC statistics: resolution impact?

## 2<sup>nd</sup> reprocessed dataset OSEs

Tco639 (18Km)

29 June – 31 December 2019

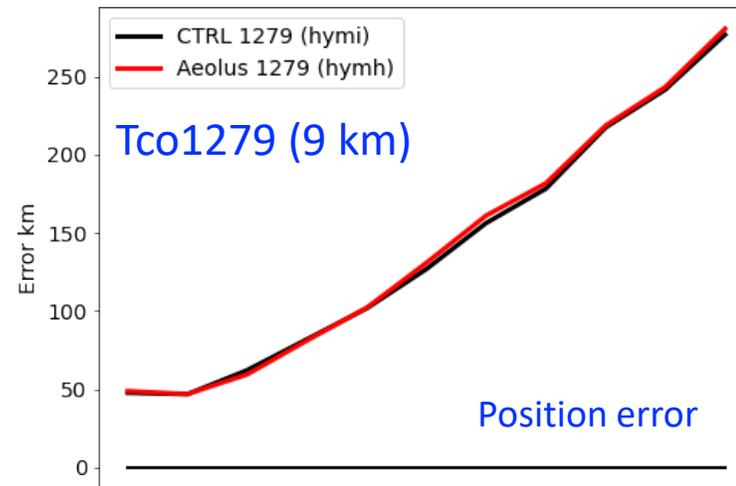
Position error abs - Basin: glob



Tco1279 (9 km)

29 June – 1 December 2019

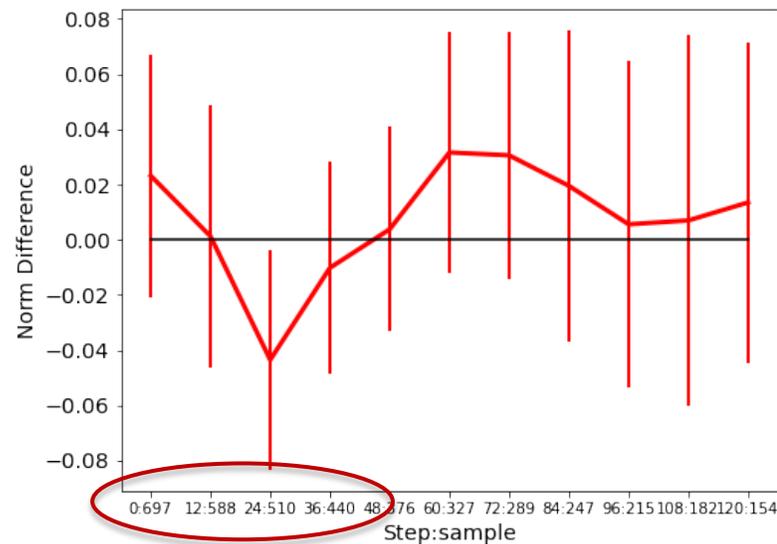
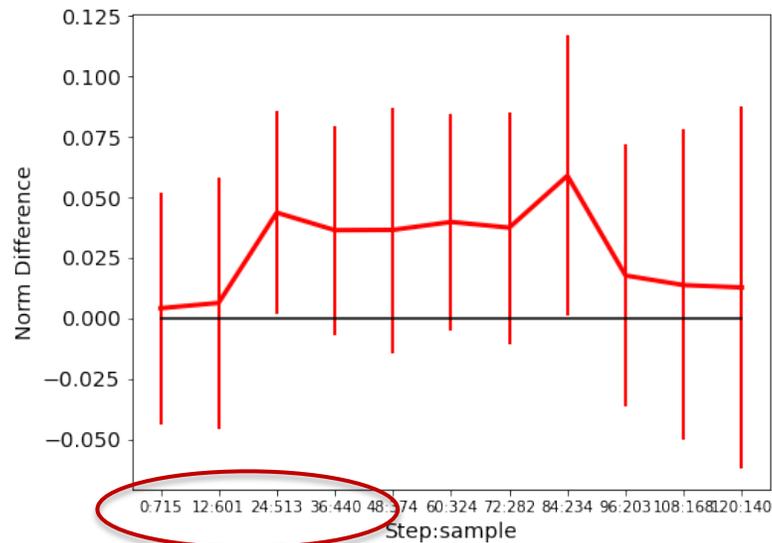
Position error abs - Basin: Glob



