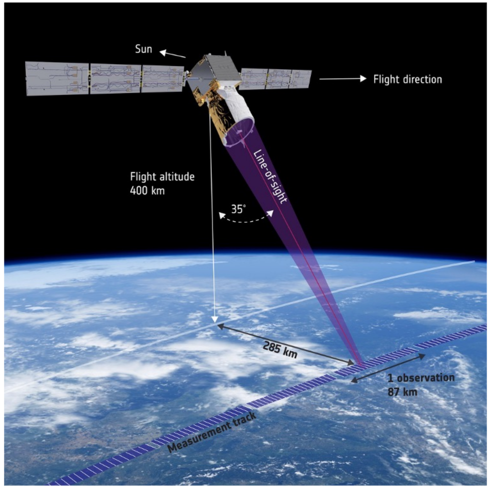
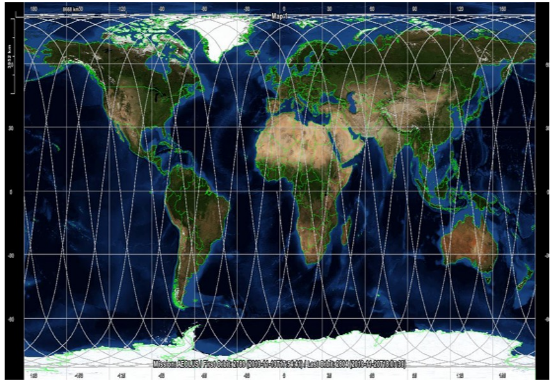
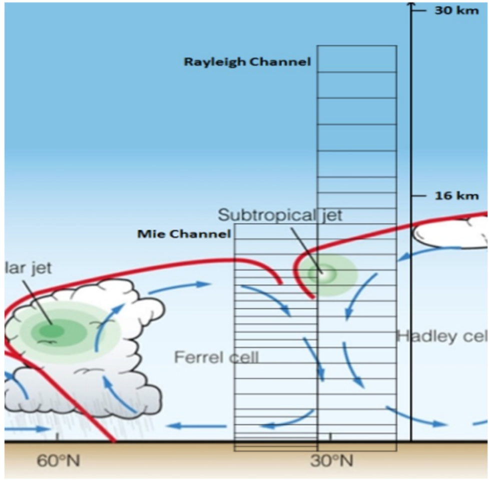
ASSIMILATING AEOLUS WIND PROFILES - ASSESSING THE BENEFIT OF USING VARIATIONAL QUALITY CONTROL DURING TROPICAL CYCLONES

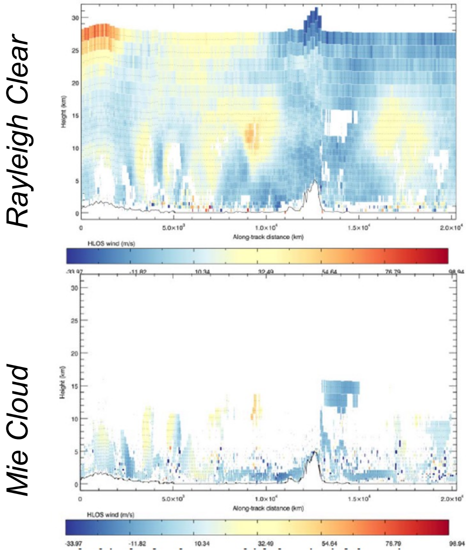
Iliana Genkova[1], Karina Apodaca[2], Lidia Cucurull[3], Jim Purser[1], Peter Marinescu[4], Lisa Bucci[5]

[1] LYNKER for NCEP, [2]SPIRE GLOBAL, Inc., [3]NOAA/OAR/AOML, [4]CSU, [5]NHC









Figures from ESA and Mike Rennie

Atmospheric Dynamics Mission - Aeolus

Atmospheric **La**ser **D**oppler **In**strument

- Launch: 22 August 2018
- Sun-synchronous orbit
- Mean altitude ~320km
- Local time 18:00 ascending node
- Inclination: 96.97deg
- Repeat cycle 7 days / 111 orbits
- Orbits per day ~16
- UV Doppler wind LIdar at 355 nm
- Two receiver channels:
  Mie receiver: aerosol and cloud backscatter
  Rayleigh receiver: molecular backscatter

