A Systematic Assessment of Dropsonde Impact during the 2017-2019 Hurricane Seasons using the Basin-Scale HWRF: Overall Impacts

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Project Plan Snapshot

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OBJECTIVE: To conduct a composite study that quantifies the radial impact of dropsondes from manned (C-130, P3, G-IV) and unmanned (GH) aircraft on TC forecasts of track, intensity, and structure over the 2017–2019 hurricane seasons

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SQs:

1) What is the overall impact of all dropsondes from missions between 2017-2019?
2) What is the importance of having dropsondes in the full TS-Gales region (<250 km)?
3) What impact do inner-core dropsondes (<75 km) have on forecasts?

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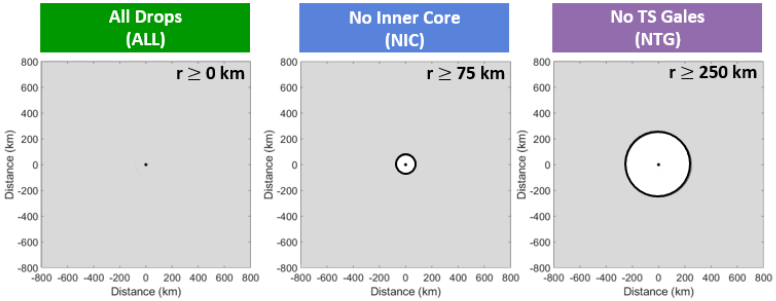
Experiment Suite: Assimilated Dropsonde Observations

Dropsondes are allowed *outside* a given radius (r)



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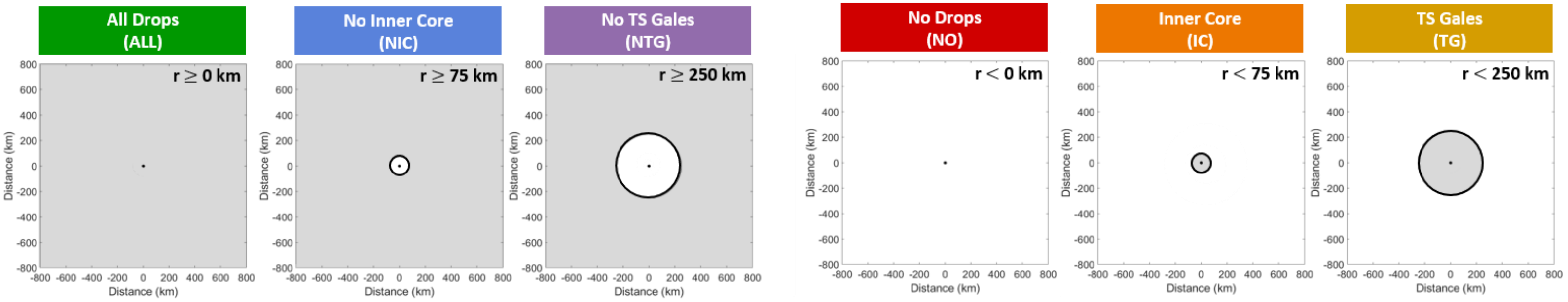

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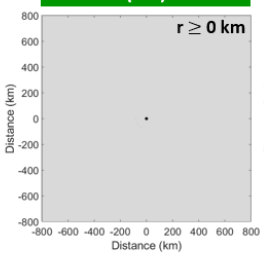
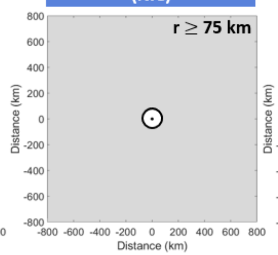
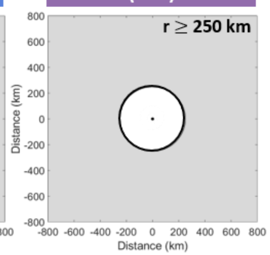
All Drops (ALL)



No Inner Core (NIC)

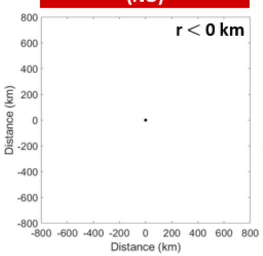


No TS Gales (NTG)

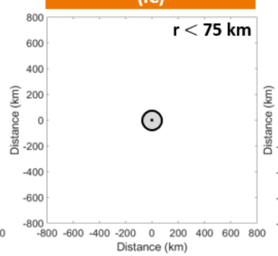


Dropsondes are allowed *inside* a given radius (r)

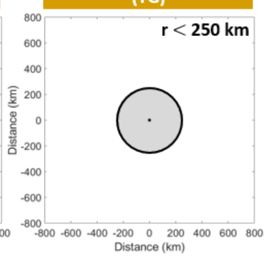
No Drops (NO)



Inner Core (IC)



TS Gales (TG)



Scope of Study:

Years	Days	Cycles	S_{drp}*/S_{all}
2017-2019	~125	498	22/47

*Storms with assimilated dropsondes

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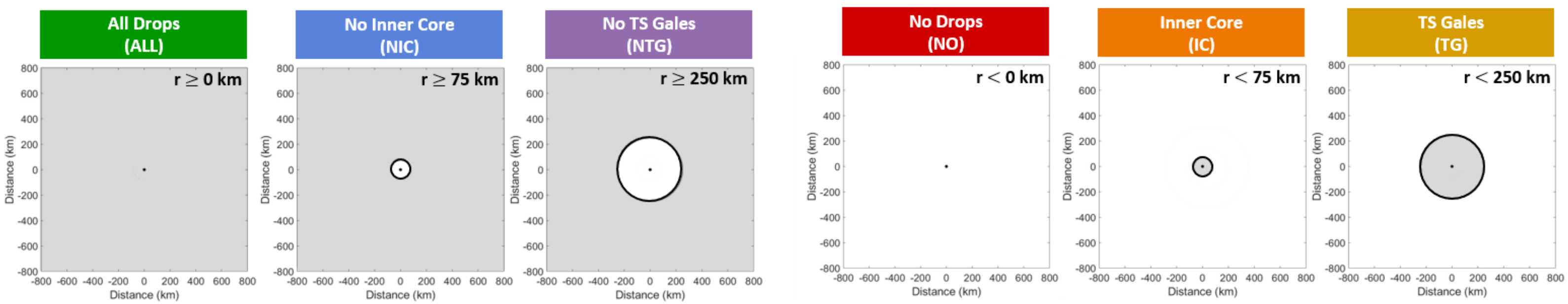

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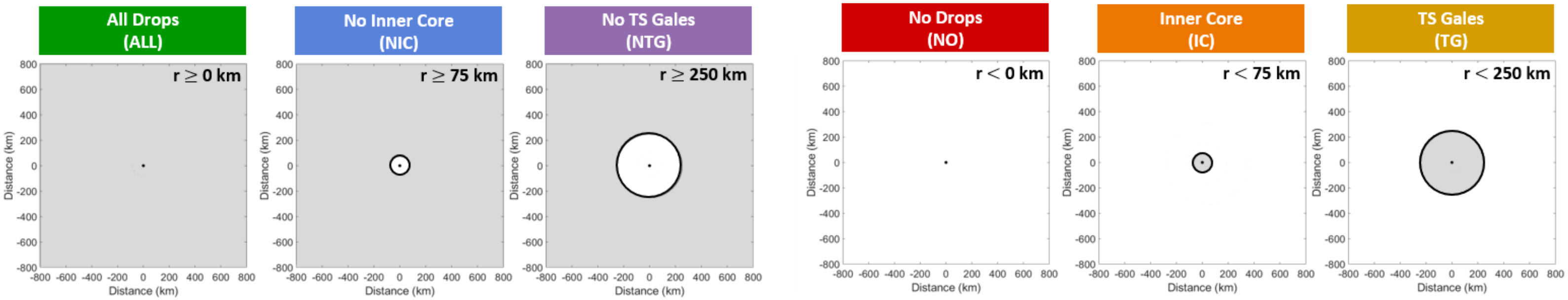

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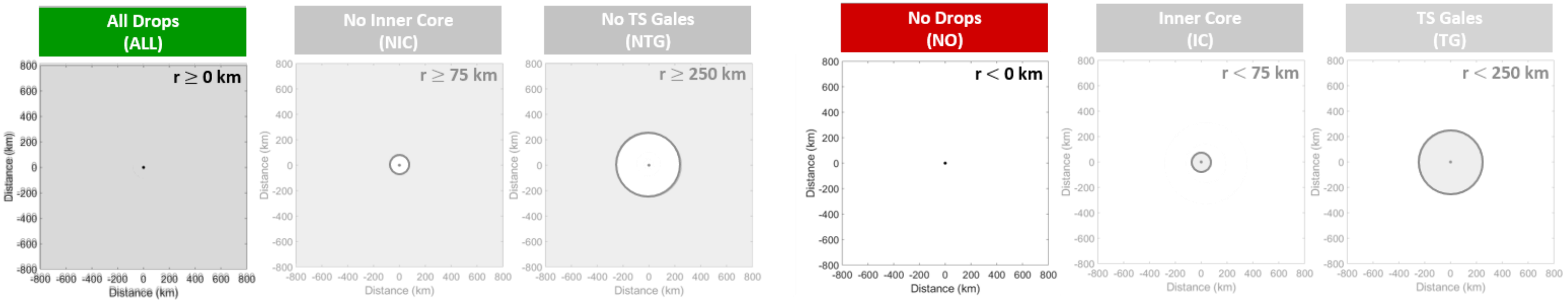

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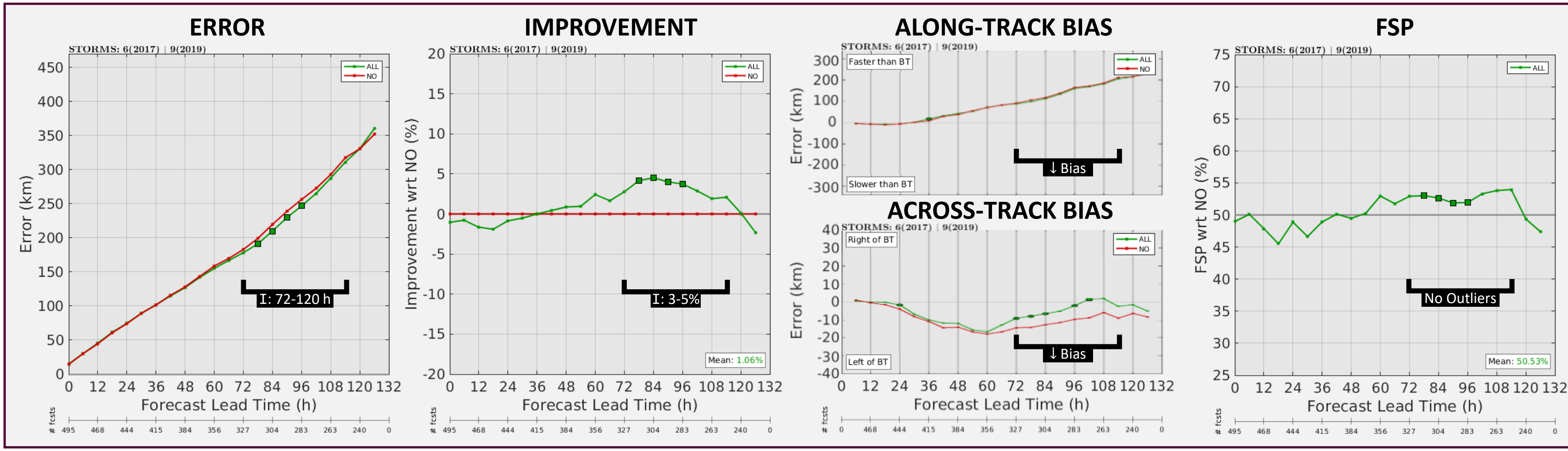
■ (●): 95% (90%) sig.

Full* Sample

Basin: AL | Verification: Consistent with NHC



OVERALL ASSESSMENT

The inclusion of dropsondes improves track forecasts between 72-120 h around 3-5%. Additionally, the assimilation of dropsondes reduces the across-track bias and the improvement found isn't driven by large outliers.

■ (●): 95% (90%) sig.

Stratification By Data Availability

Basin: AL | Verification: Consistent with NHC

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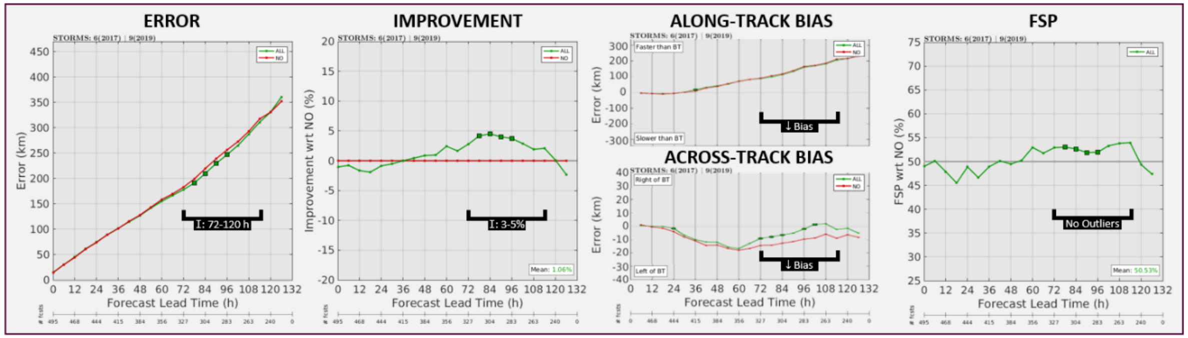
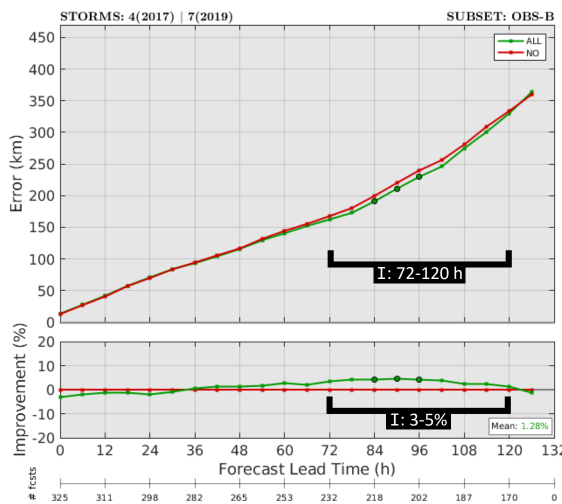
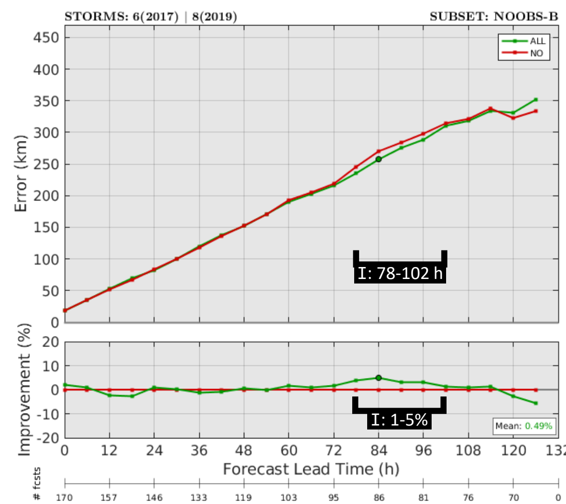


OBS-B



Cycles that *did* have assimilated dropsondes in the parent domain

NOOBS-B



Cycles that *did not* have assimilated dropsondes in the parent domain

■ (●): 95% (90%) sig.