CTRL (no Aeolus)  
Aeolus

2<sup>nd</sup> half 2019:  
from neutral/negative to neutral

At higher resolution the degradation disappears

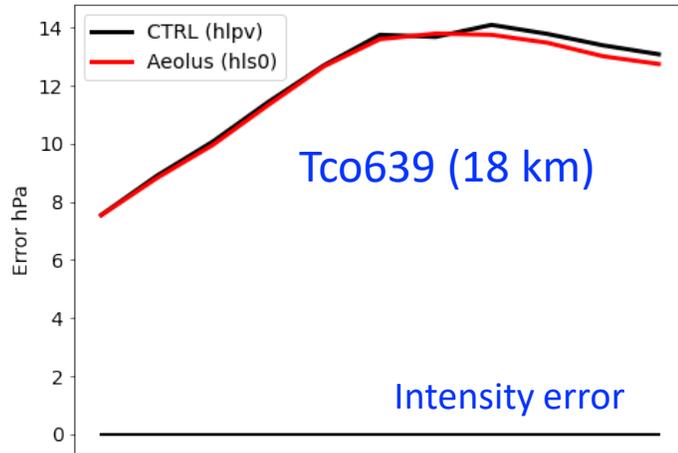


# TC statistics: resolution impact?

2<sup>nd</sup> reprocessed dataset OSEs

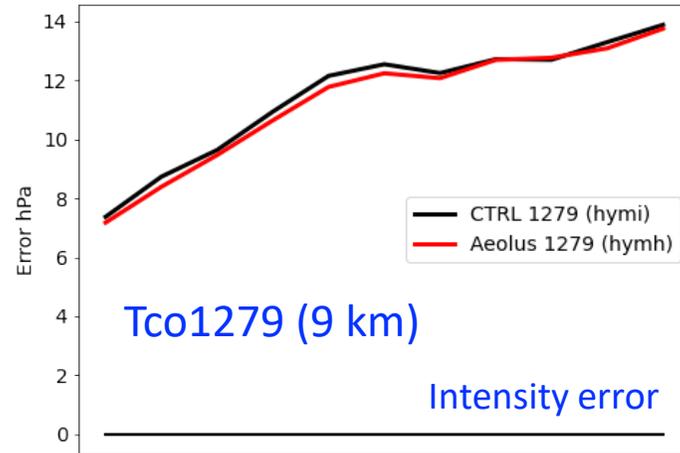
29 June – 31 December 2019

Central Pressure error abs - Basin: glob



29 June – 1 December 2019

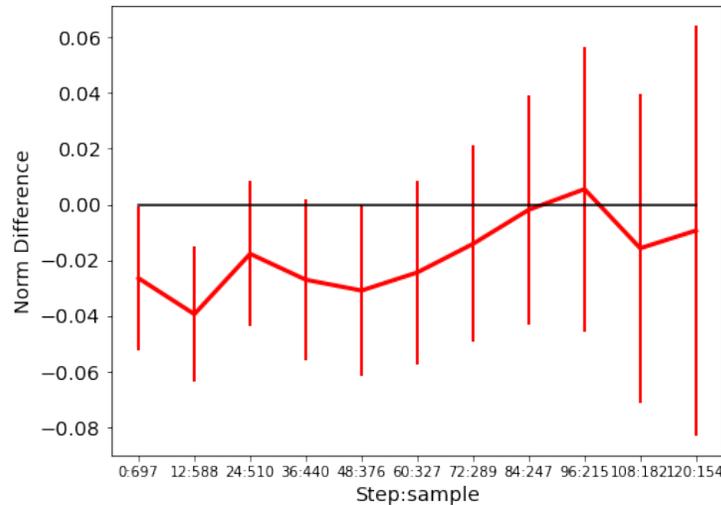
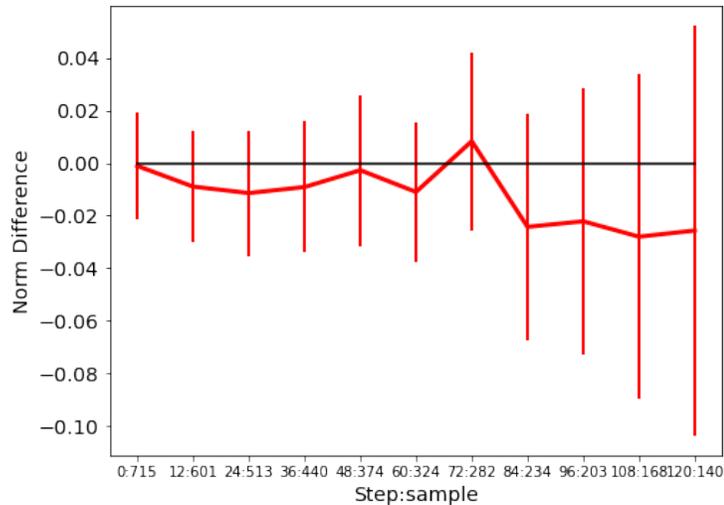
Central Pressure error abs - Basin: Glob