The *Line-of-Sight* points:

- 35 deg from nadir to derive horizontal wind components
- orthogonally to the ground orbital track velocity vector to avoid contribution form satellite velocity

NWP models use Level 2B product - pressure and temperature corrected HLOS wind profile product, starting 9 Jan 2020 at ECMWF

"A US Effort for ADM-Aeolus Calibration and Validation", Michael Hardesty and 15 co-PIs

Proposed Work: **Comparison of ADM-Aeolus winds to conventional Atmospheric Motion Vectors (AMVs)**

2007

Team:

• ***Compare ADM-A***
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to the existing uppe

• ***Investigate how***
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additionally interpr
altitudes correlate.
available for simila
components separ

UNDERSTANDING THE AEOLUS DATA

11th International Winds Workshop, 20-24 February 2012, Auckland, New Zealand
Satellite and Airborne Wind-LIDAR Atmospheric Motion Vectors Comparison - A Case Study
Iliana Genkova, Martin Weissmann, Steve Wanzong

ADM-Aeolus Science and CAL/VAL Workshop, 9-13 February 2015, ESA-ESRIN, Frascati, Italy
Investigating the complementary nature of satellite atmospheric motion vectors (AMVs) and Doppler lidar winds
Iliana Genkova, Martin Weissmann, Steven Wanzong, Chris Velden, Kathrin Folger

13th International Winds Workshop. 27 June - 1 June 2016, Asilomar Conference Grounds, California, USA
On improving the use of AMVs at NCEP GSI
Iliana Genkova, Andrew Collard

Aeolus CAL/VAL and Science Workshop, 26-29 March 2019 in ESA-ESRIN, Frascati, Italy
Aeolus wind profiles and the NCEP's NWP model
Iliana Genkova, Andrew Collard, Will McCarty

Aeolus CAL/VAL and Science Workshop, 2-6 November 2020
Assessment of Data Assimilation Techniques for Improved Use of Aeolus Wind Profiles in NOAA's NWP Systems With a Focus on TC Predictability
Karina Apodaca, Lidia Cucurull, Lisa Bucci, Peter Marinescu, Iliana Genkova, James Purser, Hui Liu

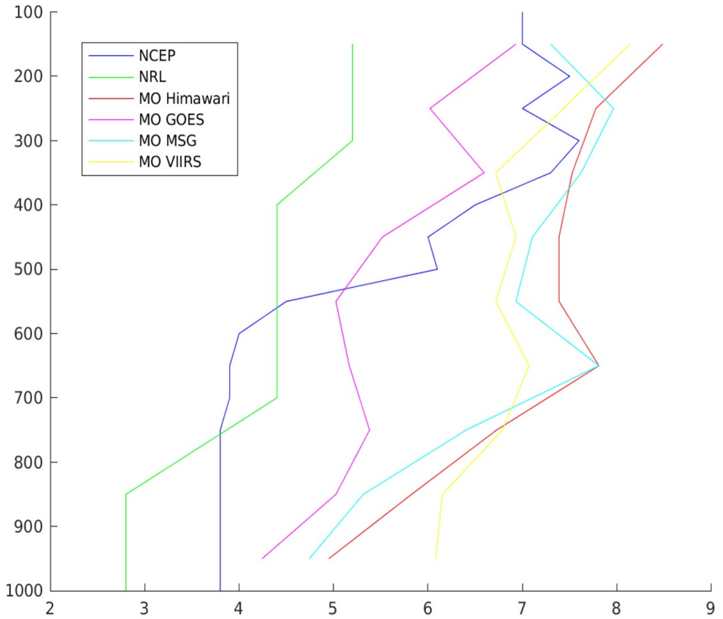
15th International Winds Workshop,April 12 - 16, 2021, KNMI, De Bildt, The Netherlands (Virtual)
Updates on AMV Datasets and Their Use at NCEP GSI
Iliana Genkova, Catherine Thomas, Daryl Kleist, Jaime Daniels, Karina Apodaca, Dave Santek, Lidia Cucurul

