(Image from Marvel's Guardians of the Galaxy Vol. 2)

GROOT* User's Guide

*GRaphics for OSEs & OSSEs on TCs

Created by Sarah D. Ditchek[1,2]

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If using this graphics package in publications or presentations, please see the last slide for acknowledgement wording.

Capabilities Overview

GROOT
(GRaphics for OSEs & OSSEs on TCs)

Hurricane Component: GROOT-H		Global Component: GROOT-G
Error Statistics individual storms, composites, various subsets (editverif.m, runverif.ksh)	Verification Capability	**Error Statistics** individual storms, composites, various subsets (editverif.m, runverif.ksh)
Assimilated Observations individual storms, storm-centered composites (editverif.m, runverif.ksh)	Verification Capability	**Assimilated Observations** individual storms, storm-centered composites (editverif.m, runverif.ksh)
GRB Graphics plan-view and azimuthally-averaged graphics for individual storms for each experiment and difference graphics between experiments (editgrb.m, rungrb.ksh)	GRB Capability	**GRB Graphics (FUTURE WORK)** plan-view and azimuthally-averaged graphics for individual storms for each experiment and difference graphics between experiments (editgrb.m, rungrb.ksh)
Retrieval Scripts all required files for error statistics, assimilated observations, and GRB graphics (retrievalscripts/)		**Retrieval Scripts (FUTURE WORK)** all required files for error statistics, assimilated observations, and GRB graphics (retrievalscripts/)

Why Use GROOT?

Benefits

Comprehensive

- results for both individual storms and composite studies are generated
- retrieval scripts to grab GROOT-required files from HPSS are provided
- capabilities are continuously being added

Project Flexibility

- user input is confined to a brief namelist
- any number of experiments can be compared (recommended maximum: 6)
- customization of colors and of baseline model available in the namelist
- it works with model output from HWRF, the basin-scale HWRF, and FV3GFS
- user can switch between GROOT-H and GROOT-G with ease – same way to run both components!

Uniformity

- uniform, publication-ready graphics are generated
- graphics generated are those that are often needed in OS(S)E studies that evaluate TC performance

WHAT WILL THIS USER'S GUIDE GO OVER?

Graphics types created by GROOT-H for experiments run with the basin-scale HWRF and HWRF, followed by step-by-step instructions of how to get and run the package. Again, all graphics shown will eventually be generated by GROOT-G unless otherwise indicated, but currently only error statistics and assimilated observations graphics are available for GROOT-G.

*For GROOT-G, for each experiment, place your atcf files for all cycles desired in 1 folder, named according to the experiment run.

High-Level Verification Capability Overview

NAMELIST OVERVIEW (*editverif.m – edit this*)

SECTION 1: Set directories of the package, where the graphics go, and model properties (4)
SECTION 2: Identify experiments and associated colors (4)
SECTION 3: Case Study Options (3)
SECTION 4: Error Graphics Options (4)
SECTION 5: Conventional Graphics Options (6)
SECTION 6: Satellite Graphics Options (6)

RUN OVERVIEW (*runverif.ksh – edit this)*

SECTION 1: Set Folders (4|5)
SECTION 2: Identify Experiments (3|4)
SECTION 3: Account Information (4|4)
SECTION 4: Date Range of Files (0|2)
(GROOT-H|GROOT-G*)

MAIN VERIFICATION SCRIPT OVERVIEW (*scripts/runverif.m – no need to edit)*

load namelist settings
for run the package
    for each individual storm *(each storm submitted as separate batch scripts so clock won't run out)*
        set up directories and naming conventions; find common cycles across experiments
        grabs and processes the bdeck
        plots the track of the storm
        runs assimilated obs capability script – conv: processes files and makes graphics *(namelist switch)*
        runs assimilated obs capability script – sat: processes files and makes graphics *(namelist switch)*
        runs error statistics capability script: processes files and makes graphics – full storm → NHC verification → subsets
    end
    for all storms combined - only if there is more than 1 storm in your sample! *(submitted as separate batch scripts)*
        identify how many basins are in the sample & get stratifications and consistent y-axes for each graphic
        run error statistics capability script: processes files and makes graphics – NHC verification → subsets
        runs assimilated obs capability script – conv: processes files and makes graphics
        runs assimilated obs capability script – sat: processes files and makes graphics
    end
end *(batch script cleans up files created and emails you when it's done – SUBMISSION_FINISHED.txt appears in your directory)*

High-Level GRB Capability Overview

NAMELIST OVERVIEW *(editgrb.m – edit this)*

SECTION 1: Choose storm, experiments, and associated colors (12)
SECTION 2: Set directories (3)
SECTION 3: Set switches (8)
SECTION 4: Choose variables (misc)

RUN OVERVIEW (*rungrb.ksh – edit this)*

SECTION 1: Account Information (4)