Stratification By Data Availability

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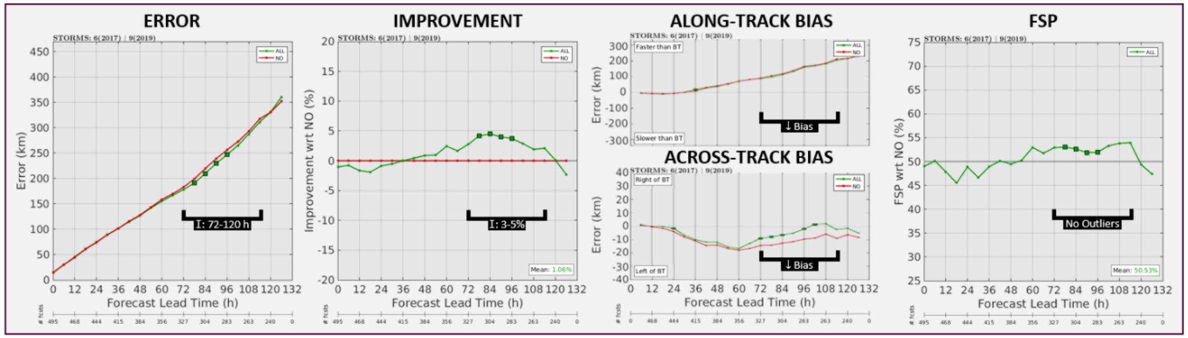

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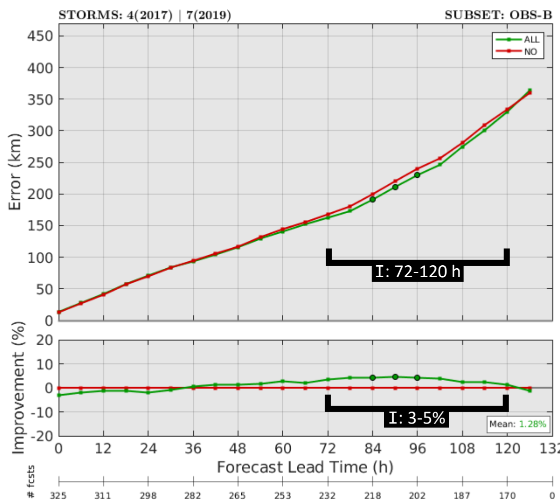
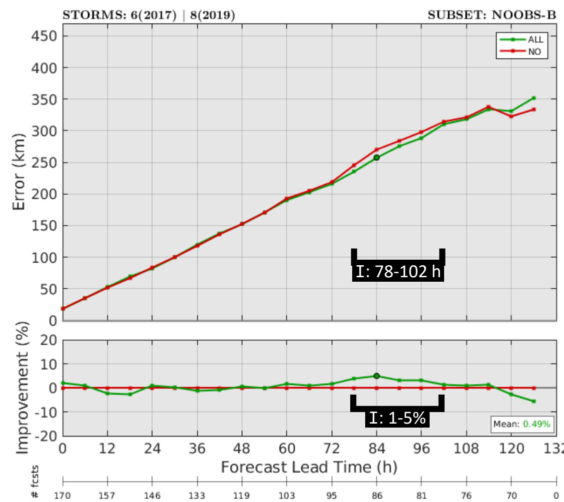


NOOBS-B



This indicates that cycles with dropsondes in the parent domain (OBS-B) outperformed those cycles without dropsondes in the parent domain (NOOBS-B). Not shown is that cycles from storms with dropsondes showed 5-6% improvement between 72-120 h.

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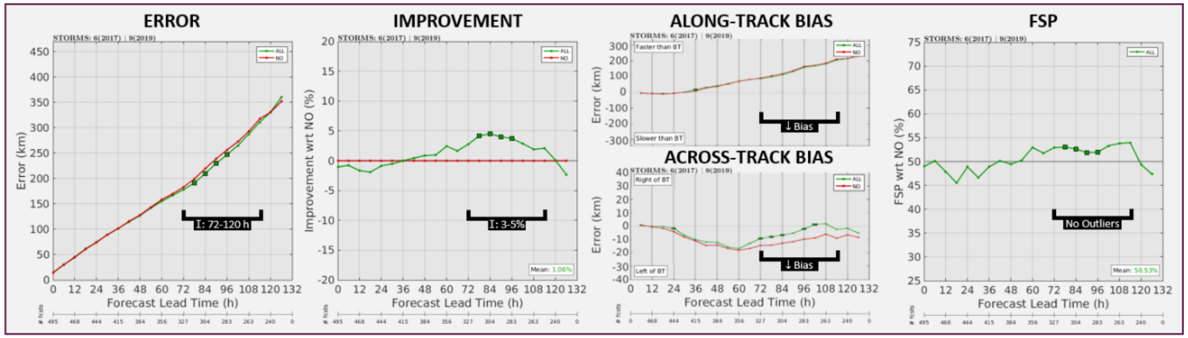
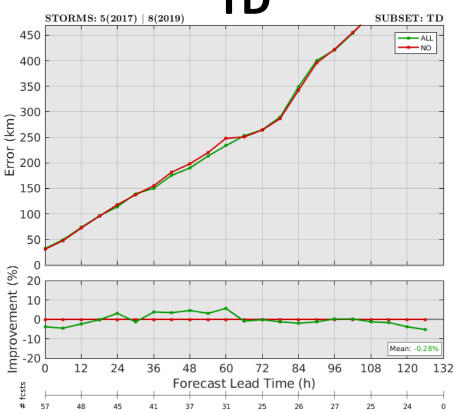
Stratification By Intensity

Basin: AL | Verification: Consistent with NHC

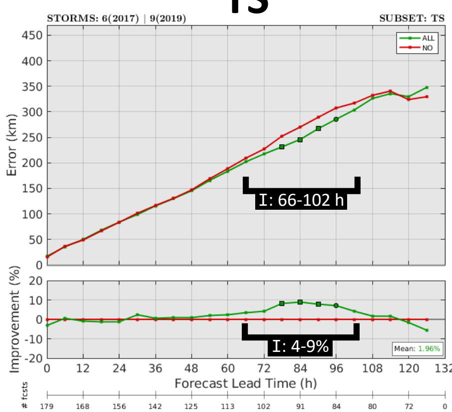
FULL SAMPLE



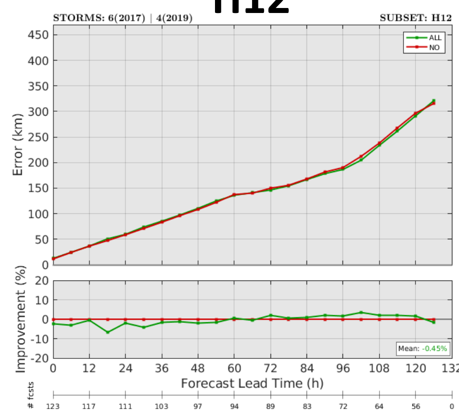
TD



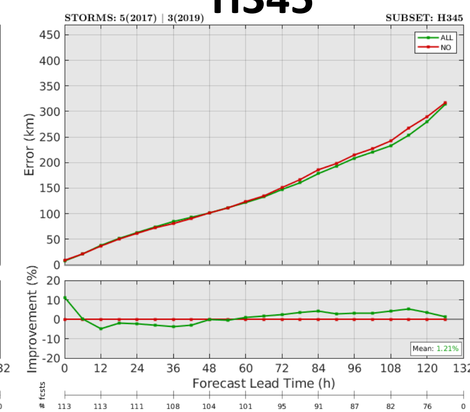
TS



H12



H345



■ (●): 95% (90%) sig.

Stratification By Intensity

Basin: AL | Verification: Consistent with NHC

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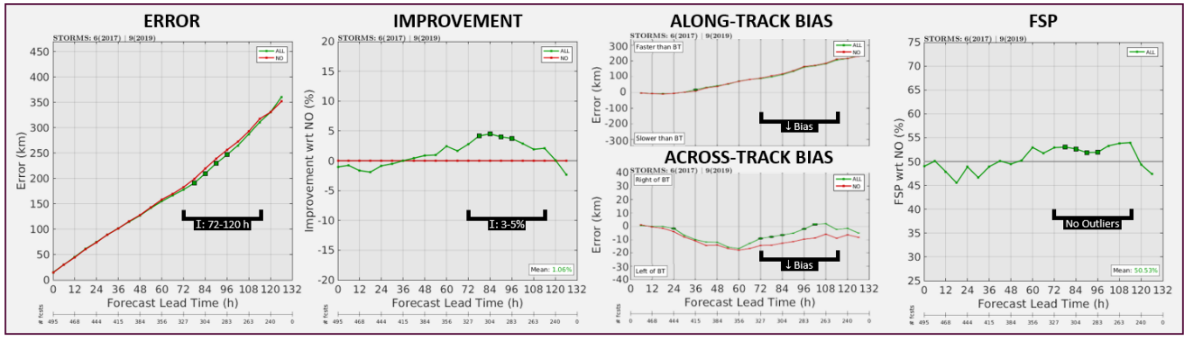
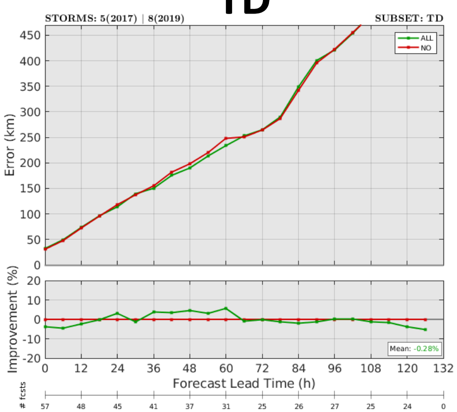
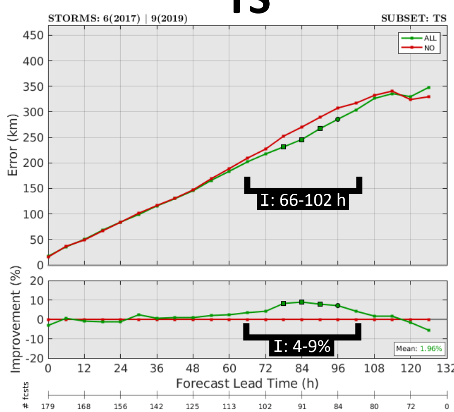


TD



TS



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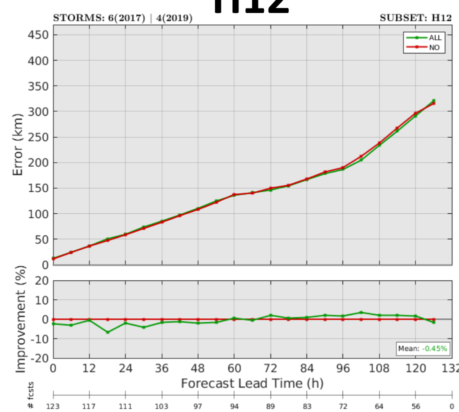

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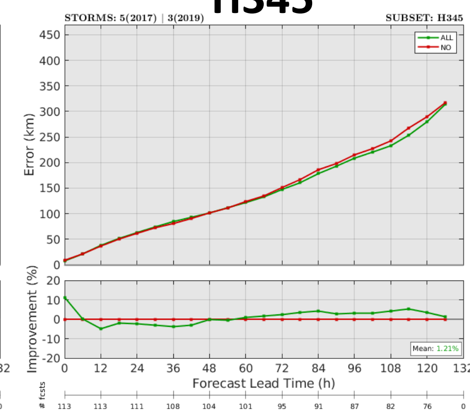

Cycles from storms of TS intensity drove track improvement, with 4-9% track improvement between 66-102 h.

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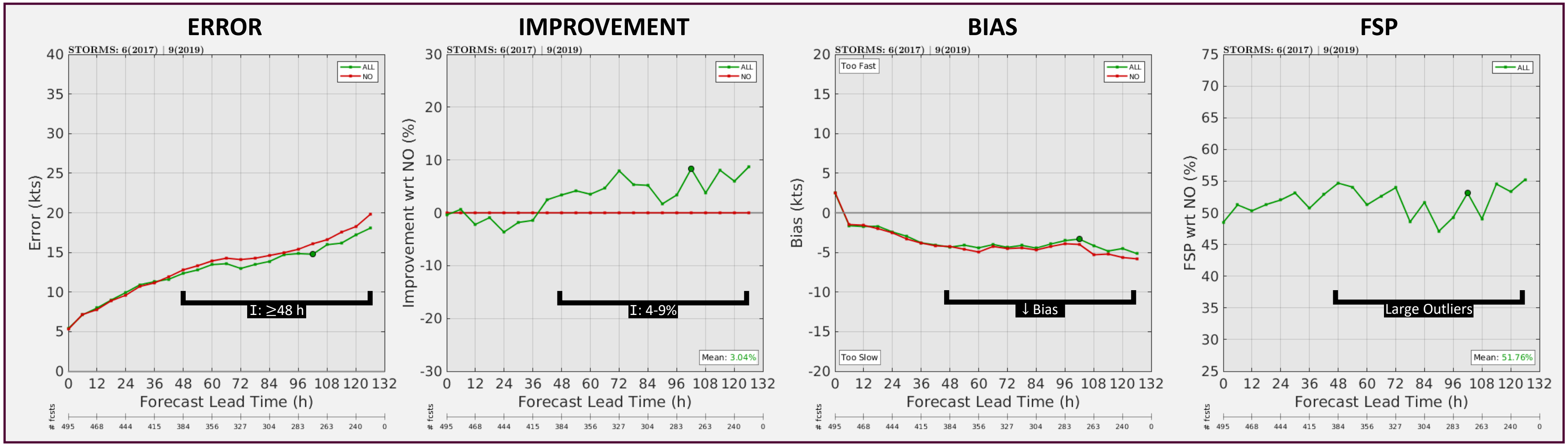

OVERALL ASSESSMENT

The inclusion of dropsondes improves wind speed forecasts ≥48 h around 4-9%. Additionally, the assimilation of dropsondes slightly reduces the bias and the improvement found is driven by some large outliers.