AOML/NCEP GFS/GSI EXPERIMENTAL SETUP

- August-October 2019
- Control - low-res experiment with NCEP's full DA observing system , C384 (~25 km)/ C192 (~50 km) , 127 levels (up to 80 km)
- Experiment 1 - add Aeolus (focus on TC Lorena)
- Experiment 2 - add Aeolus + Var QC (VQC)
- Compare O-B RMS, bias, counts
- Compare forecast to TC Track, Surface Pressure, and Wind

Hurricane Lorena
near Baja California
September 20, 2019
Credit NASA

IR AMVs Observation Errors - NCEP, NRL, MetOffice

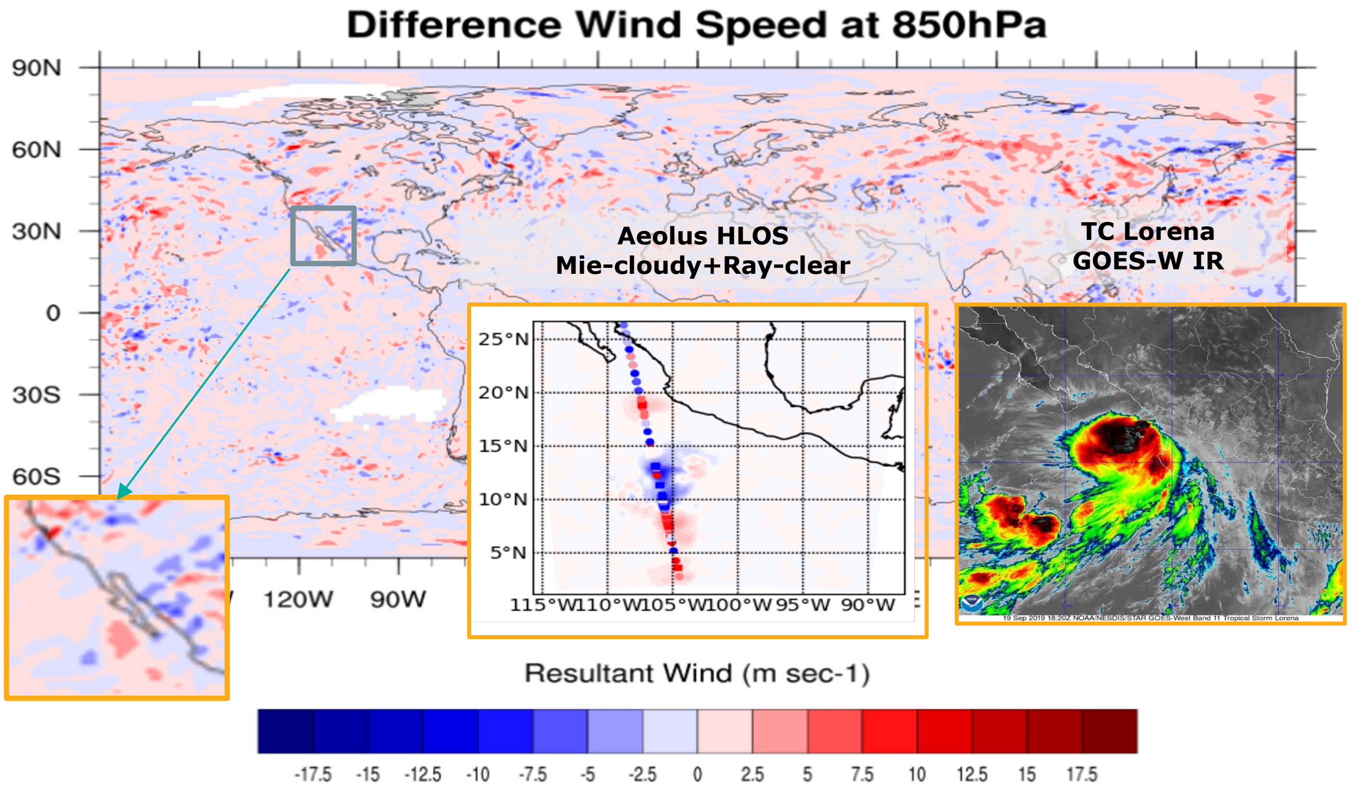


Aeolus Observation Errors = f(HLOS Error Estimate)