MAIN GRB SCRIPT OVERVIEW *(scripts/rungrb.m – no need to edit)*

for run the package *(submits various batch scripts to ensure the clock doesn't run out)*
- **set up directories and naming conventions; find common cycles across experiments**
- **grabs and processes the bdeck**
- **runs the HWRFDA component *(storm and synoptic grids; namelist switch)***
- **generates error statistics for later use *(no graphics are generated – this is all done in the verification capability)***
- **creates .mat files of chosen variables *(storm and/or synoptic grids; namelist switch)***
- **if selected in namelist, converts u/v to radial/tangential wind and windspeed *(storm and synoptic grids; namelist switch)***
- **if selected in namelist, converts absolute vorticity to relative vorticity *(storm and synoptic grids; namelist switch)***
- **creates storm-centered graphics and difference graphics *(storm and synoptic grids; namelist switch)***
- **creates shear graphics *(for synoptic grid, only; only if corresponding u/v files are generated)***
- **clean up .mat files to save space**

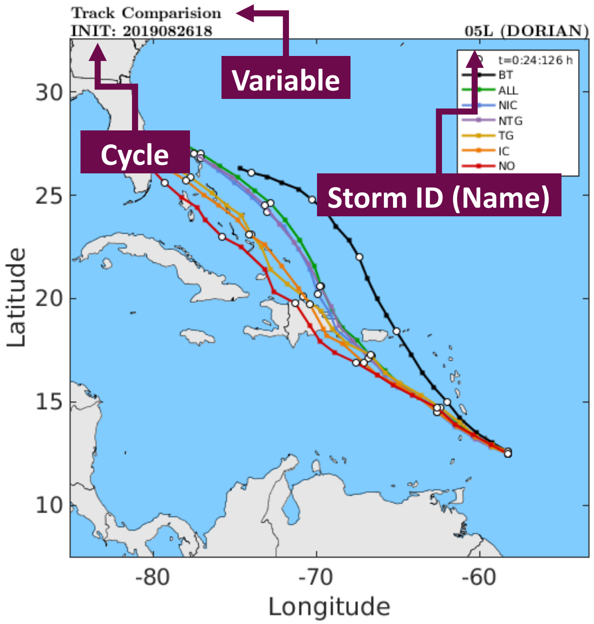
end

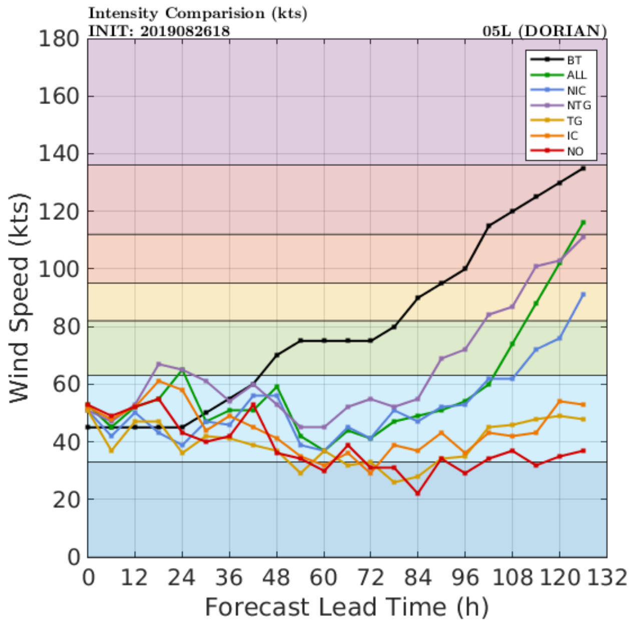
*Generation of these graphics can be turned off in the namelist by setting identgraphicsbycycle=0

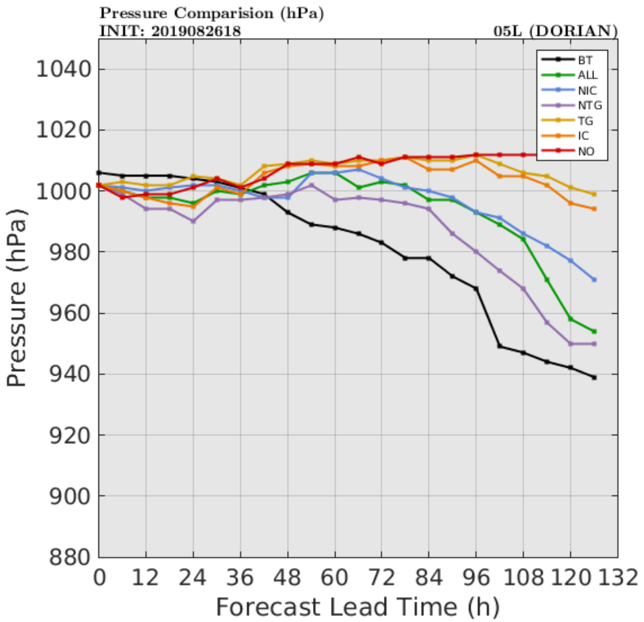
One Storm: Each Cycle | One Storm: All Cycles | Composite Graphics