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Stratification By Year

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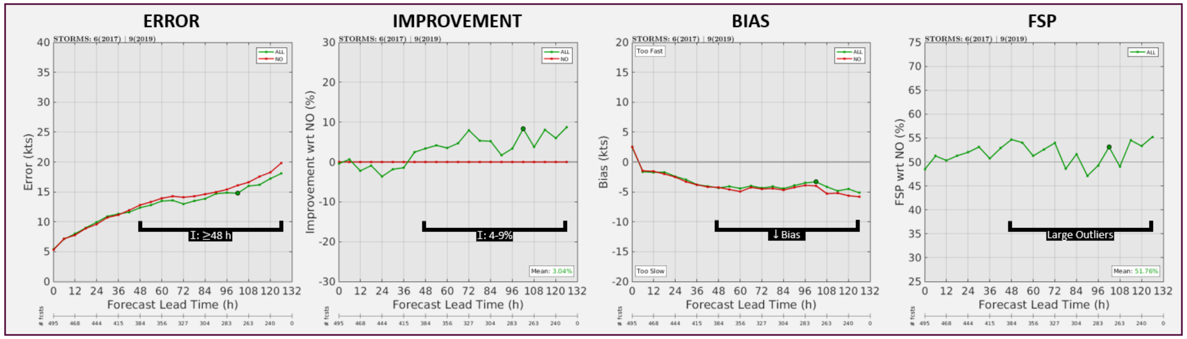
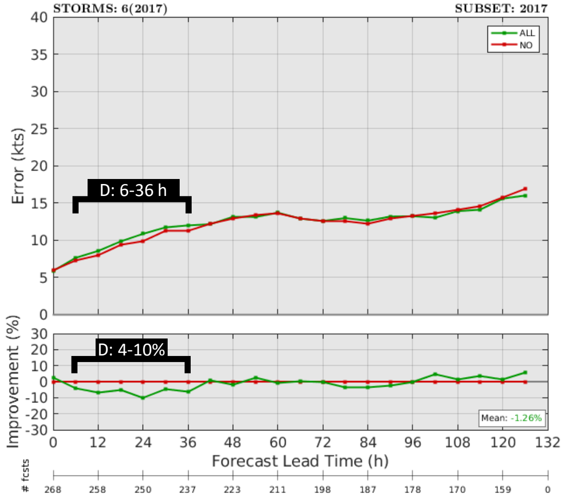
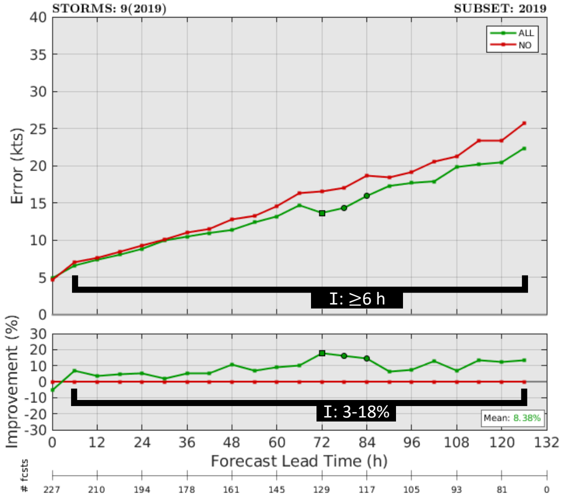


2017



2019



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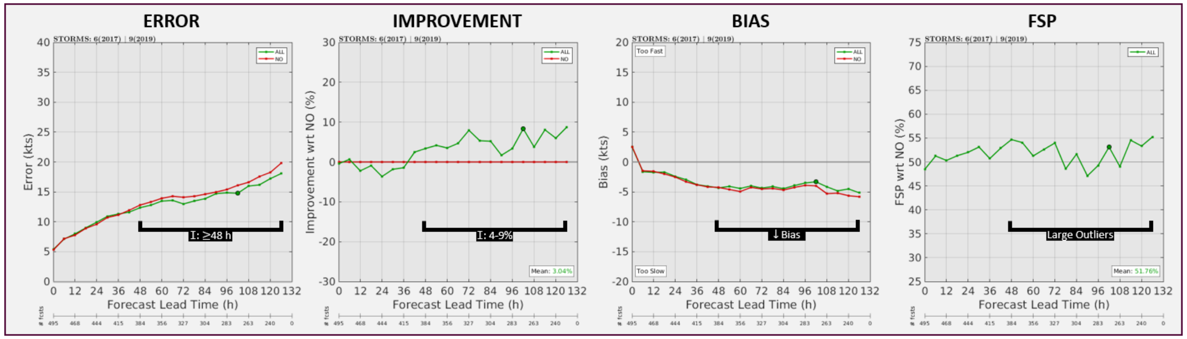

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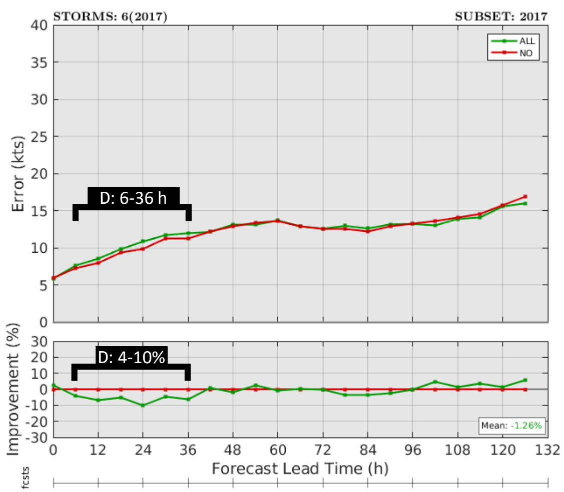
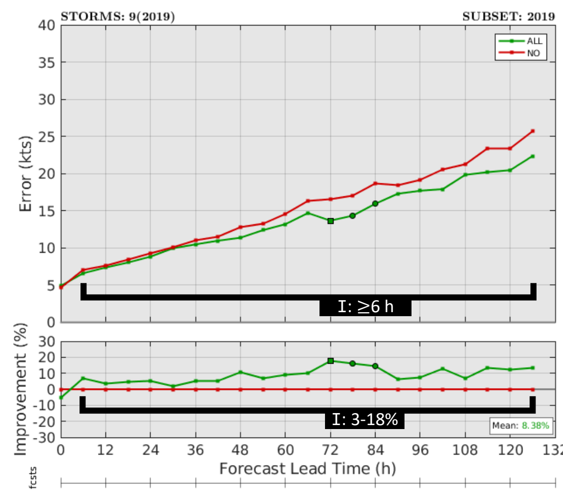


2019



Between 2017 and 2019 there was a change to the observing system method – end-point dropsondes and an inner circumnavigation were both added. Could this be driving the interannual difference shown?

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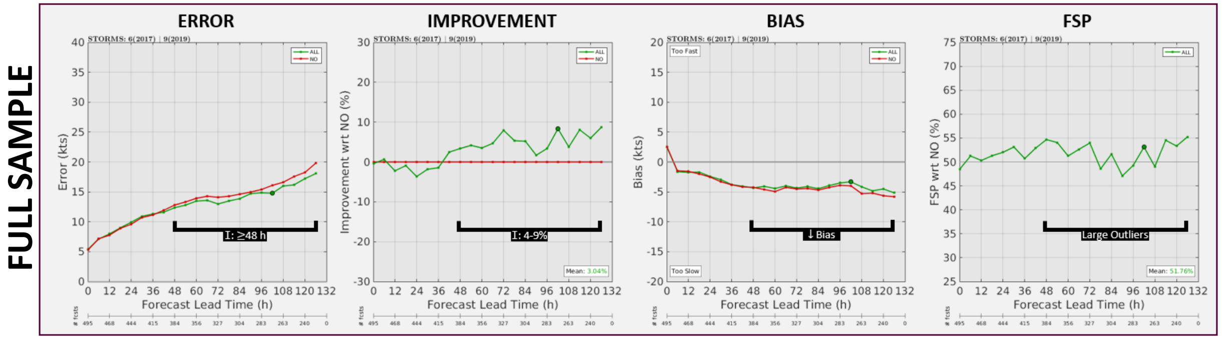

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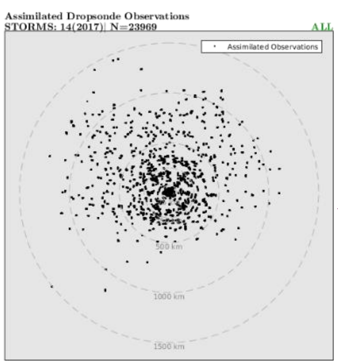

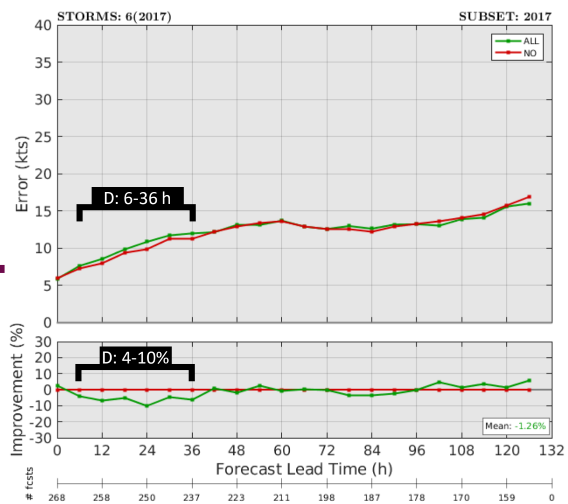

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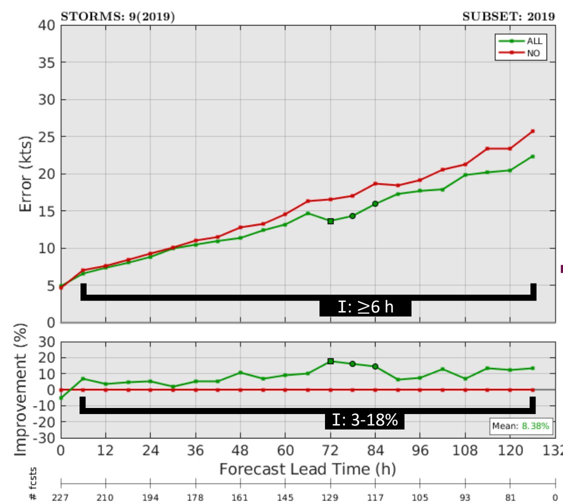

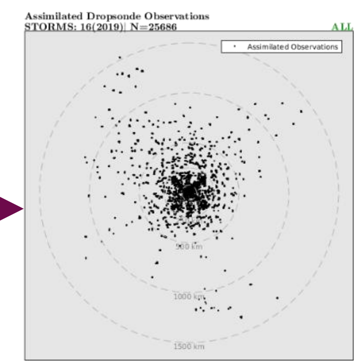

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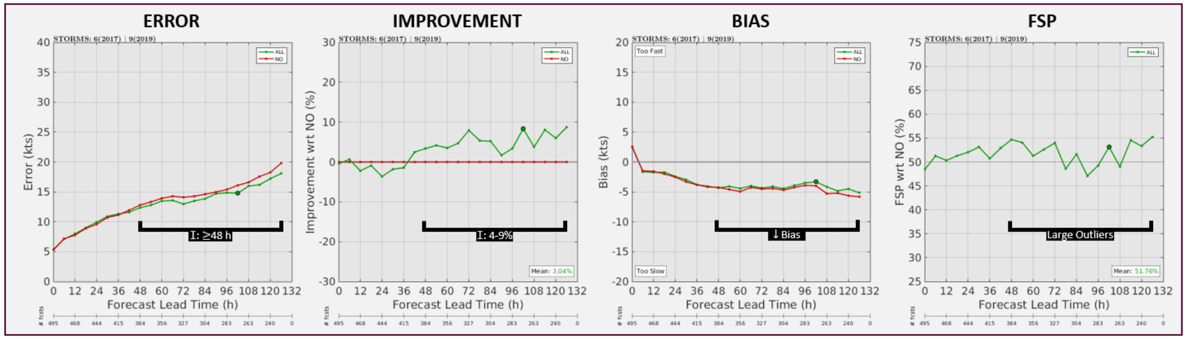
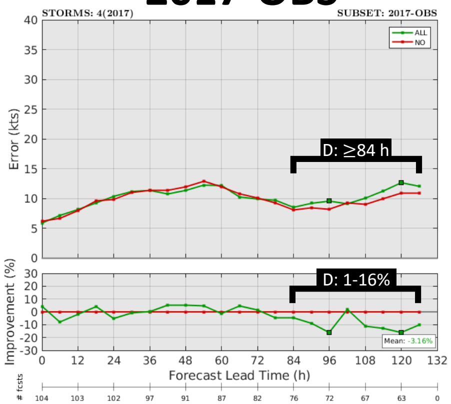
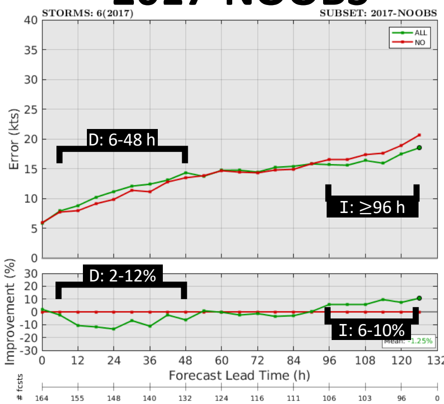


2017-OBS



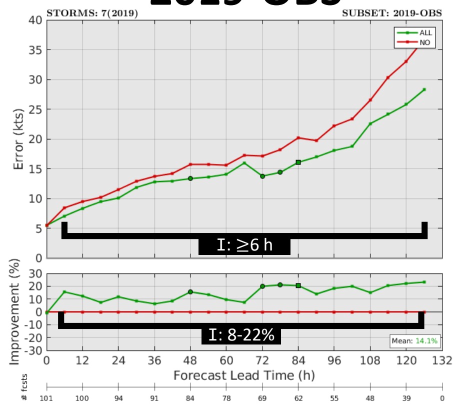
Cycles from 2017 storms that *did* directly assimilate dropsondes

2017-NOOBS



Cycles from 2017 storms that *did not* directly assimilate dropsondes

2019-OBS



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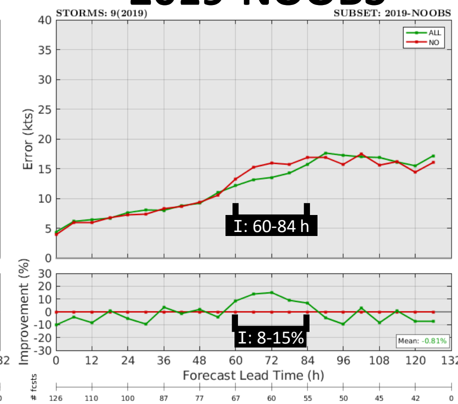

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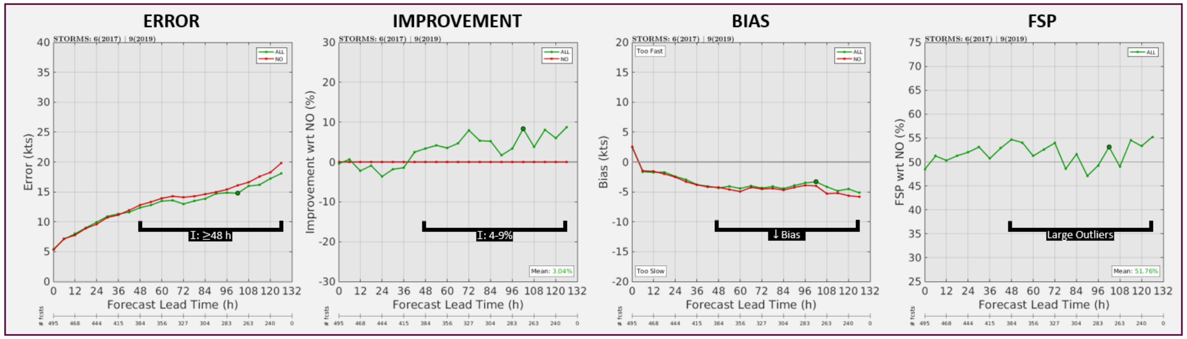

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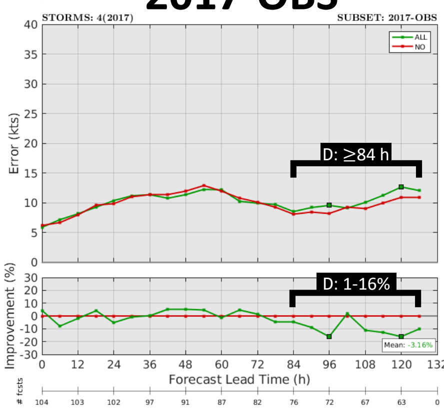

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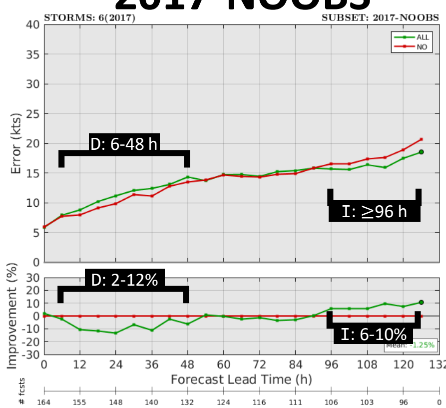