CTRL (no Aeolus)  
Aeolus

2<sup>nd</sup> half 2019:  
from neutral to positive impact

A higher RES seems to give better results!

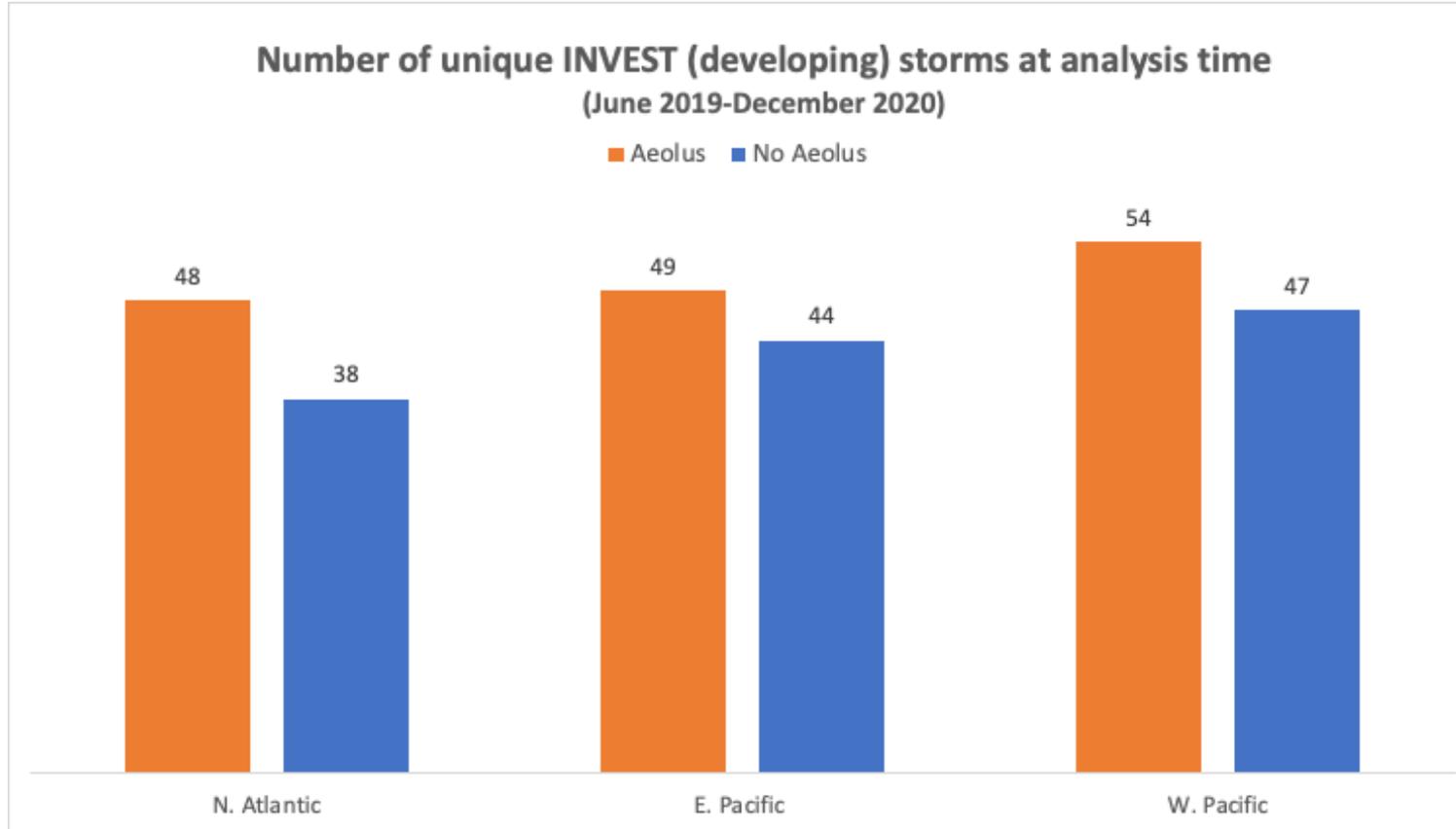


**Do the statistics change with the intensity of the storm?**

No signal based on the wind speed but...