Raw Value Graphics

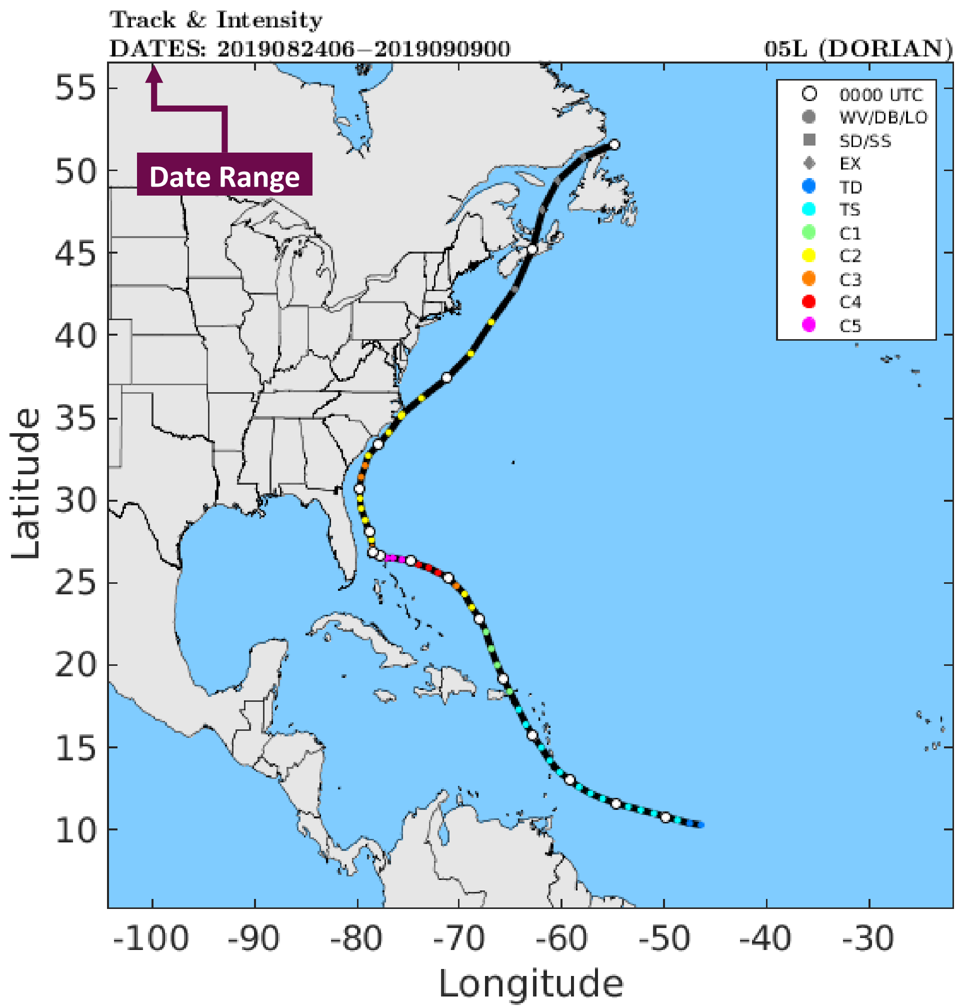
The below graphics as well as graphics for Along-Track Error, Across-Track Error, R34/R50/R64 (for each the NE, SE, SW, and NW quadrants as well as overall), PO, RO, and RMW are generated* for each cycle.