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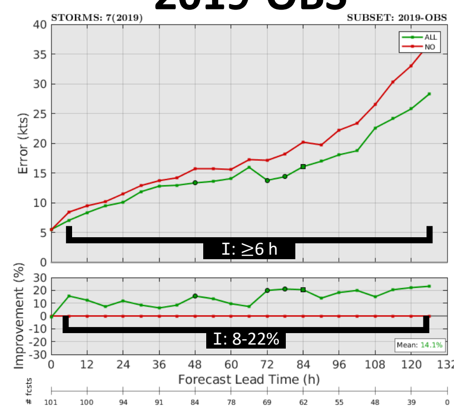
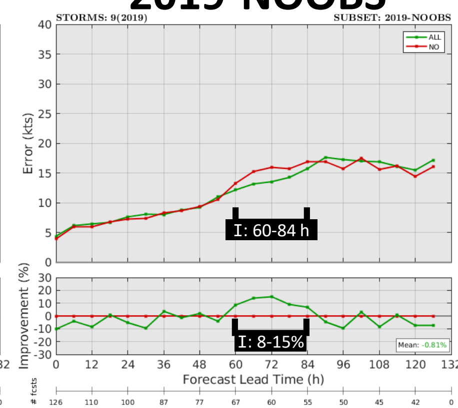


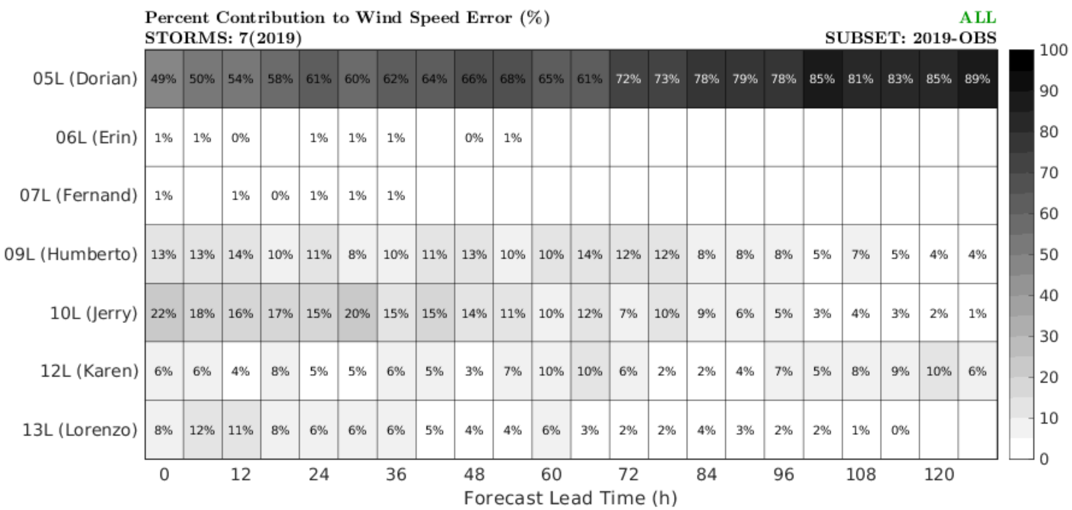
2019-NOOBS



This indicates that cycles from storms with dropsondes in 2019 (2019-OBS) drove wind speed improvement in the full sample.

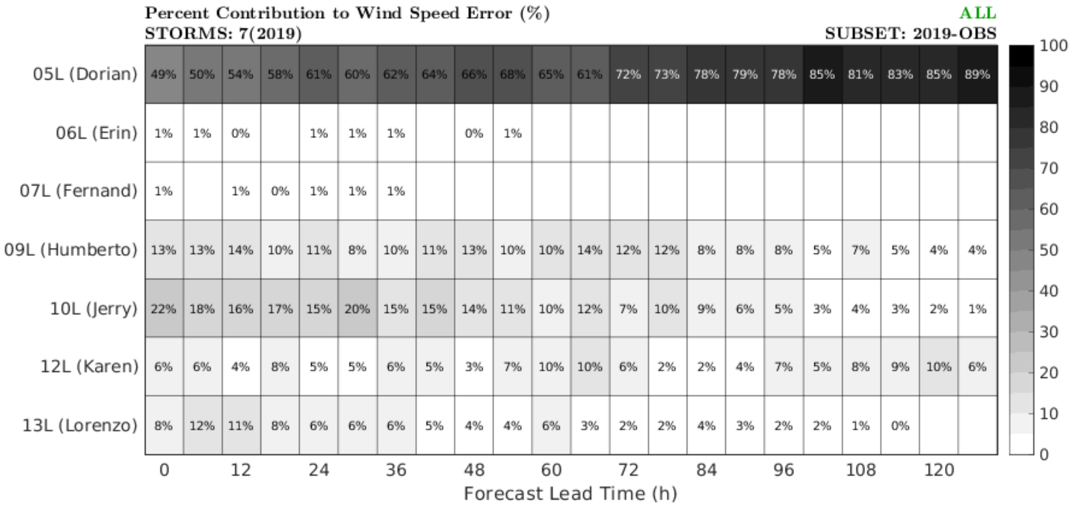
Assessment of 2019-OBS Performance

Individual Storm Contribution

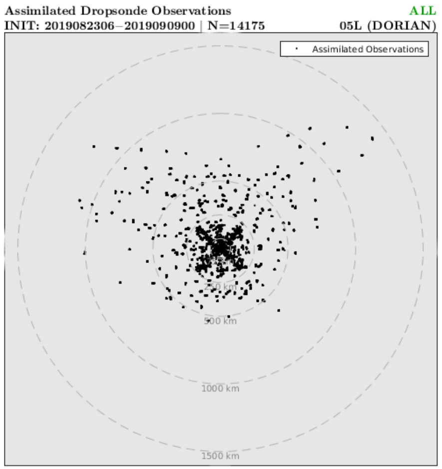


Assessment of 2019-OBS Performance

Individual Storm Contribution



Dorian's Dropsonde Distribution



Assessment of 2019-OBS Performance

Individual Storm Contribution

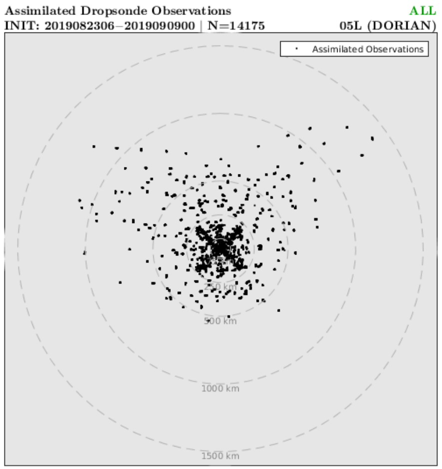
Percent Contribution to Wind Speed Error (%) ALL
STORMS: 7(2019) SUBSET: 2019-OBS

Storm	0		12		24		36		48		60		72		84		96		108		120	
05L (Dorian)	49%	50%	54%	58%	61%	60%	62%	64%	66%	68%	65%	61%	72%	73%	78%	79%	78%	85%	81%	83%	85%	89%
06L (Erin)	1%	1%	0%		1%	1%	1%		0%	1%												
07L (Fernand)	1%		1%	0%	1%	1%	1%															
09L (Humberto)	13%	13%	14%	10%	11%	8%	10%	11%	13%	10%	10%	14%	12%	12%	8%	8%	8%	5%	7%	5%	4%	4%
10L (Jerry)	22%	18%	16%	17%	15%	20%	15%	15%	14%	11%	10%	12%	7%	10%	9%	6%	5%	3%	4%	3%	2%	1%
12L (Karen)	6%	6%	4%	8%	5%	5%	6%	5%	3%	7%	10%	10%	6%	2%	2%	4%	7%	5%	8%	9%	10%	6%
13L (Lorenzo)	8%	12%	11%	8%	6%	6%	6%	5%	4%	4%	6%	3%	2%	2%	4%	3%	2%	2%	1%	0%		

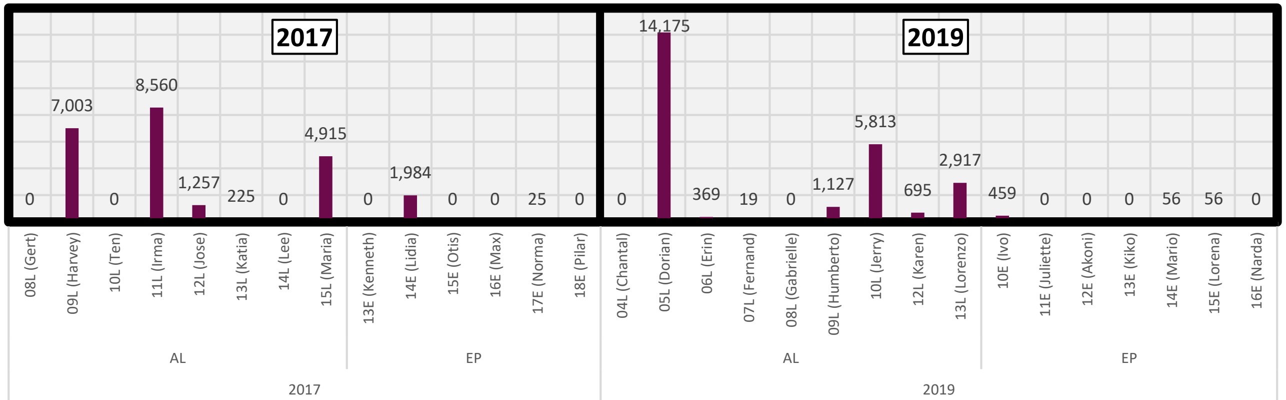
Forecast Lead Time (h)

Color scale: 0 – 100

Dorian's Dropsonde Distribution



Assimilated Dropsonde Observations



Assessment of 2019-OBS Performance

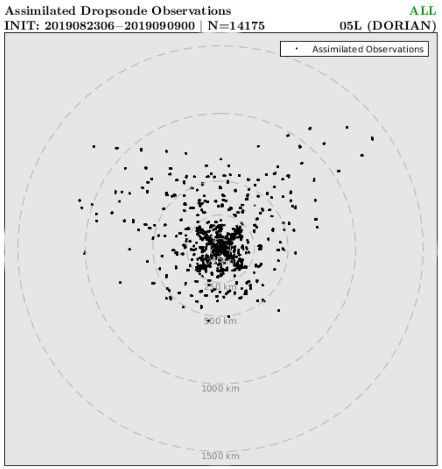
Individual Storm Contribution

Percent Contribution to Wind Speed Error (%) — ALL
STORMS: 7(2019) — SUBSET: 2019-OBS

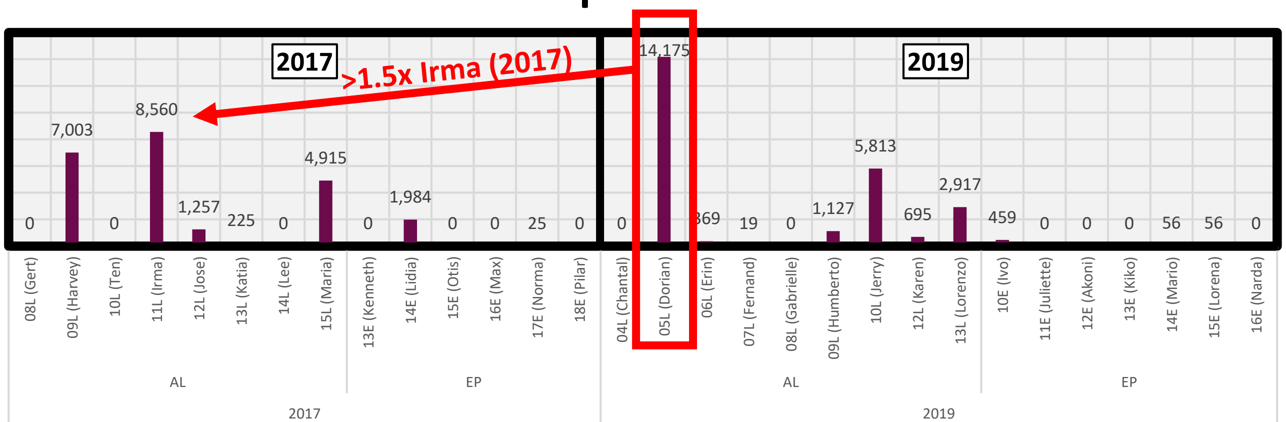
Storm	0	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126
05L (Dorian)	49%	50%	54%	58%	61%	60%	62%	64%	66%	68%	65%	61%	72%	73%	78%	79%	78%	85%	81%	83%	85%	89%
06L (Erin)	1%	1%	0%		1%	1%	1%		0%	1%												
07L (Fernand)	1%		1%	0%	1%	1%	1%															
09L (Humberto)	13%	13%	14%	10%	11%	8%	10%	11%	13%	10%	10%	14%	12%	12%	8%	8%	8%	5%	7%	5%	4%	4%
10L (Jerry)	22%	18%	16%	17%	15%	20%	15%	15%	14%	11%	10%	12%	7%	10%	9%	6%	5%	3%	4%	3%	2%	1%
12L (Karen)	6%	6%	4%	8%	5%	5%	6%	5%	3%	7%	10%	10%	6%	2%	2%	4%	7%	5%	8%	9%	10%	6%
13L (Lorenzo)	8%	12%	11%	8%	6%	6%	6%	5%	4%	4%	6%	3%	2%	2%	4%	3%	2%	2%	1%	0%		

Forecast Lead Time (h)

Dorian's Dropsonde Distribution



Assimilated Dropsonde Observations

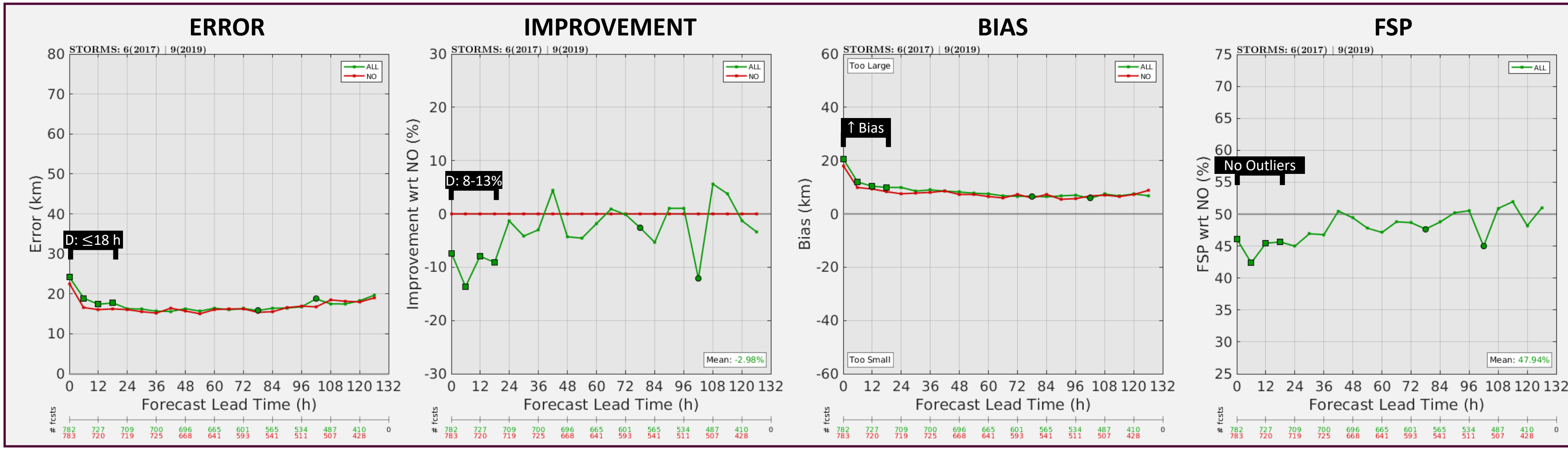


*Covers 2017 & 2019, only

■ (●): 95% (90%) sig.