<u>MetOffice</u>
OE_Mie=0.7*HLOSEE+2.9 -> OE_Mie=1.4*HLOSEE+1.7
OE_Pay=2.0*HLOSEE+1.4

<u>AOML/NCEP adopted ECMWF's OE (as of 2019)</u>
OE_Mie=2*HLOSEE
OE_Ray=1.4*HLOSEE

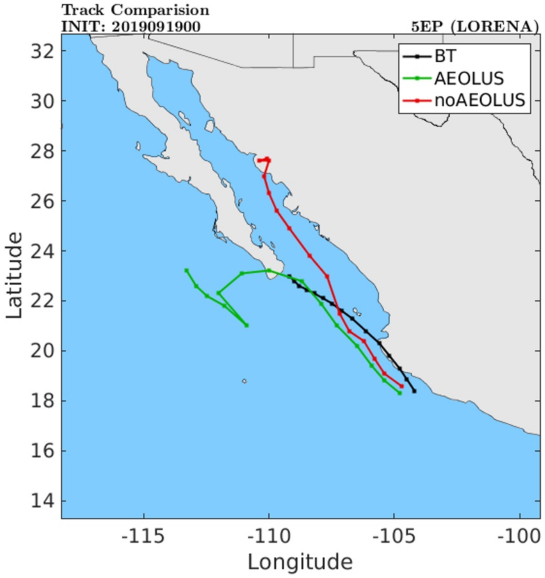
FV3GFS Analysis : AEOLUS_DA–CNTL - TC Lorena: Sep. 17-22, 2019

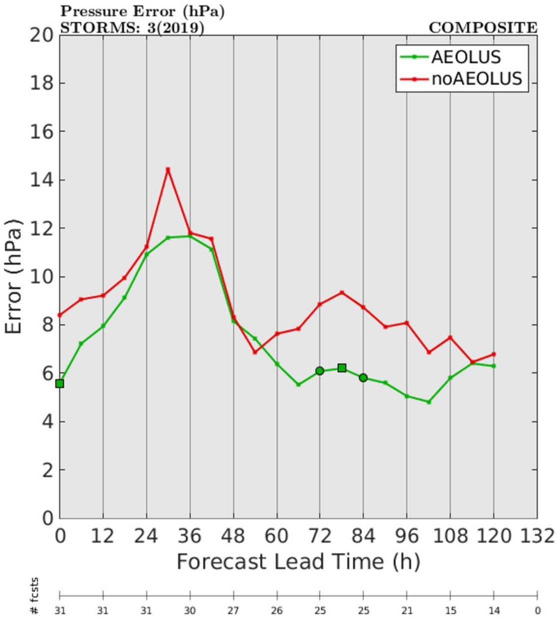


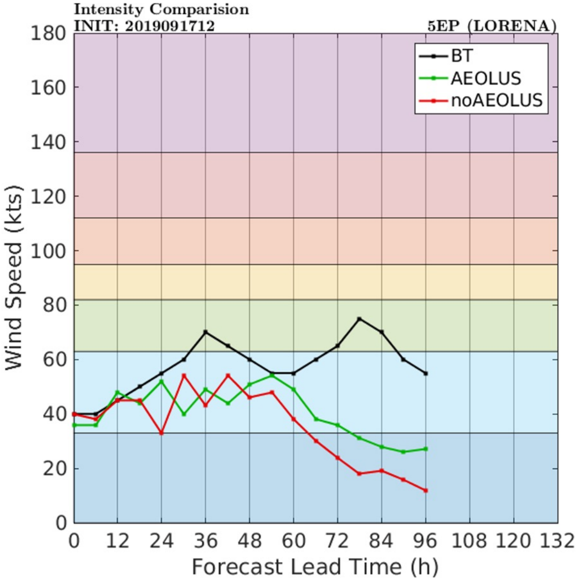
with ECMWF recommended static QC and HLOS OE + Static BC

- Focus on improving TC analysis and forecast in NOAA operational FV3GFS and HWRF
- Complex synoptic features in TC with regions of strong gradients in fields near the TC environment - motivates advanced DA strategies

FV3GFS: verification against National Hurricane Center best TC - Track, Surface Pressure, and Wind







Red: Control
Green: Aeolus
Black: NHC Best

- Initial degradation on track followed by improvement
- Error reduction in Pressure forecast
- Composite wind speed for 3 storms: Aeolus closer to NHC actual wind
- *but…* High case-to-case variability in FM-A/FM-B TC assessment

Outliers or good quality data near the TC?