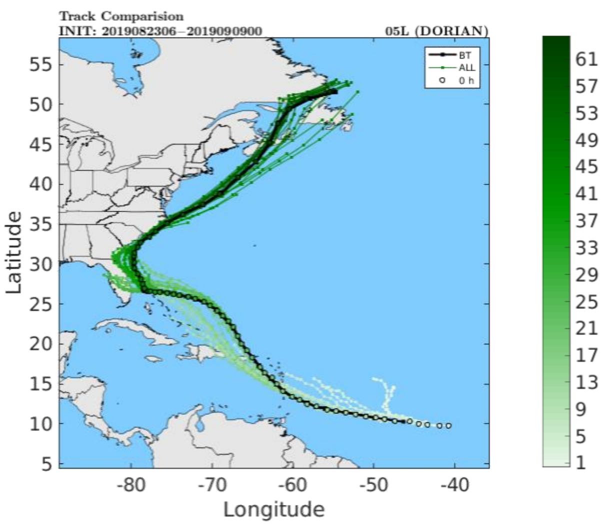


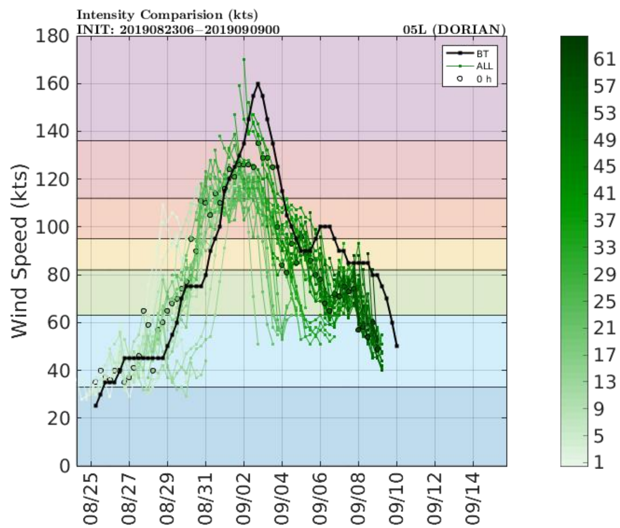
Best Track Graphic

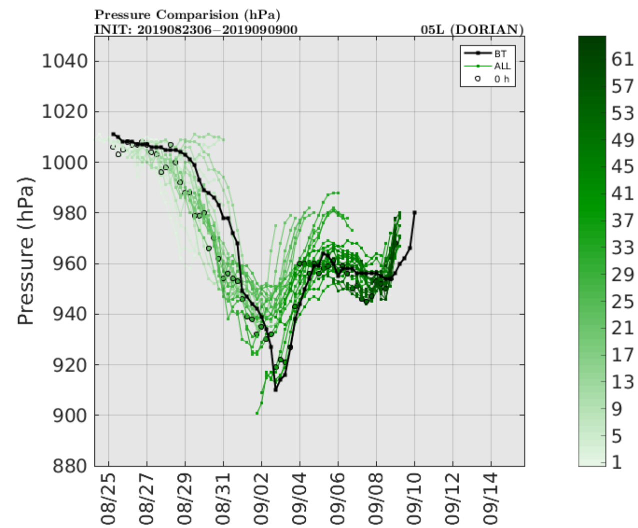


Raw Value Graphics

The below graphics as well as graphics for Along-Track Error, Across-Track Error, R34/R50/R64 (for each the NE, SE, SW, and NW quadrants), PO, RO, and RMW are generated for each experiment.







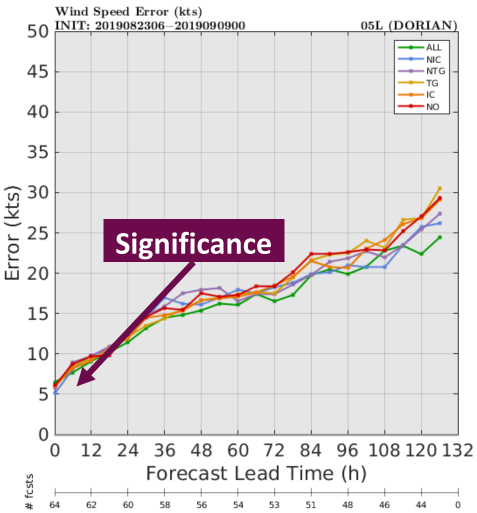
*Since these fields are “bias” fields, only E and I are calculated, as B would be redundant.

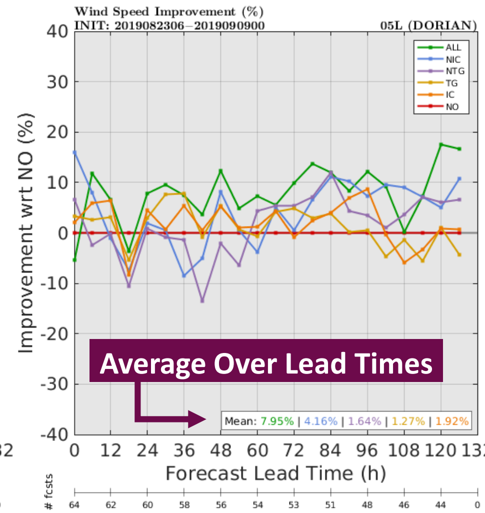
One Storm: Each Cycle | **One Storm: All Cycles** | Composite Graphics