Full* Sample

Basin: AL | **Verification:** Consistent with NHC



OVERALL ASSESSMENT

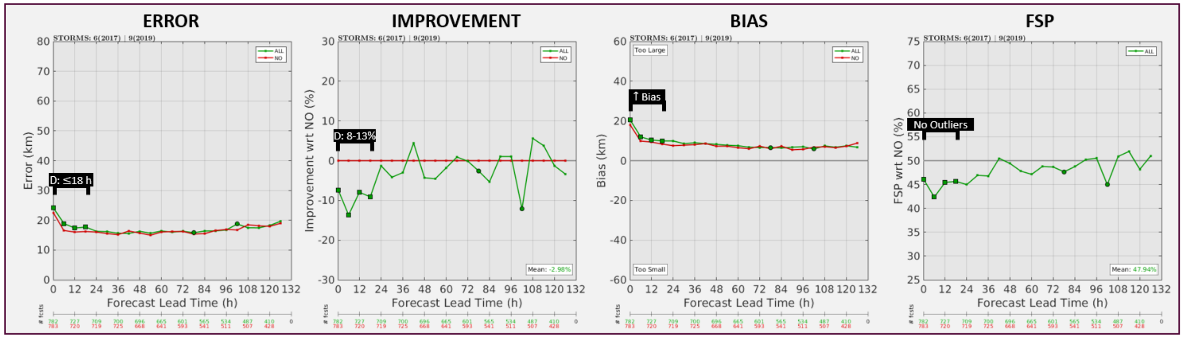
The inclusion of dropsondes degrades forecasts ≤18 h around 8-13%. Additionally, the assimilation of dropsondes slightly increased the bias and the degradation found was not driven by outliers.

■ (●): 95% (90%) sig.

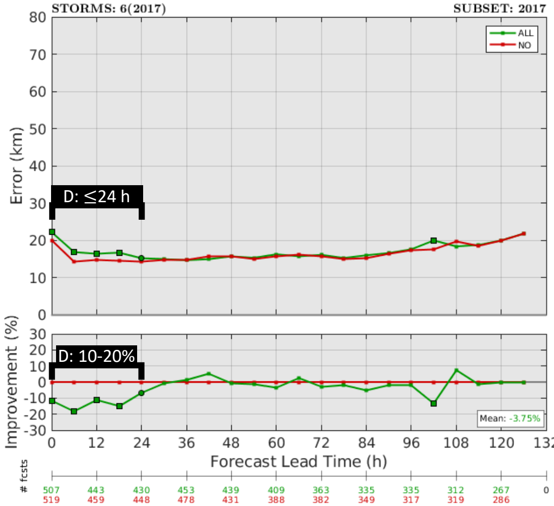
Stratification By Year

Basin: AL | **Verification:** Consistent with NHC

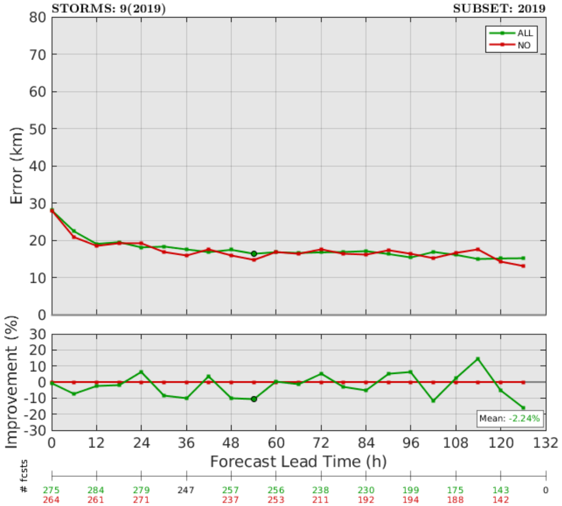
FULL SAMPLE



2017



2019



■ (●): 95% (90%) sig.

Stratification By Year

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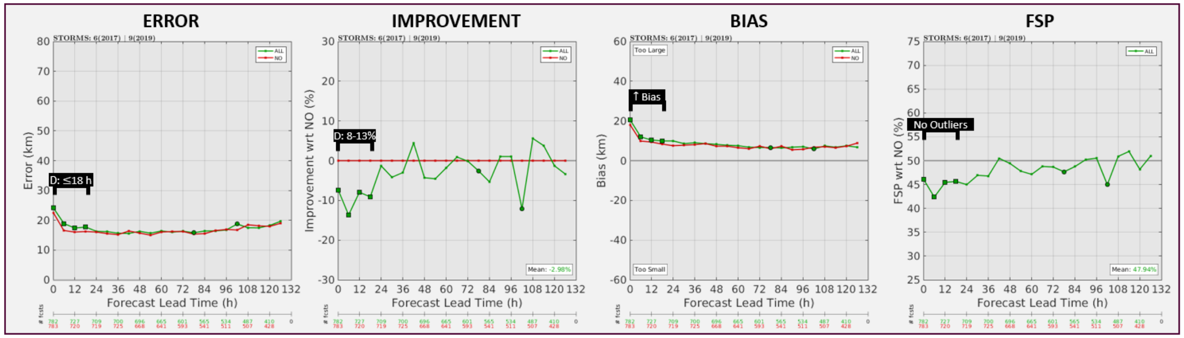
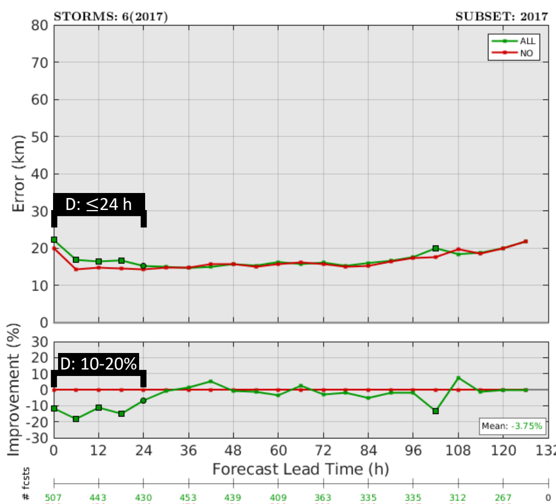
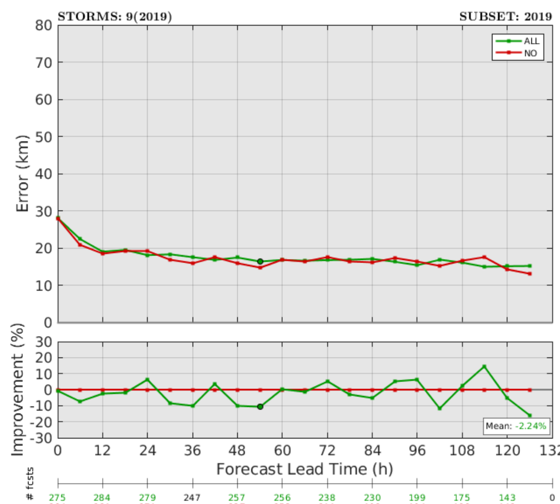
FULL SAMPLE



2017



2019



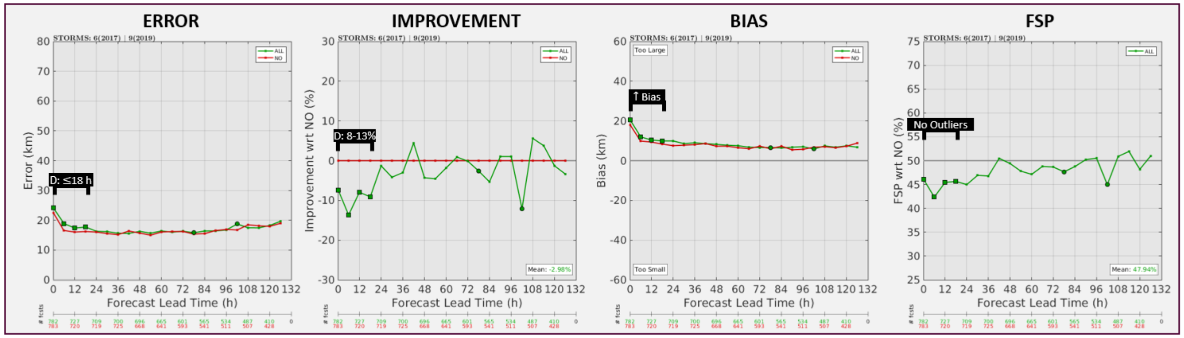
Between 2017 and 2019 there was a change to the observing system method – end-point dropsondes and an inner circumnavigation were both added. Could this be driving the interannual difference shown?

■ (●): 95% (90%) sig.

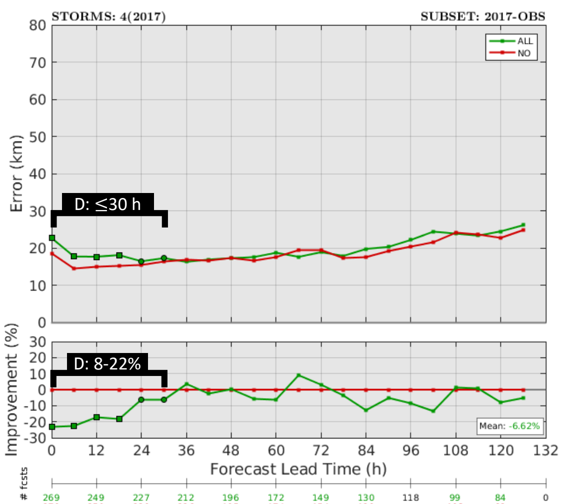
Stratification By Year & Data Availability

Basin: AL | **Verification:** Consistent with NHC

FULL SAMPLE

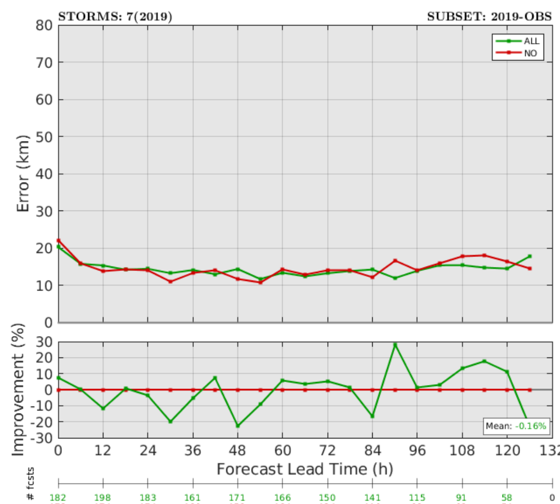


2017-OBS



Cycles from 2017 storms that *did* directly assimilate dropsondes

2019-OBS



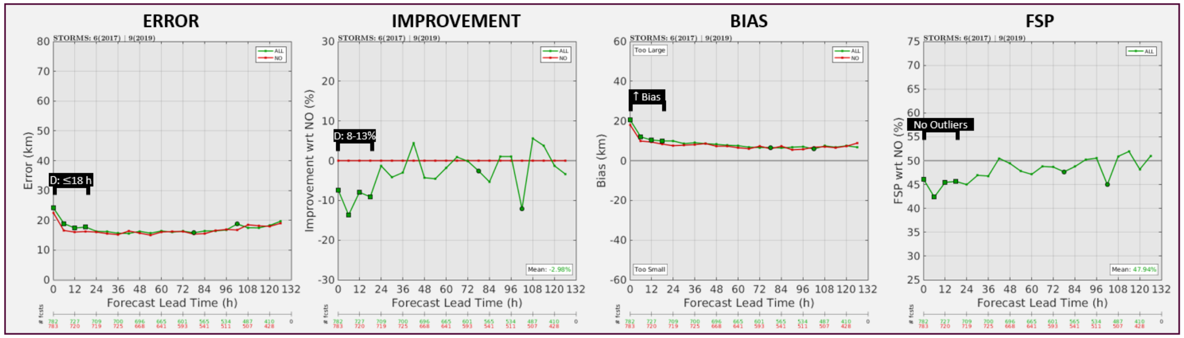
Cycles from 2019 storms that *did* directly assimilate dropsondes

■ (●): 95% (90%) sig.

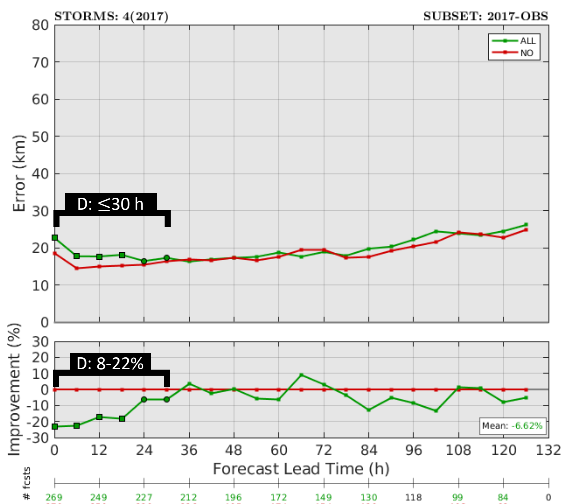
Stratification By Year & Data Availability

Basin: AL | **Verification:** Consistent with NHC

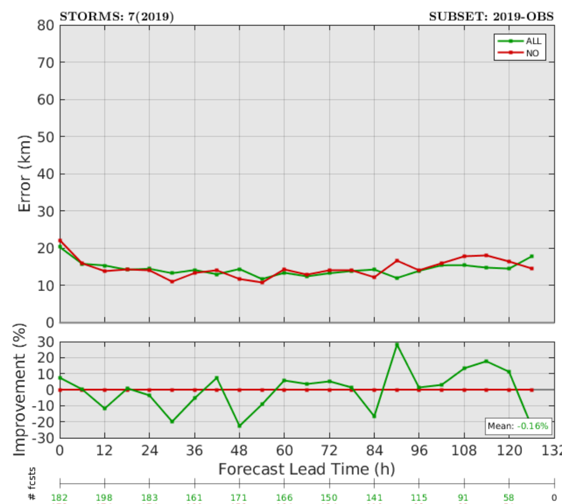
FULL SAMPLE



2017-OBS



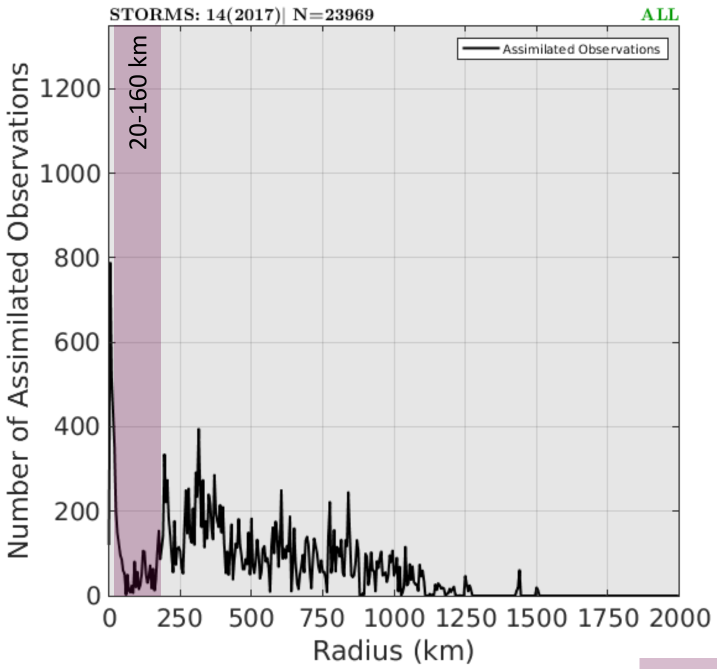
2019-OBS



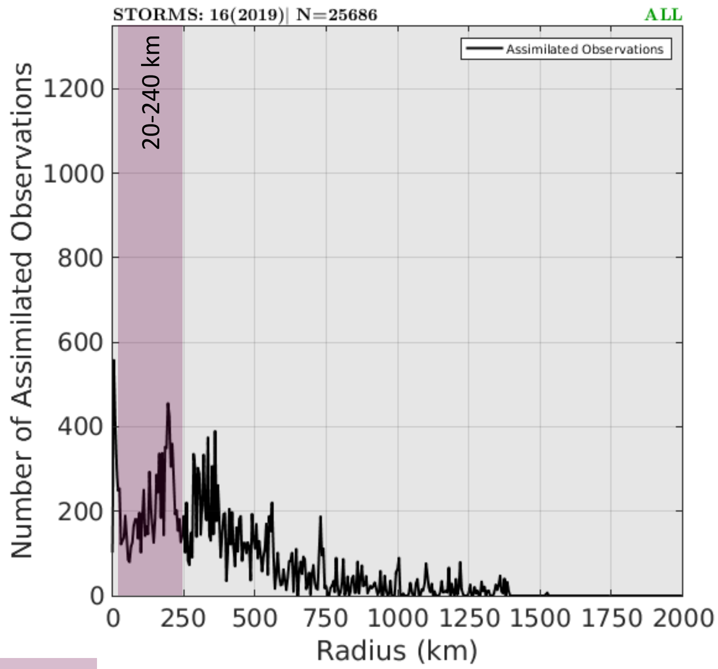
This indicates that cycles from storms with dropsondes in 2017 (2017-OBS) drove R64 degradation in the full sample.