# Developing tropical storms

## Impact of Aeolus HLOS assimilation on developing tropical storms



**TOTAL INVEST (in the period)**

L 68  
E 58  
W 65

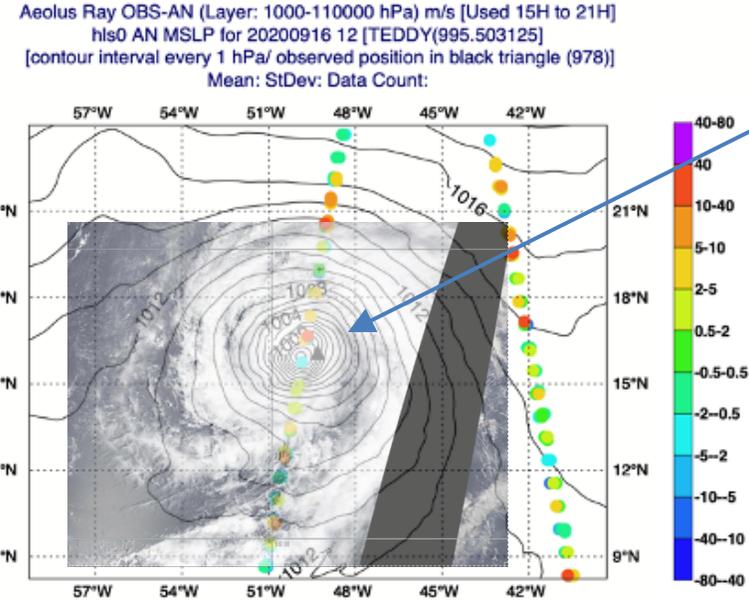
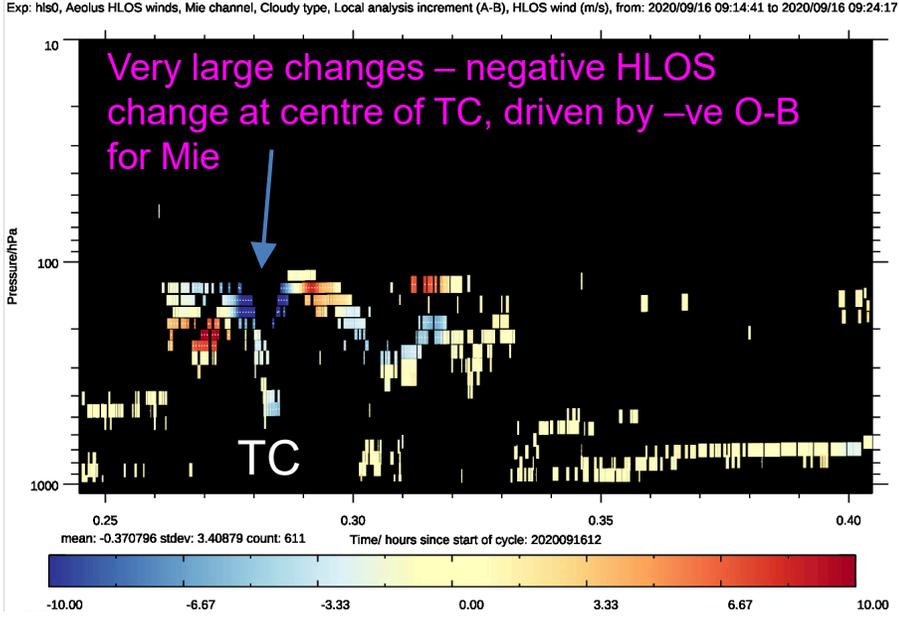
- INVEST (short for *investigative area*) is a designated area of disturbed weather that is being monitored for potential development into tropical cyclone within the next 5 days
- Not all the INVEST storms develop into a tropical cyclone
- **The assimilation of Aeolus HLOS observations helps detecting more tropical disturbances**