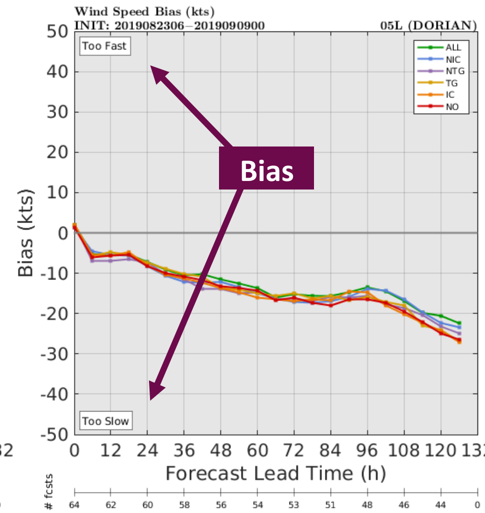
Errors, Improvement, Bias, & FSP

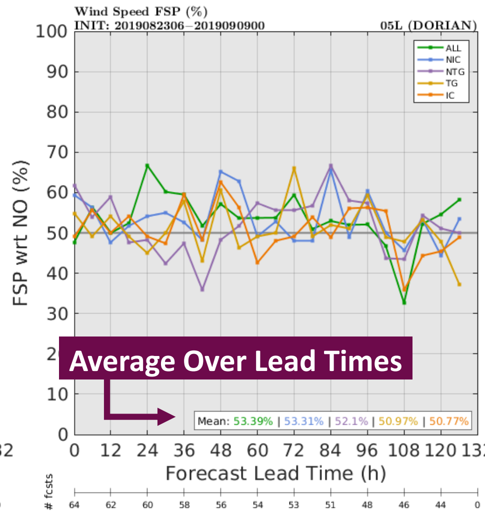
By Forecast Lead Time

The below graphics are generated for Track, Along-Track Error*, Across-Track Error*, Wind Speed, Pressure, R34/R50/R64 (for each the NE, SE, SW, and NW quadrants as well as overall), PO, RO, and RMW.









Error (E) is defined as the absolute value of the difference between the forecast and best track at the forecast verifying time.

$$\mathrm{E} = \mathrm{abs}(\mathrm{exp}_{t=\mathrm{BT}_{t=\mathrm{verif}}} - \mathrm{BT}_{t=\mathrm{verif}})$$

Improvement (I), compares how much better (or worse) an experiment performed over a baseline experiment.

$$\mathrm{I} = 100 * \left(1 - \frac{\overline{\mathrm{exp}}}{\overline{\mathrm{baseline}}}\right)$$

Bias (B) is defined as the difference between the forecast and best track at the forecast verifying time.

$$\mathrm{B} = \mathrm{exp}_{t=\mathrm{BT}_{t=\mathrm{verif}}} - \mathrm{BT}_{t=\mathrm{verif}}$$

Frequency of Superior Performance (FSP) indicates how often an experiment performed better over a baseline experiment.

$$\mathrm{FSP}_{\mathrm{exp}_{t=\mathrm{fhr}}} = 100 * \frac{\sum_{n=1}^{\# fcsts} \begin{cases} 1, & \text{if } \mathrm{exp_E} < \mathrm{baseline_E} \\ .5, & \text{if } \mathrm{exp_E} = \mathrm{baseline_E} \\ 0, & \text{if } \mathrm{exp_E} > \mathrm{baseline_E} \end{cases}}{\# fcsts}$$

■ : 95% sig. | ● : 90% sig. | Paired t-test w/ serial correlation

Also included is a combined error/improvement graphic!

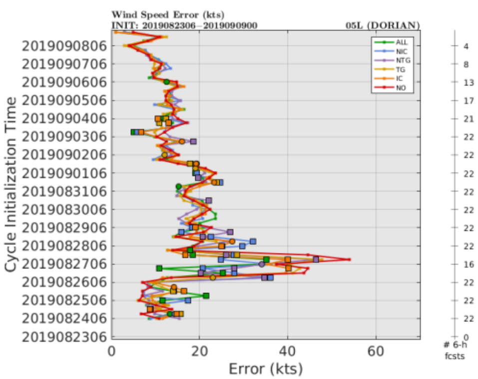
*Since these fields are "bias" fields, only E and I are calculated, as B would be redundant.

One Storm: Each Cycle | **One Storm: All Cycles** | Composite Graphics

Errors, Improvement, Bias, & FSP

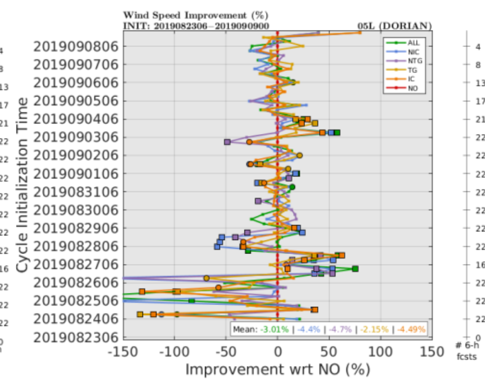
By Cycle

The below graphics are generated for Track, Along-Track Error*, Across-Track Error*, Wind Speed, Pressure, R34/R50/R64 (for each the NE, SE, SW, and NW quadrants as well as overall), PO, RO, and RMW.



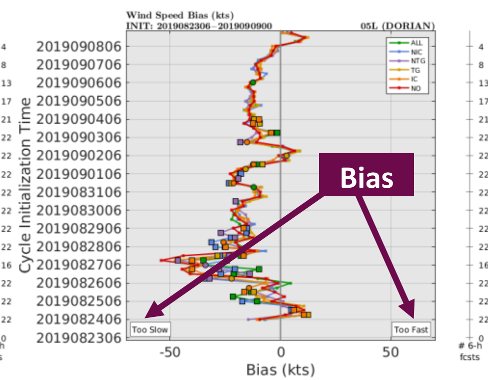
Error (E) is defined as the absolute value of the difference between the forecast and best track at the forecast verifying time.

$$E = \mathrm{abs}(\mathrm{exp}_{t=\mathrm{BT}_{t=\mathrm{verif}}} - \mathrm{BT}_{t=\mathrm{verif}})$$