Dropsonde Observations Stratified By Year

2017



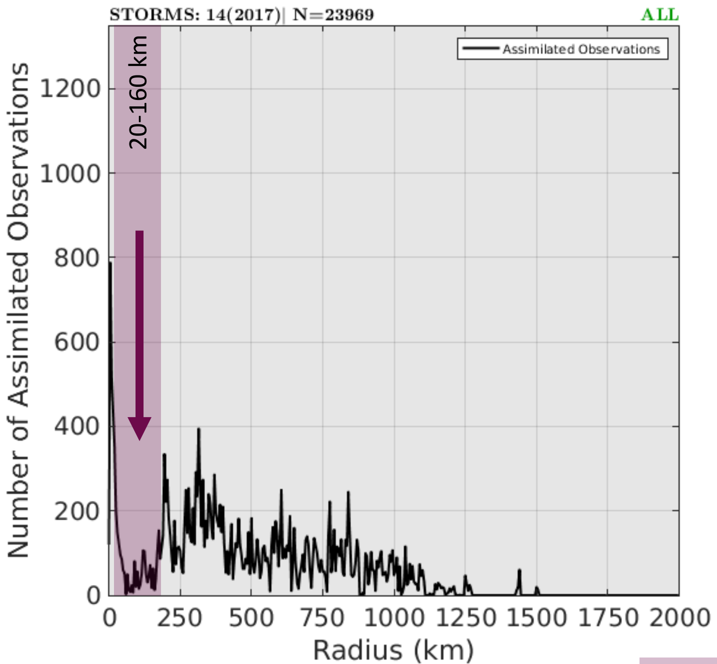
2019



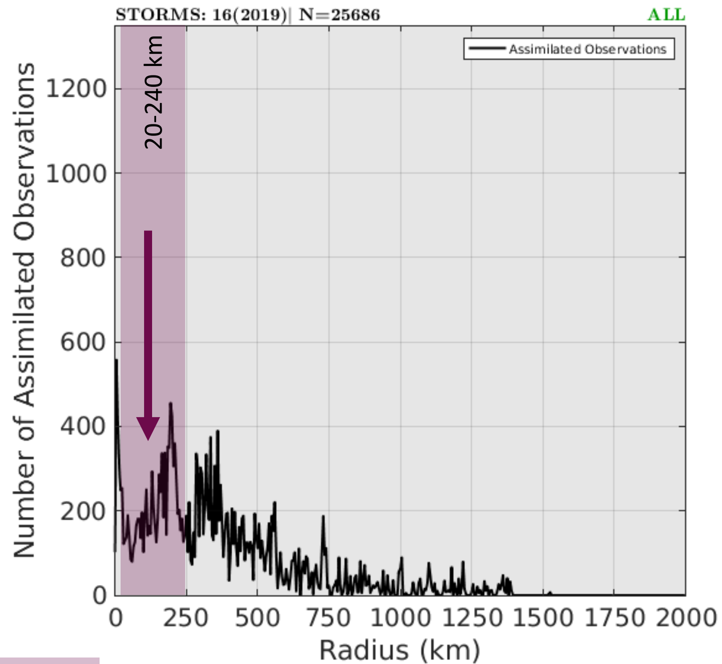
HURDAT2 R64 Observations

Dropsonde Observations Stratified By Year

2017



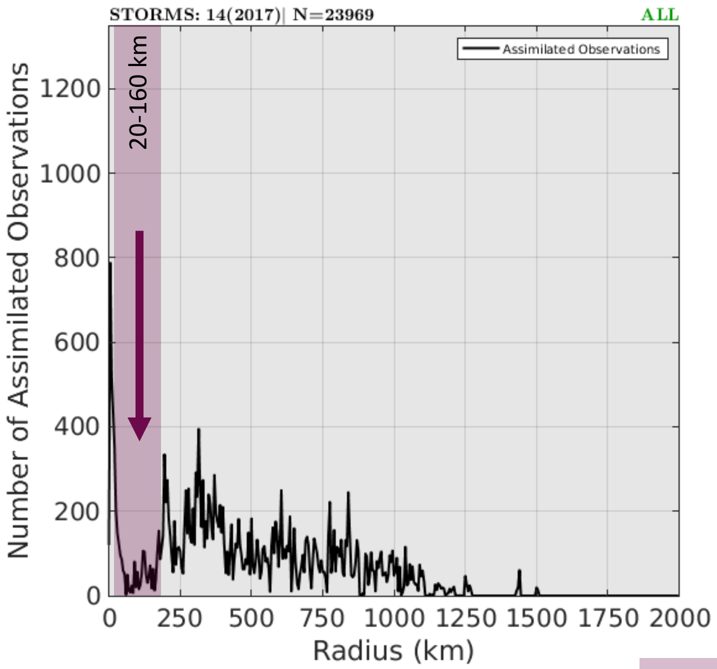
2019



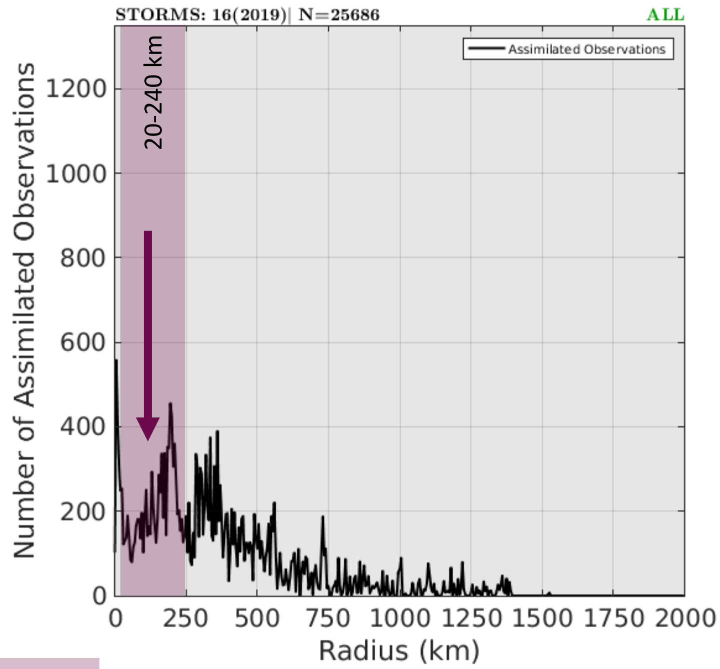
HURDAT2 R64 Observations

Dropsonde Observations Stratified By Year

2017



2019



HURDAT2 R64 Observations

When investigating the storms that contributed to the 2017 and 2019 error and looking at the radial dropsondes distributions, those storms that had very few dropsondes within the 60-160 km radial range showed more degradation at early lead times.

Conclusion

PROJECT PLAN

OBJECTIVE: a composite study that quantifies both the overall and radial impact of dropsondes from aircraft on TC forecasts of track, intensity, and structure over the 2017–2019 hurricane seasons using the basin-scale HWRF

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SETUP: 6 experiments (**ALL**, **NIC**, **NTG**, **TG**, **IC**, & **NO**) that vary where dropsondes are assimilated - each covers ~125 days over 3 years, has 498 cycles, and has 47 storms (22 with assimilated dropsondes)

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Results were shown for ALL & NO which cover 2017 and 2019.

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TRACK	WIND SPEED	R64
OVERALL Dropsondes improved track forecasts btw 72-120 h around 3-5%	**OVERALL** Dropsondes improved wind speed forecasts ≥48 h around 4-9%	**OVERALL** Dropsondes degraded R64 forecasts ≤18 h around 8-13%
STRATIFICATIONS REVEALED… • TS intensity storms drove track improvement • Cycles with dropsondes in the parent domain outperformed cycles without dropsondes in the parent domain	**STRATIFICATIONS REVEALED…** • Cycles from storms with dropsondes in 2019 drove wind speed improvement (~14% at nearly all lead times) • Dorian (2019) drove much of the wind speed improvement	**STRATIFICATIONS REVEALED…** • Cycles from storms with dropsondes in 2017 drove R64 degradation • Storms with few dropsondes in the observed R64 window had more degradation

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STAY TUNED FOR MORE RESULTS UPON THE COMPLETION OF 2018 AS WELL AS RESULTS FOR THE NTG (incl. ≥250), NIC (incl. ≥75 km), TG (incl. <250 km), AND IC (incl. <75 km) EXPERIMENTS!

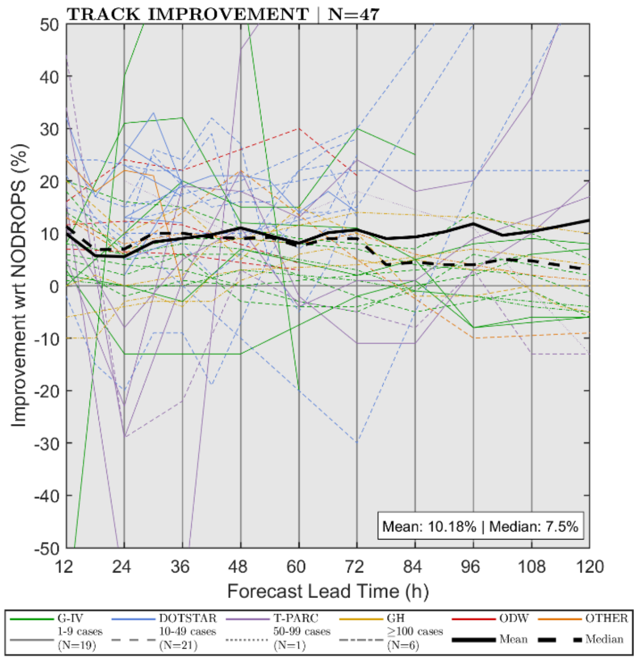
THANK YOU FOR LISTENING!

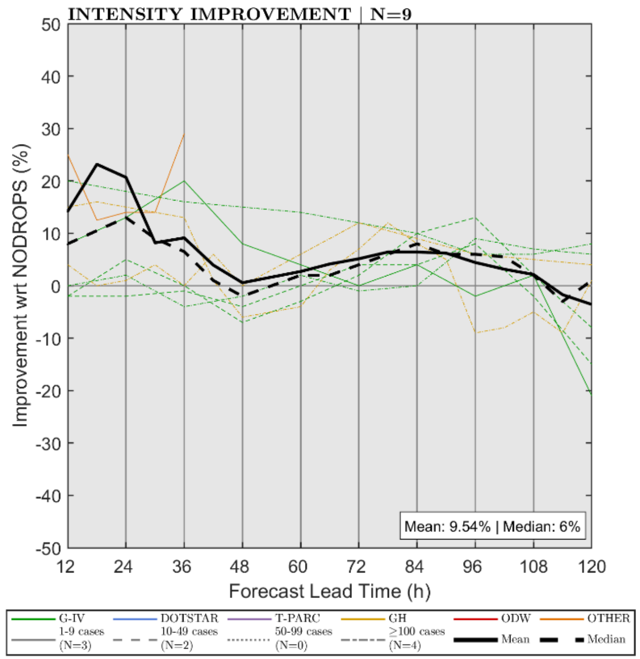
Dr. Sarah D. Ditchek
Email: sarah.d.ditchek@noaa.gov
Website: http://www.atmos.albany.edu/student/sditchek/

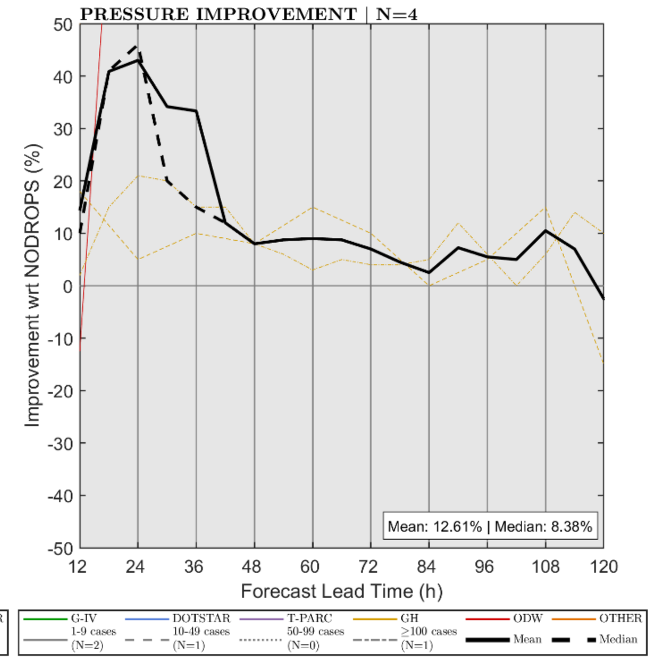
*10 experiments had unquantifiable improvement – qualitatively, all showed overall improvement due to dropsonde assimilation

Motivation

A total of 57 experiments across 30 papers ranging from 1992 – 2019 were identified that documented the impact of dropsondes on tropical cyclone forecasts, and improvement by forecast lead time was digitized. The percent improvement for 47* experiments are summarized below.







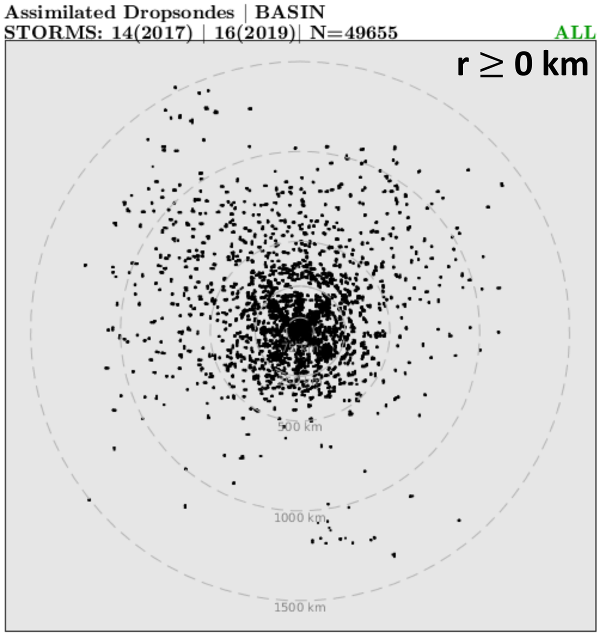
Only 6 experiments had ≥100 cases, with a mean (median) improvement of 2.85% (3.00%).

Very few studies quantified the impact of dropsondes on intensity and pressure. With many dropsondes being deployed with the purpose of identifying storm intensity, this was surprising.