**How the assimilation of Aeolus changes the storm structure?**

# TC Teddy at ~09:16 UTC on 16/09/2020; at ~0.28 hrs (near start) into the 4D-Var window (cycle 1612)

Mie-cloudy

O-B to O-A fit for Mie was improved a lot and fit for Rayleigh was also improved

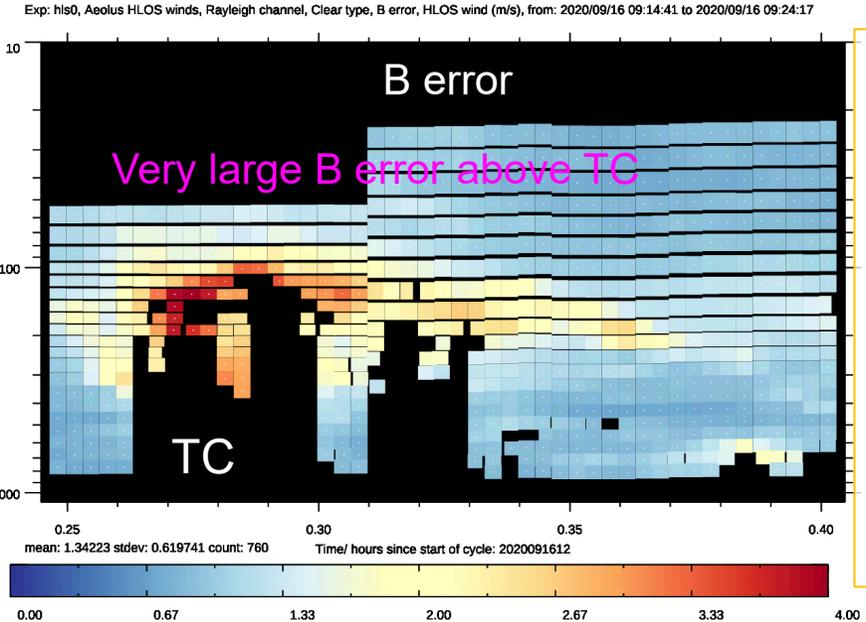
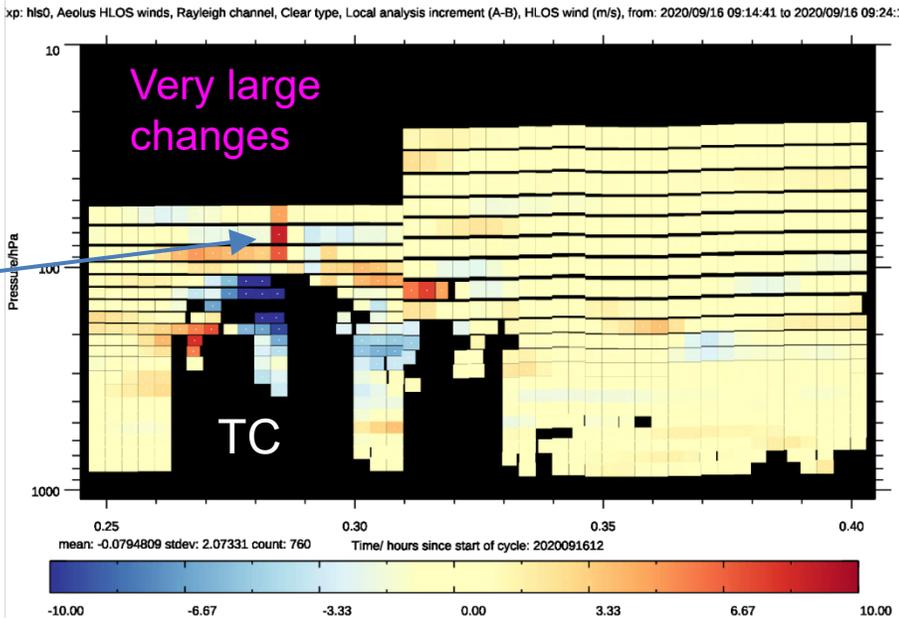


This "curtain" is the descending orbit near start of the window (direct hit on TC)

*Aeolus had negative impact on track and intensity for this cycle*

Rayleigh-clear

Strange narrow increment with Aeolus?