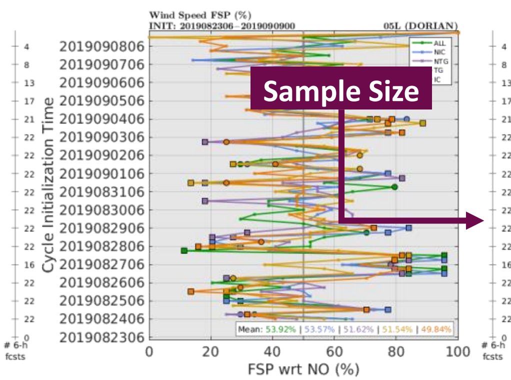
Improvement (I), compares how much better (or worse) an experiment performed over a baseline experiment.

$$I = 100 * \left(1 - \frac{\overline{\mathrm{exp}}}{\overline{\mathrm{baseline}}}\right)$$



Bias (B) is defined as the difference between the forecast and best track at the forecast verifying time.

$$B = \mathrm{exp}_{t=\mathrm{BT}_{t=\mathrm{verif}}} - \mathrm{BT}_{t=\mathrm{verif}}$$



Frequency of Superior Performance (FSP) indicates how often an experiment performed better over a baseline experiment.

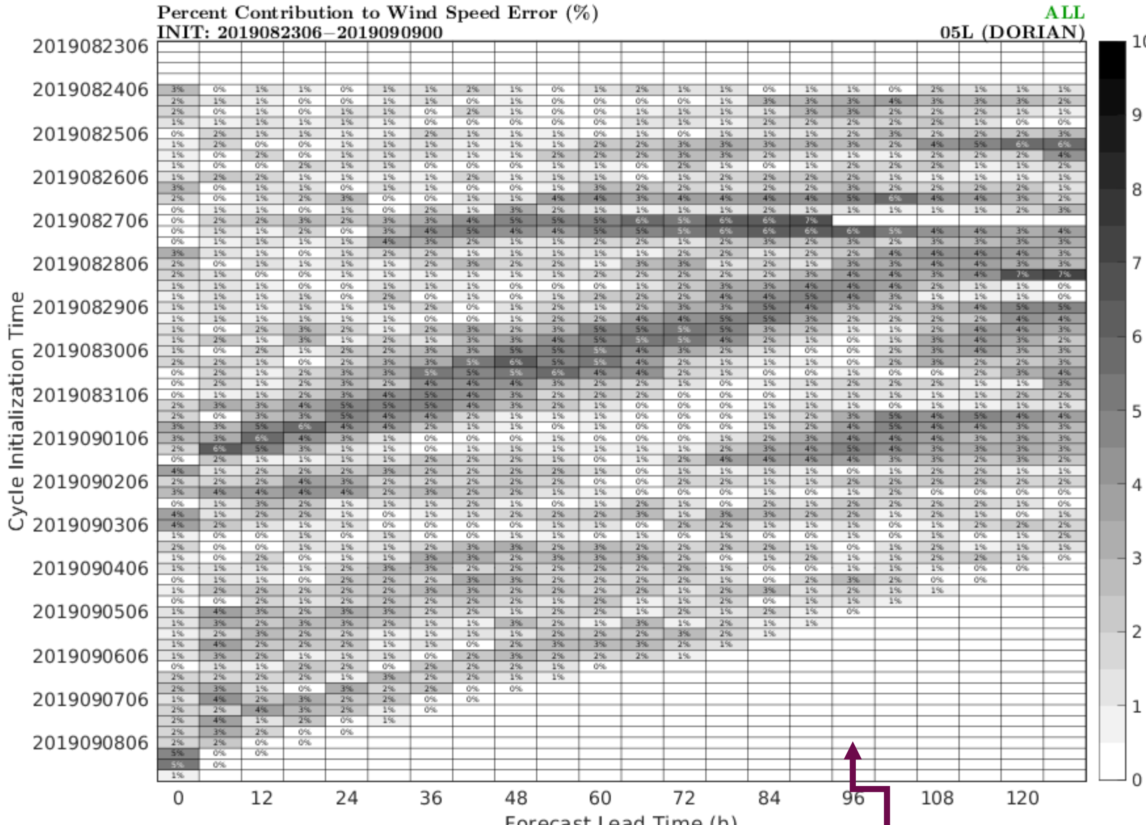
$$\mathrm{FSP}_{\mathrm{exp}_{t=\mathrm{fhr}}} = 100 * \frac{\sum_{n=1}^{\#\,fcsts} \begin{cases} 1, & \text{if } \mathrm{exp}_E < \mathrm{baseline}_E \\ .5, & \text{if } \mathrm{exp}_E = \mathrm{baseline}_E \\ 0, & \text{if } \mathrm{exp}_E > \mathrm{baseline}_E \end{cases}}{\#\,fcsts}$$

■ : 95% sig. | ● : 90% sig. | Paired t-test w/ serial correlation

Percent Contribution to Error

By Forecast Lead Time

The below graphic is generated for each experiment and variable so the user can gauge each cycle's contribution to the errors and, therefore, which cycles might be dominating the sample.