Dropsonde Observations

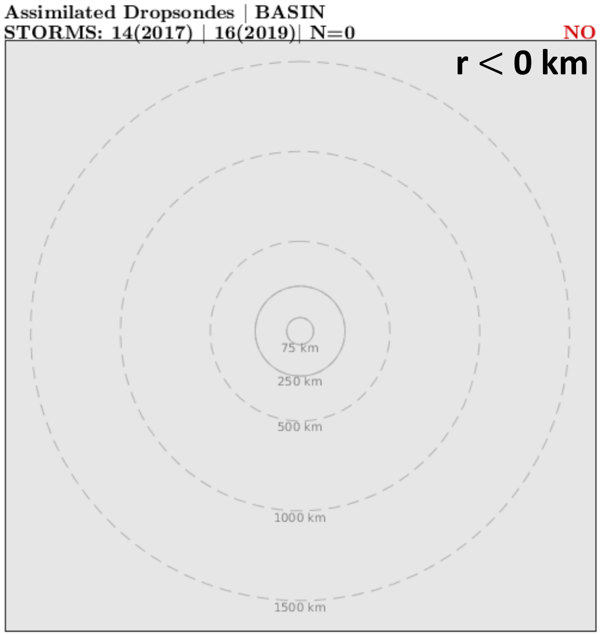
Given below are the storm-relative locations of assimilated dropsonde observations in the ALL & NO experiments.

ALL



N=49655

NO



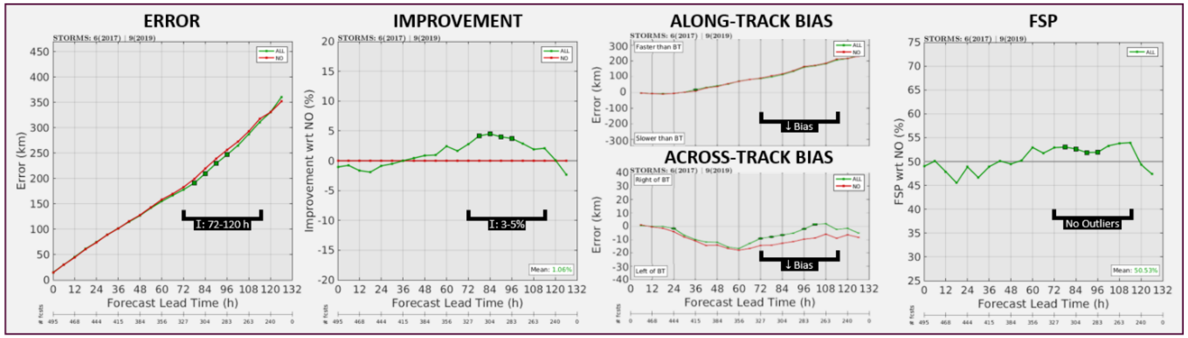
N=0

■ (●): 95% (90%) sig.

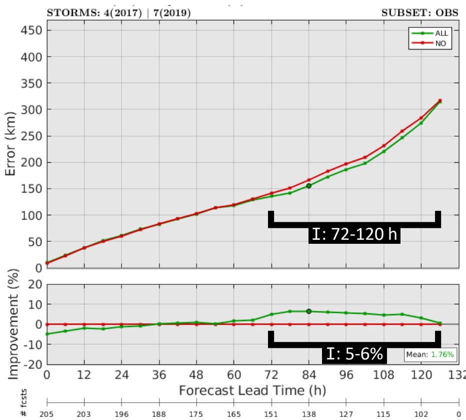
Stratification By Data Availability

Basin: AL | Verification: Consistent with NHC

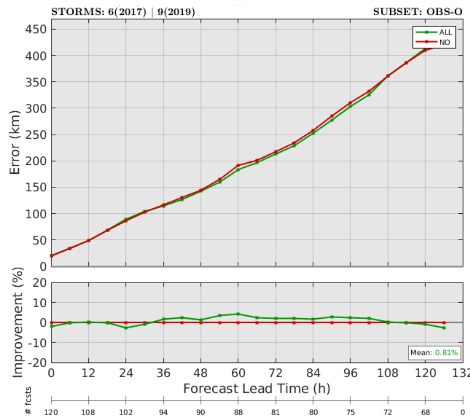
FULL SAMPLE



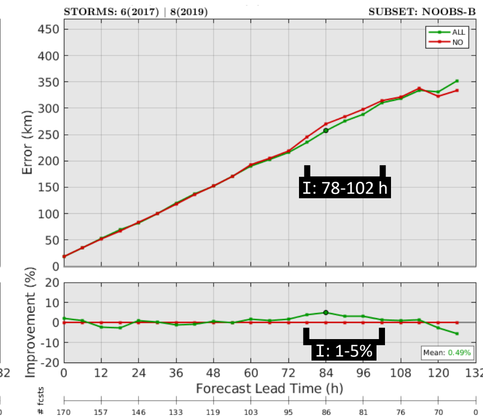
OBS



OBS-O



NOOBS-B



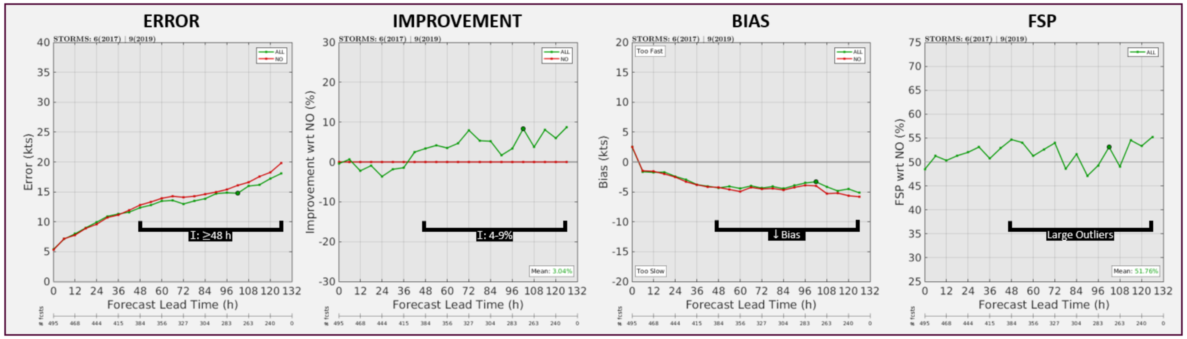
Cycles from storms with dropsondes (OBS) showed 5-6% improvement between 72-120 h.

■ (●): 95% (90%) sig.

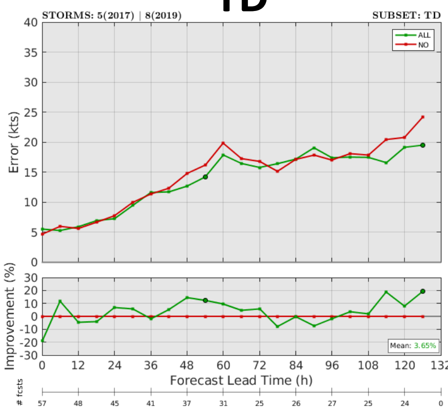
Stratification By Intensity

Basin: AL | Verification: Consistent with NHC

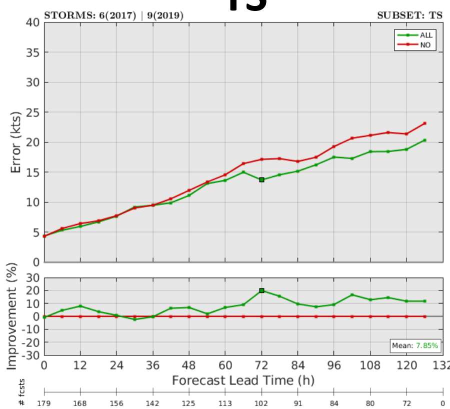
FULL SAMPLE



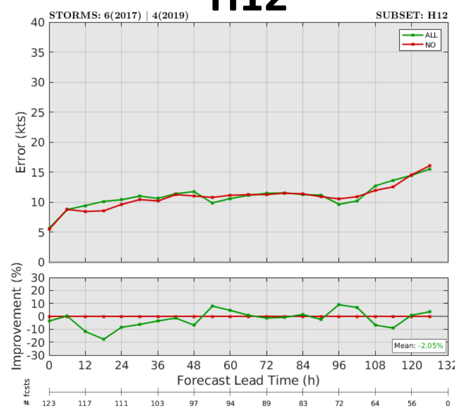
TD



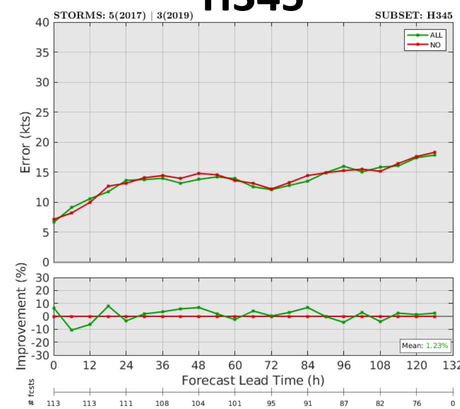
TS



H12



H345



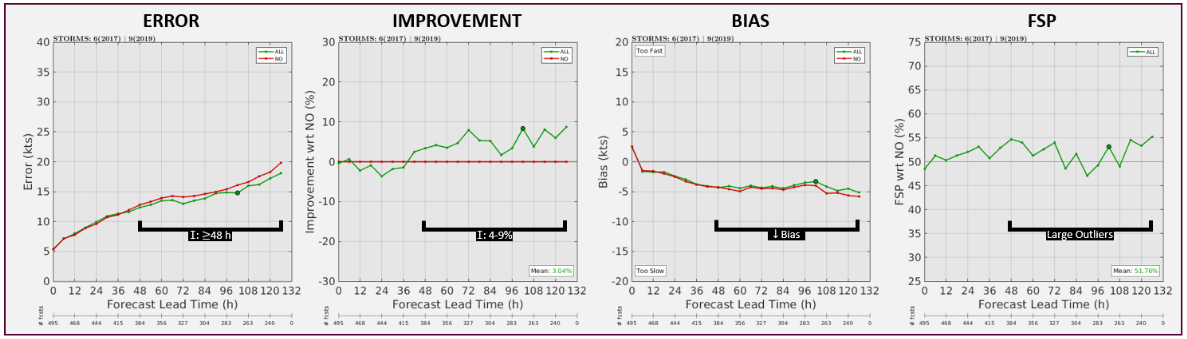
TS intensity storms drove wind speed improvement, but this improvement was mostly due to Dorian (2019).

■ (●): 95% (90%) sig.

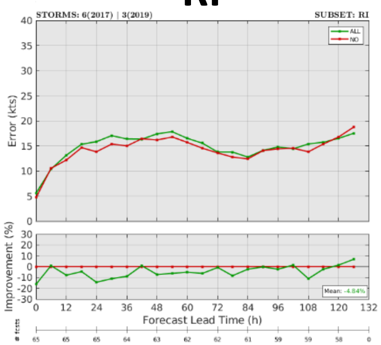
Stratification By Intensity Change

Basin: AL | **Verification:** Consistent with NHC

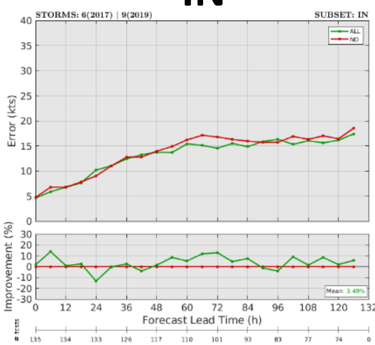
FULL SAMPLE



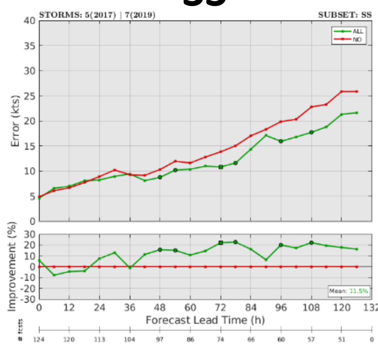
RI



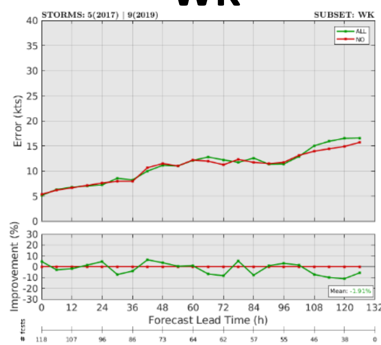
IN



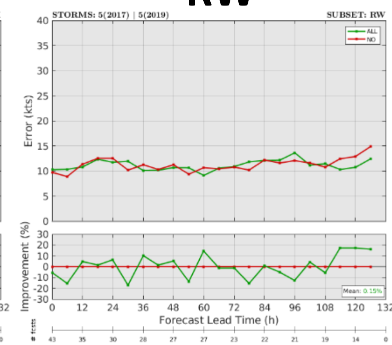
SS



WK



RW



For the BT of a storm, calculate running -6 h to +6 h intensity change to capture what type of intensity change the storm is currently undergoing

For cycles where at t=0 that value is…

$x \geq 15$ kt, : categorize as RI

$5 \leq x < 15$ kt: categorize as IN

$-5 < x < 5$ kt: categorize as SS

$-15 < x \leq -5$ kt: categorize as WK

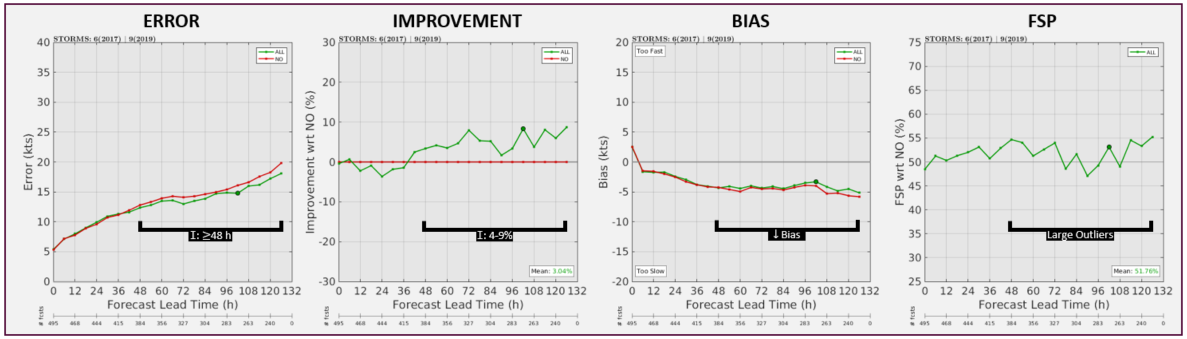
$x \leq -15$ kt: categorize as RW

■ (●): 95% (90%) sig.