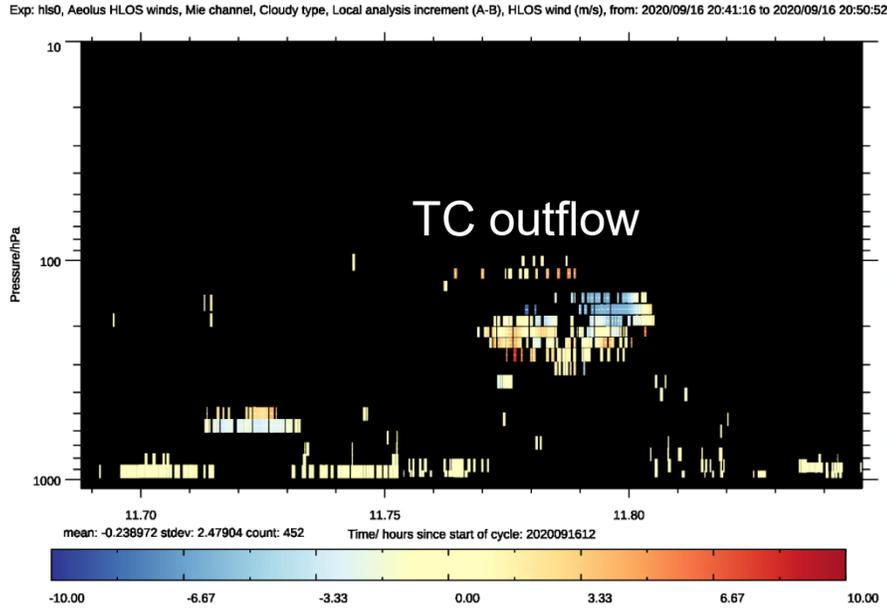


- Are Mie winds over-fitted?
- Representativeness error larger in TCs?
- An issue with **B** at start of 4D-Var window?
- Negative O-Bs at top are consistent with vertical wind aliased into HLOS wind

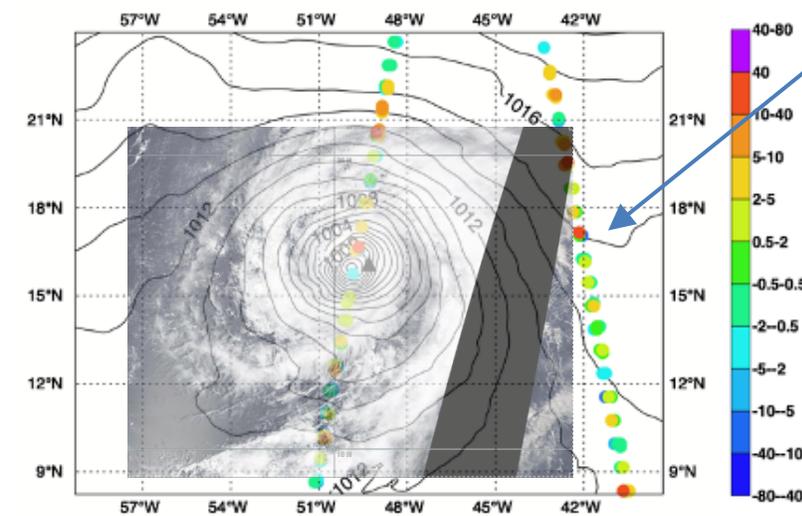
# TC Teddy at ~20:47 UTC on 16/09/2020; at ~11.8 hrs (near end) into the 4D-Var window (cycle 1612)