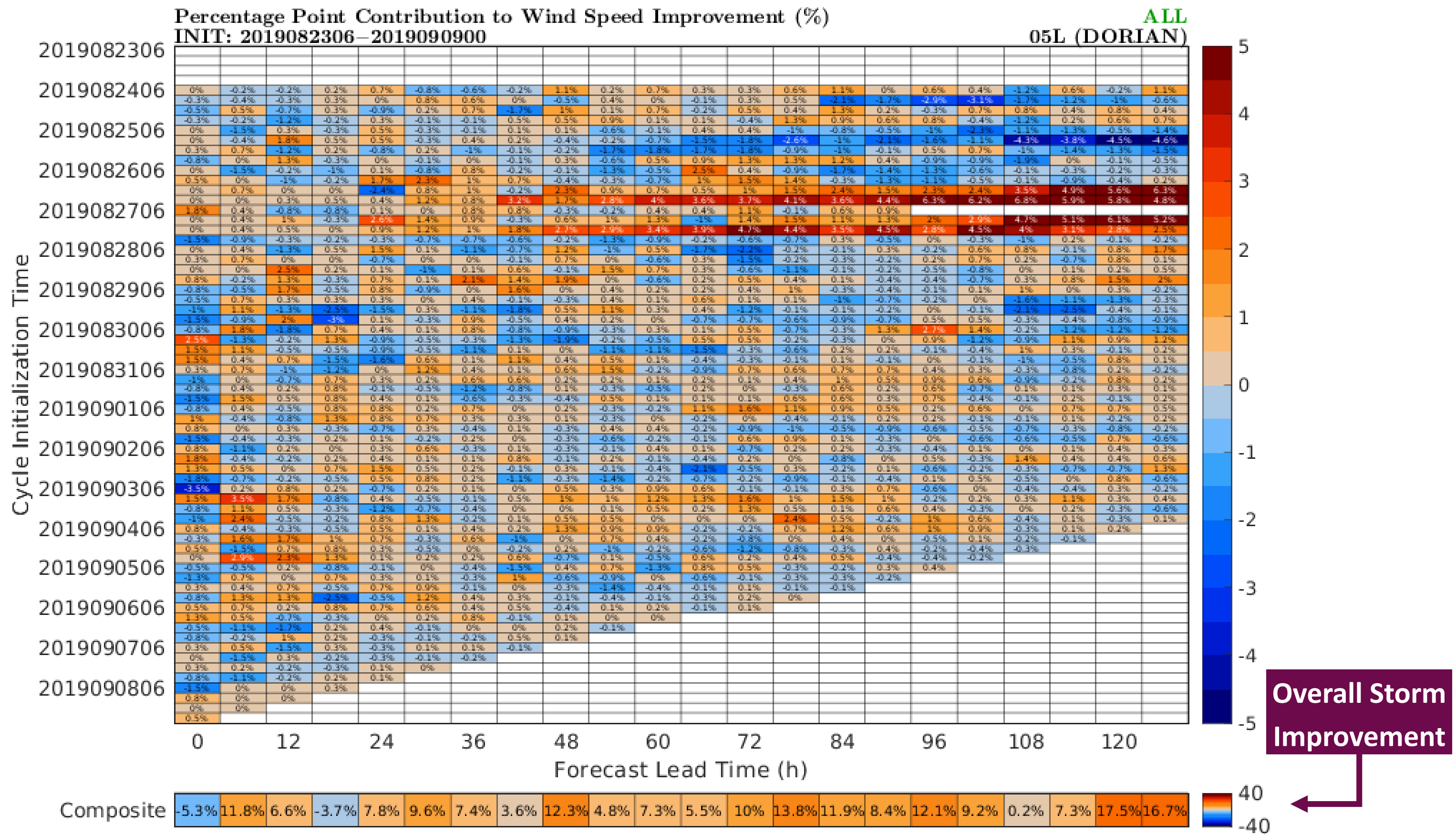


Rounded to the nearest integer – while most columns add up to 100%, some will add up to 100 ±1-5% .