Stratification By Year & Data Availability

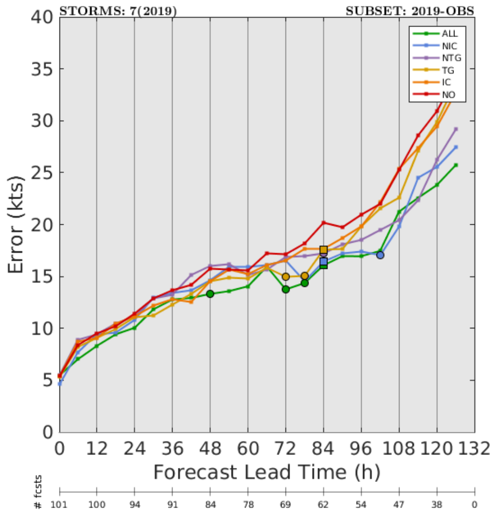
Basin: **AL** | **Verification:** **Consistent with NHC**

FULL SAMPLE



2019-OBS

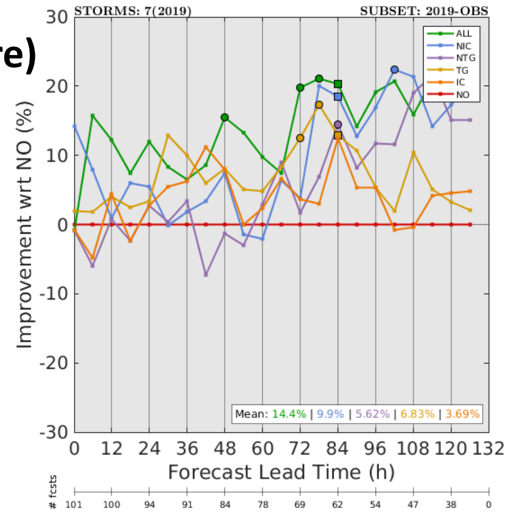
ERROR



PERFORMANCE RANKING

1) ALL (dropsondes everywhere)
2) NIC (deny <75 km)
3) NTG (deny <250 km)
4) TG (deny ≥250 km)
5) IC (deny ≥75 km)
6) NO (deny everywhere)

IMPROVEMENT



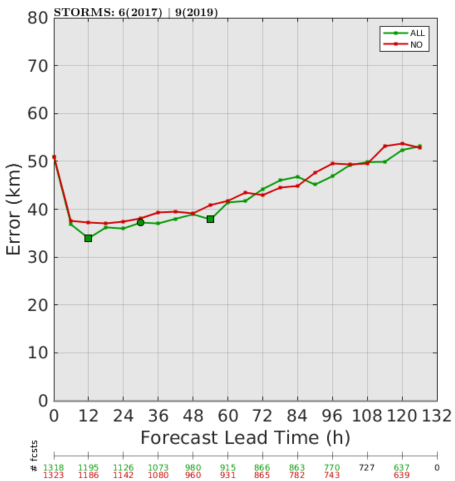
Overall, ALL performed the best. Between 24-78 h, removing synoptic dropsondes (TG) performed second best. After 78 h, having dropsondes ≥75 km is key (ALL, NIC, NTG), particularly ≥250 km (NTG).

■ (●): 95% (90%) sig.

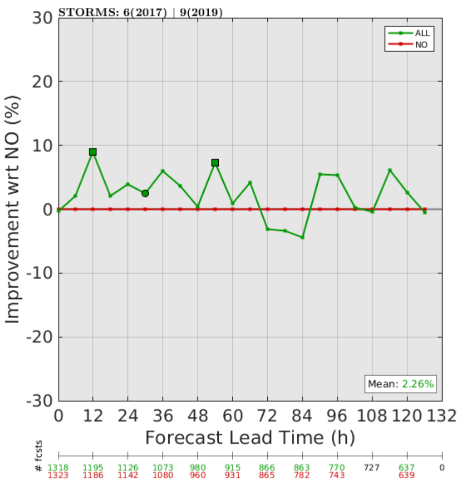
Full Sample

Basin: **AL** | **Verification:** **Consistent with NHC**

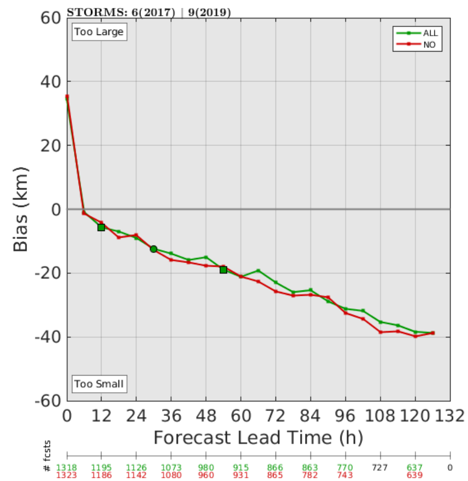
ERROR



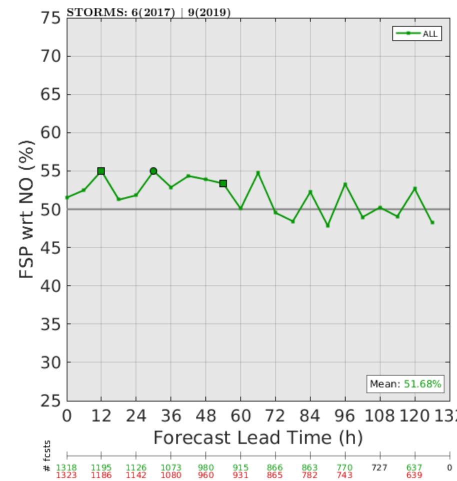
IMPROVEMENT



BIAS



FSP



OVERALL ASSESSMENT

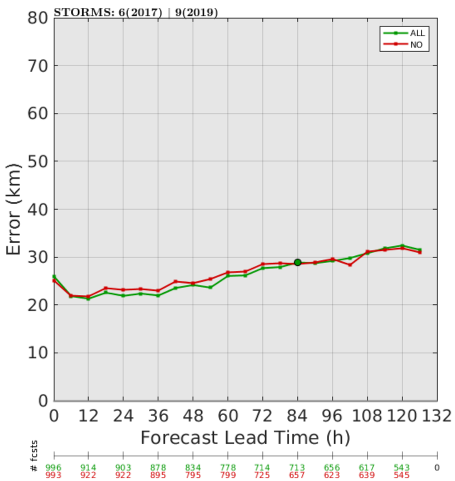
The inclusion of dropsondes improves R34 forecasts at nearly all lead times on average 2%, with many lead times above 5%. Additionally, the assimilation of dropsondes reduces the bias and the improvement found isn't driven by large outliers.

■ (●): 95% (90%) sig.

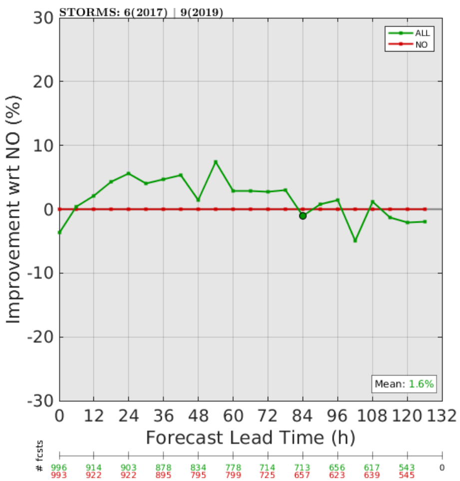
Full Sample

Basin: AL | **Verification:** Consistent with NHC

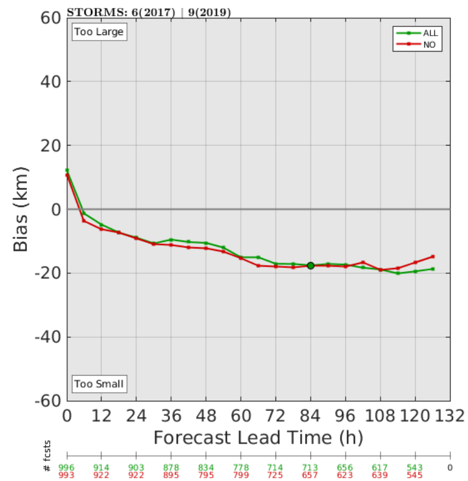
ERROR



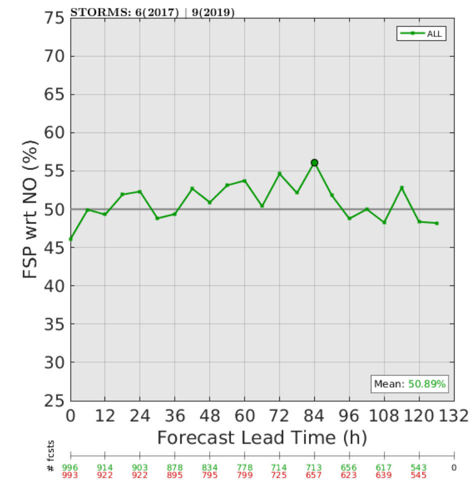
IMPROVEMENT



ALONG-TRACK BIAS



FSP



OVERALL ASSESSMENT

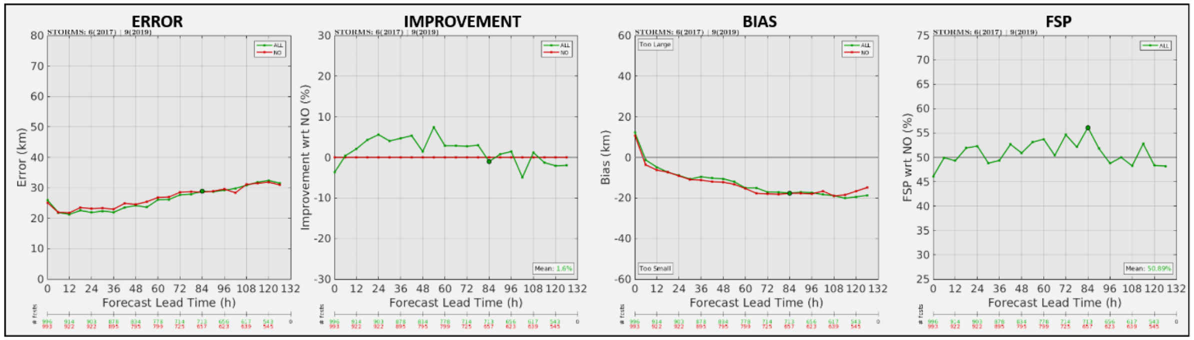
The inclusion of dropsondes improves R50 forecasts ≤78 h around 3-7%. Additionally, the assimilation of dropsondes reduces the bias and the improvement found is driven by large outliers.

■ (●): 95% (90%) sig.

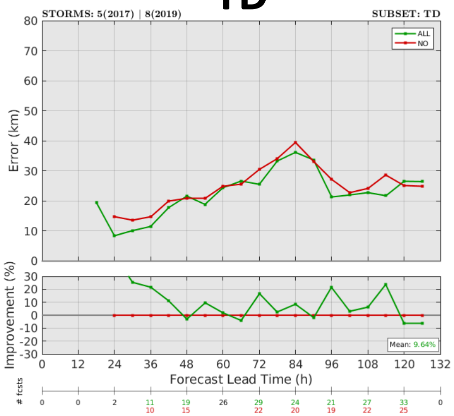
Stratification By Intensity

Basin: AL | **Verification:** Consistent with NHC

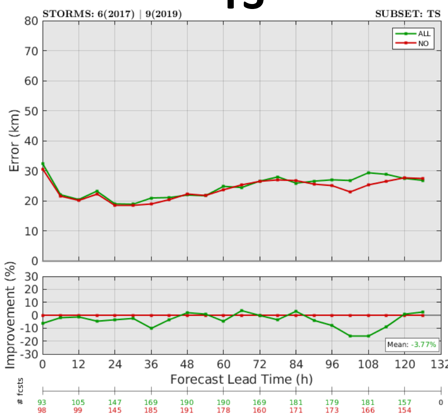
FULL SAMPLE



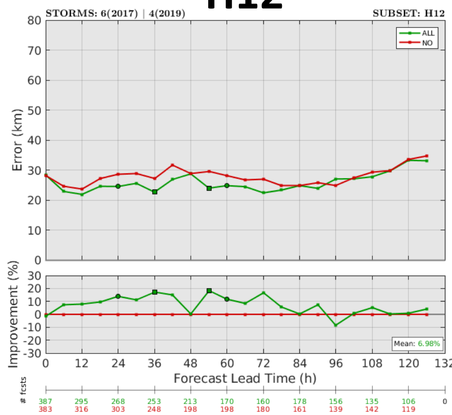
TD



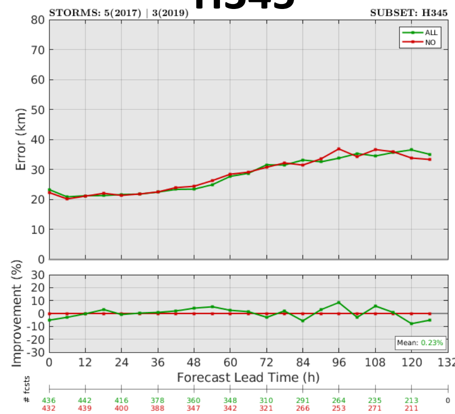
TS



H12



H345



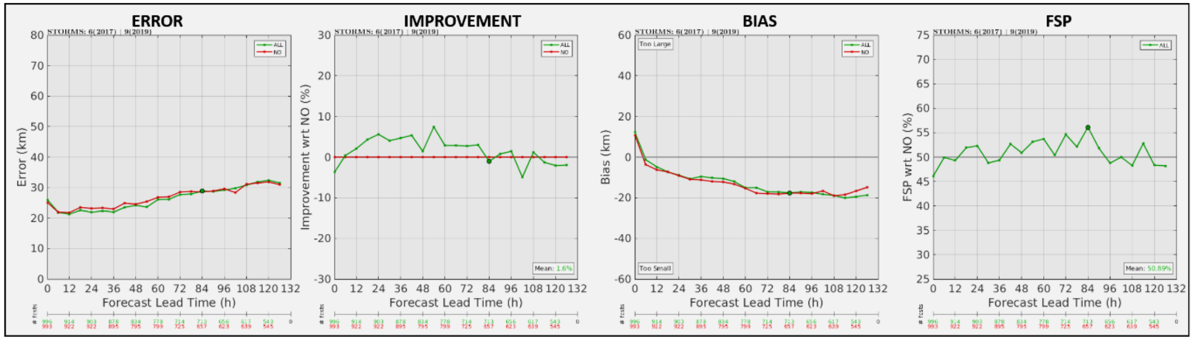
H12 intensity storms drove R50 improvement, with 10-20% R50 improvement ≤78 h.

■ (●): 95% (90%) sig.

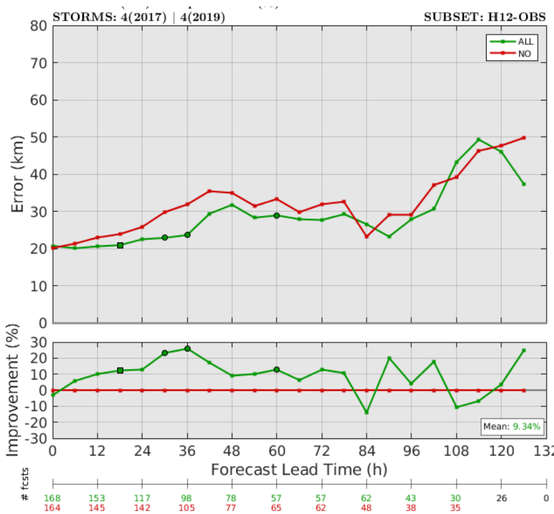
Stratification By H12 & Data Availability

Basin: AL | **Verification:** Consistent with NHC

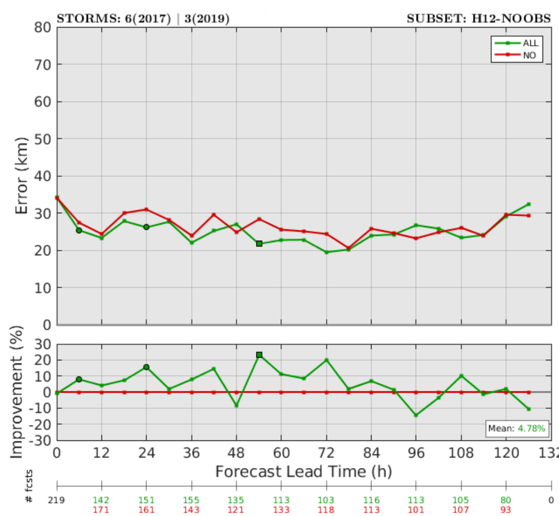
FULL SAMPLE



H12-OBS



H12-NOOBS



This indicates that cycles from H12 storms with dropsondes (H12-OBS) drove R50 improvement in the full sample.