Suboptimal observational weight assignment prior to minimization: Rejecting good/assimilating bad obs near the TC where they have a better chance at impacting the synoptic environment!

Variational Quality Control

Assimilate what you can, reject what you must!

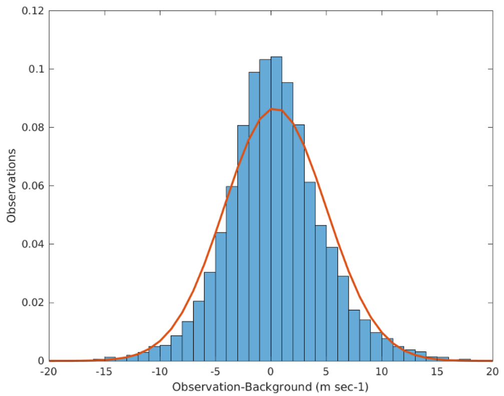
Power of Assimilation: St. John Henry Newman

- Even good quality data show significant departures from the pure Gaussian form
- Current Gaussian-based operational data assimilation may not be sufficient
- New VarQC scheme in NOAA/NCEP GFS was extended to the Aeolus DW observation operator
- Var QC is based on Chevron-family or Huber probability density functions
- Suited for unimodal and leptokurtic distributions (taller peaks and broader tails than a pure Gaussian)
- Requires Variational Quality Control (VarQC) parameter tuning

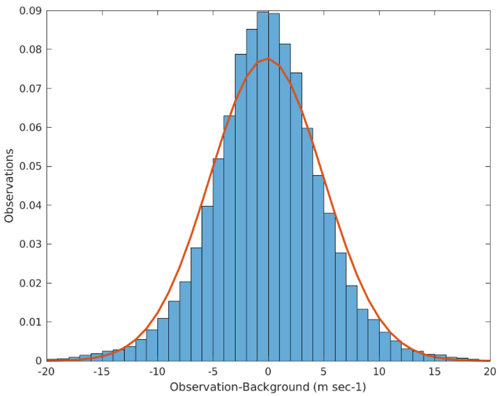
- *We hope that by assigning adaptive weights to AEOLUS observations near the TC inner and outer cores, minimization can achieve synergy between HLOSEE based OE, observational weights, the background, and the analysis*

O-B PDF's after static QC+BC

Aeolus Mie-cloudy
Valid: 2019080518



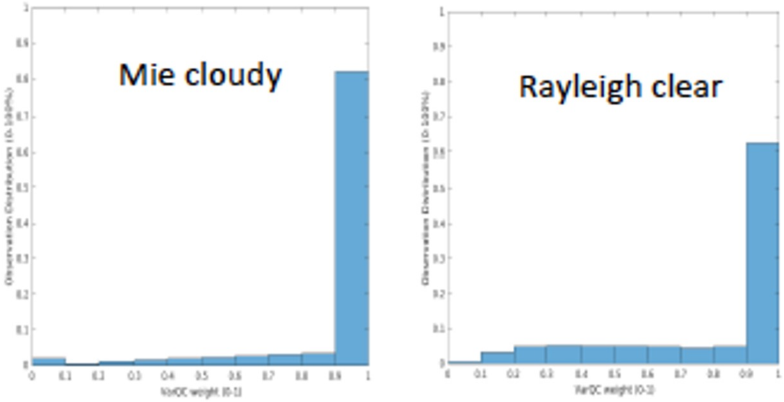
Aeolus Rayleigh-clear
Valid: 2019080318



- Developed i) accurate probability model for the Aeolus observations from O-B values ii) Bias Correction ("M1" principal mirror temperature bias correction, ECMWF) coefficients (weekly, applied the following week)
- Statistical assessment on Mie-cloudy and Rayleigh-clear innovations statistics indicate departures from the pure Gaussian form - unimodal and leptokurtic distributions, with some asymmetry
- Aeolus assimilation may benefit from advanced Var QC by assigning adaptive weights to observation outliers, depending on the observation increment and probability of gross error
- Purser, et. al. 2019 Var QC (implemented in GFS, 2021) was adopted for Aeolus