Mie-cloudy

O-B to O-A fit for Mie was improved a lot and fit for Rayleigh was also improved



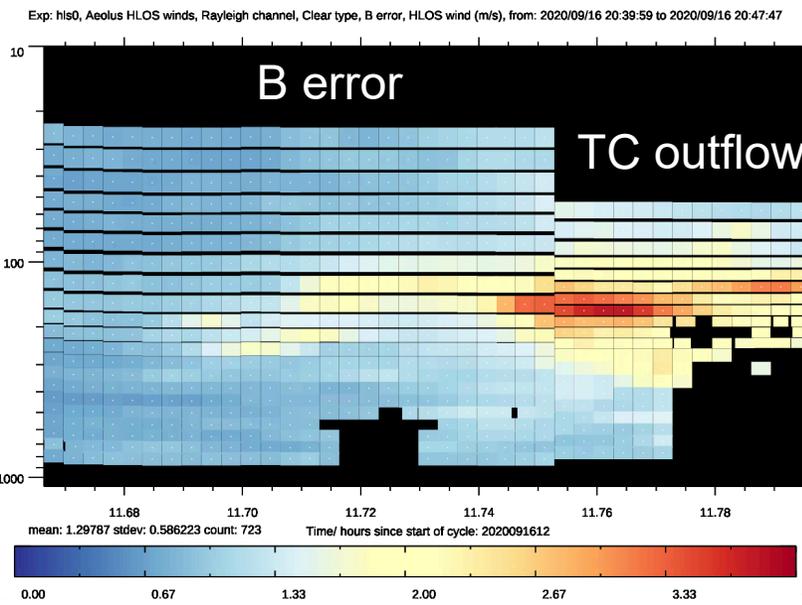
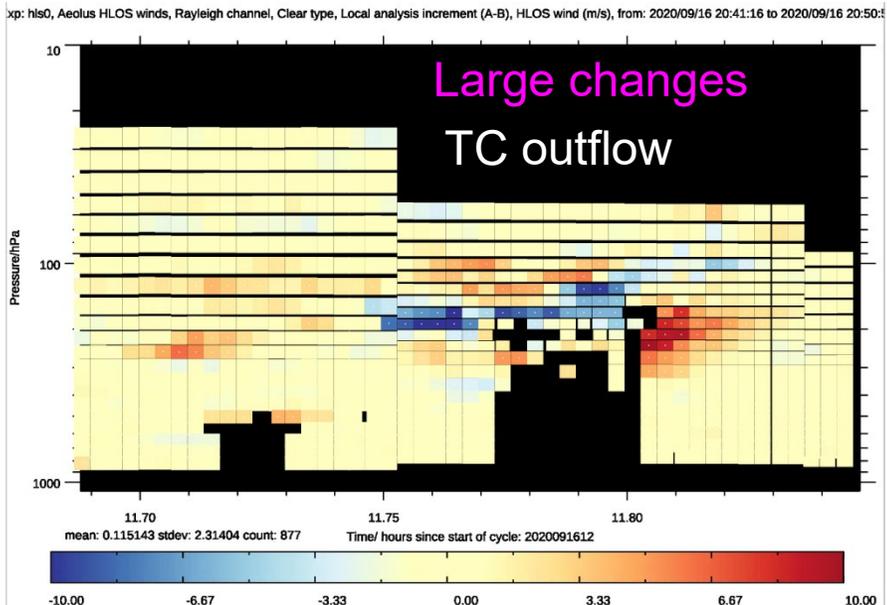
Aeolus Ray OBS-AN (Layer: 1000-110000 hPa) m/s [Used 15H to 21H]  
 hls0 AN MSLP for 20200916 12 [TEDDY(995.503125)]  
 [contour interval every 1 hPa/ observed position in black triangle (978)]  
 Mean: StDev: Data Count:



Ascending orbit near the end of the window, further away from TC

*Aeolus had negative impact on track and intensity for this cycle*

Rayleigh-clear



# Conclusions

Aeolus data quality was not consistent over time: based on our OSEs timeframe, best data quality in 2019

Aeolus impact also not consistent over time

- The global statistics showed that the assimilation of Aeolus observations has a neutral impact on the trajectory fc but a neutral/positive impact on the intensity fc
- The worst impact occurred in July-December 2019

The statistics are sensitive to the OSEs resolution: *the higher the resolution, the better the results*

The statistics are sensitive to the dataset used: signal of improvement with better data quality. *This is promising for Aeolus 2!*

The assimilation of Aeolus winds improves the detection of developing storms

No clear signals looking at TC cases

Large negative increments over the top of TC (mainly Mie)

Further investigations would be needed: *Mie error to be tuned? Representativeness error? Time in the assimilation window? Possible aliasing of strong updrafts into HLOS wind is consistent with negative O-B; impact on cyclogenesis*

*We have to keep in mind that the resolution of the data assimilation in global models are still considered insufficient for impact on the TC core processes (i.e. intensity). Instead, the target is to improve environmental properties influencing the intensity changes such as vertical wind shear.*

Thanks for your attention!