- VarQC deals with rejection limits outside of the Gaussian
- Not discarding observations that lead to large departures, but assigning less weight during the final

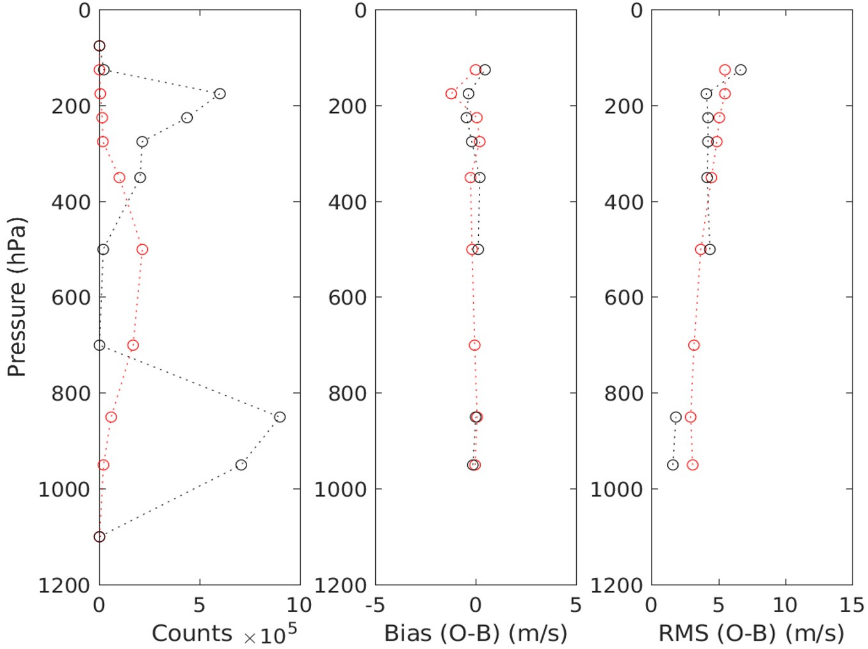
Adaptive weight distribution valid: 2019082018



VarQC adaptive weights 0 to 1 rang

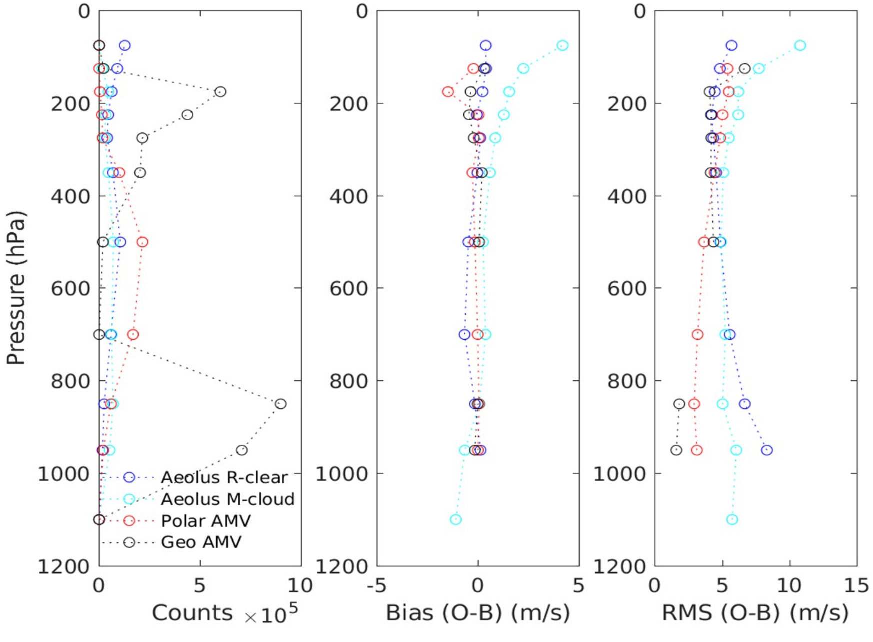
- 0 least impact to the analysis
- 1 most impact to the analysis

CONTROL

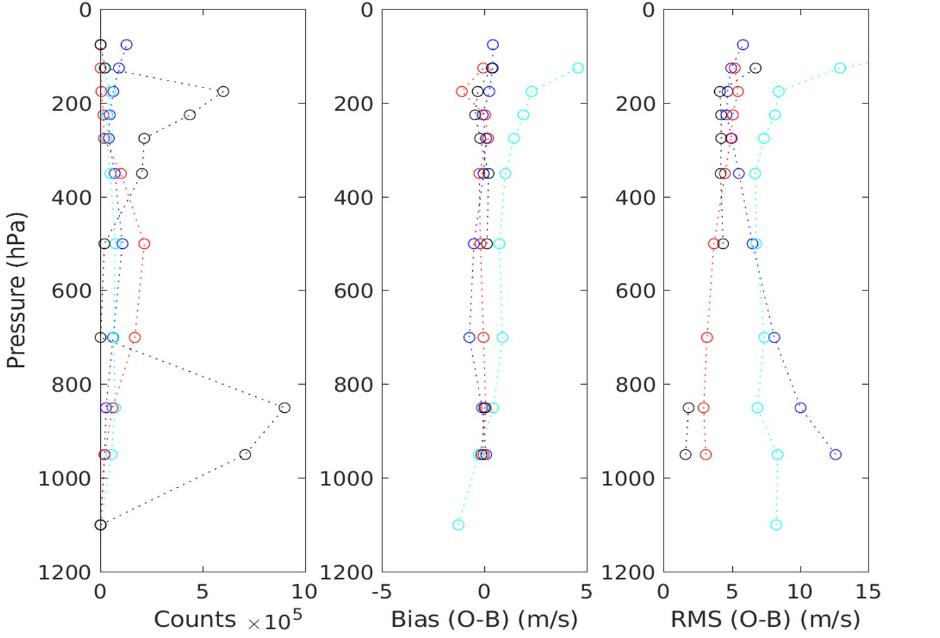


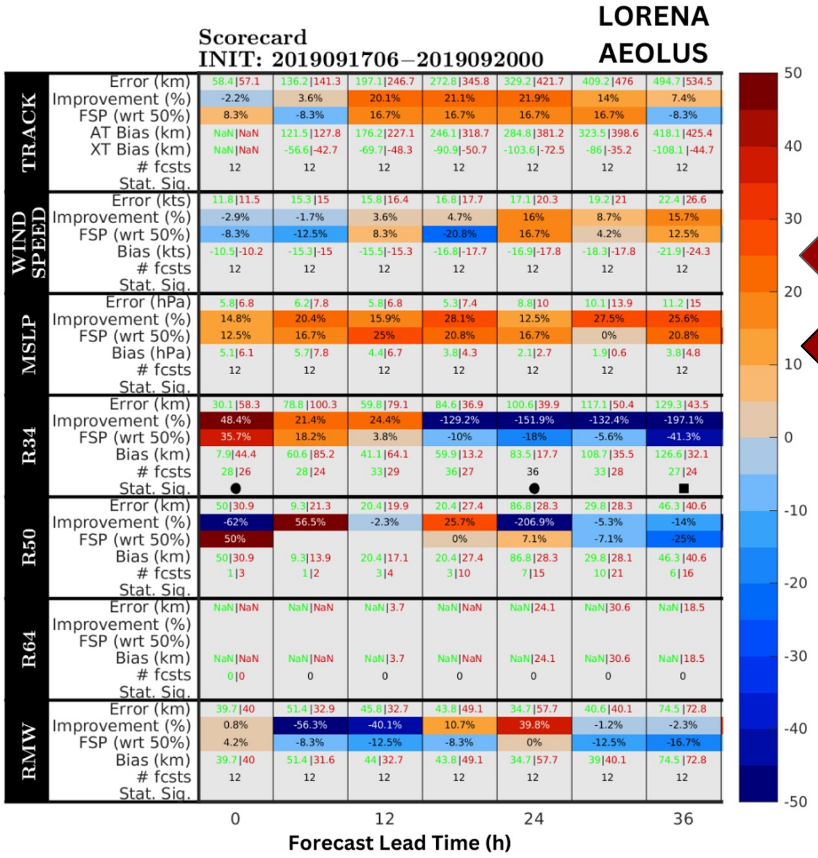
Polar IR AMVs
GEO IR AMVs

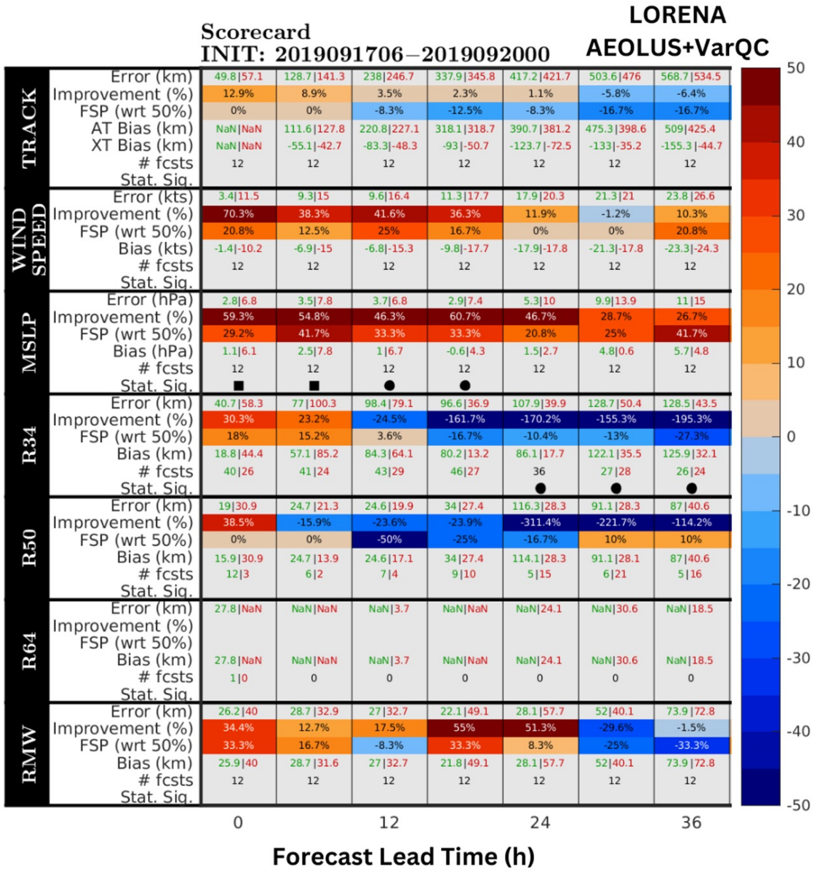
AEOLUS



AEOLUS+VQC







TC Forecast metrics scorecards for track, wind speed, MSLP, various radii of storm intensity winds in FV3GFS with AEOLUS and Aeolus+VarQC wrt to CONTROL

Improvement

Degradation

CONCLUSIONS

- FV3 GFS forecasts of Tropical Cyclones, when using ECMWF static QC showed positive impact from assimilating Aeolus winds profiles
- Utilizing Variational Quality Control with assimilating Aeolus winds profiles and keeping more observations appears to be beneficial to short term FC of TC
- Nominal Aeolus mission operations concluded on 30 April 2023. Aeolus wind profiles were not assimilated operationally in the NCEP GFS DA system because of the mission lifetime (3 years), however Aeolus' longevity and this work laid the foundation for operational use of Aeolus-2 (***Fingers crossed!***)

Apodaca, K., Cucurull L.,Genkova,I., Purser J., Su X
Assessing the benefit of variational quality control for assimilating Aeolus Mie and Rayleigh wind profiles in NOAA's Global Forecast System during tropical cyclones (under review, QJRMS)

Marinescu, P.J., Cucurull, L., Apodaca, K., Bucci, L. & Genkova, I. (2022)
The characterization and impact of Aeolus wind profile observations in NOAA's regional tropical cyclone model (HWRF). Quarterly Journal of the Royal Meteorological Society, 1–18. Available from: https://doi.org/10.1002/qj.4370
Highlighted on ESA's website:
https://earth.esa.int/eogateway/news/esa-s-wind-mission-could-help-to-forecast-tropical-storms

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