Relative Contribution to Improvement

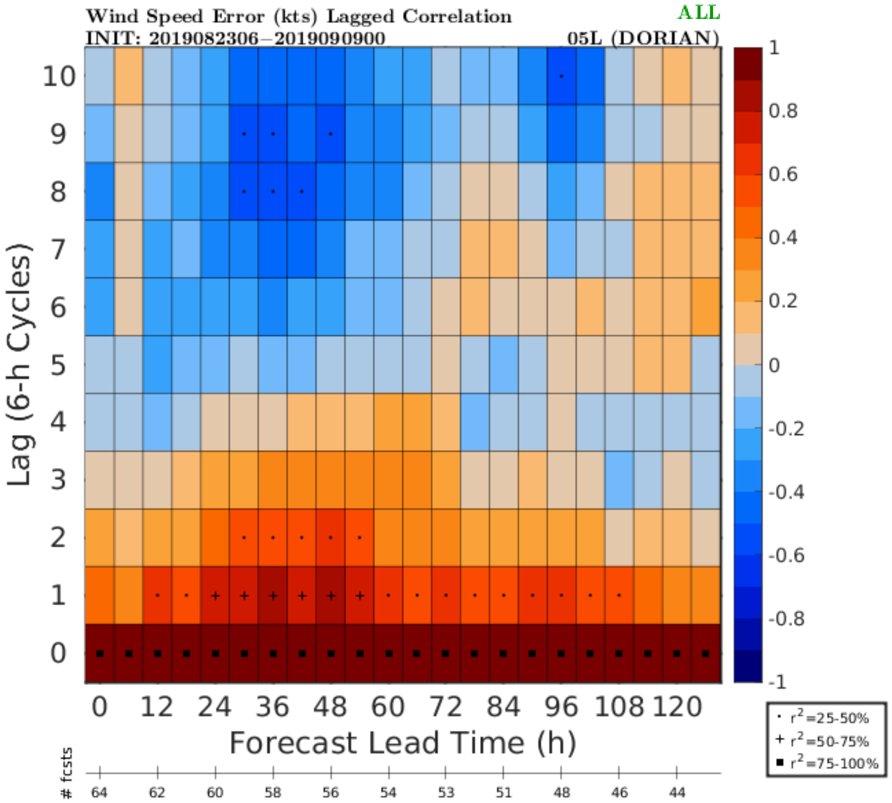
By Forecast Lead Time

The below graphic is generated for each experiment and variable so the user can gauge each cycle's contribution to the improvement and, therefore, which cycles might be dominating the sample.



Lagged Correlation

The below graphic is generated for each experiment and variable so the user can gauge lagged correlation in the full sample.



Lagged correlation of a given cycle to subsequent cycles at each forecast hour.

One Storm: Each Cycle | **One Storm: All Cycles** | Composite Graphics

Scorecard Graphic

The below graphic is generated for each experiment to give an overall snapshot of the model performance.

Credit: Idea & Base Code by Dr. Peter Marinescu

Subsets Currently Available

Consistent with NHC Verification

#	SUBSET	DEFINITION
0	NONE	Perform no subsets other than NHC verification
1-2	OBS | NOOBS	keeps only the cycles where the obs in question (was | was not) assimilated in a storm
3-4	RECON | PRERECON	keeps (from | before) the 1st cycle where the obs in question was assimilated to the (end | beginning) of the storm
5-8	TD | TS | H12 | H345	cycles with best track intensity of (TD | TS | H12 | H345) at t=0
9-13	RI | IN | SS | WK | RW	For the best track of a storm, calculate the running ± 6 h intensity change to capture what type of intensity change the storm is currently undergoing. Then, for cycles t=0, categorize as follows: (RI: $x \geq 15$ kt | IN: $5 \leq x < 15$ kt | SS: $-5 < x < 5$ kt | WK: $-15 < x \leq -5$ kt | RW: $x \leq -15$ kt)
14-16	LOW | MOD | HIGH	cycles with SHIPS shear* of (LOW | MOD | HIGH) at t=0
17-18	N30 | S30	cycles with best track latitude (≥30 N | <30 N) at t=0
19	CUSTOM	you can input a list of cycles for your own custom subset in the namelist

NOTE: #1-4 are run, and #5-8, #14-16, & #17-18 are further subset into OBS and NOOBS *only if* identconv=1 or identsatobs=1 in the namelist which lets the package know that you retrieved the required files and are running the assimilated obs component of the package.

GROOT-G

- **An additional subset called OBS-G is included that includes cycles where the obs in question was assimilated anywhere in the global domain**
- **Other than OBS-G, any OBS-related subset considers only the near-storm environment (R<2000 km)**

* Shear: 850-200 hPa mag (kt) | vortex removed | averaged 0-500 km relative to 850 hPa center

Verification: Consistent with NHC

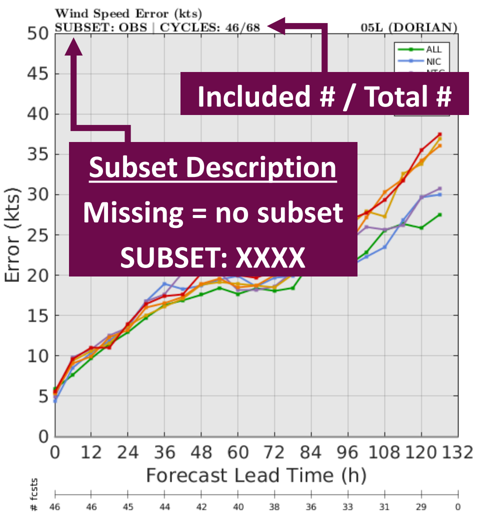
*Since these fields are "bias" fields, only E and I are calculated, as B would be redundant.

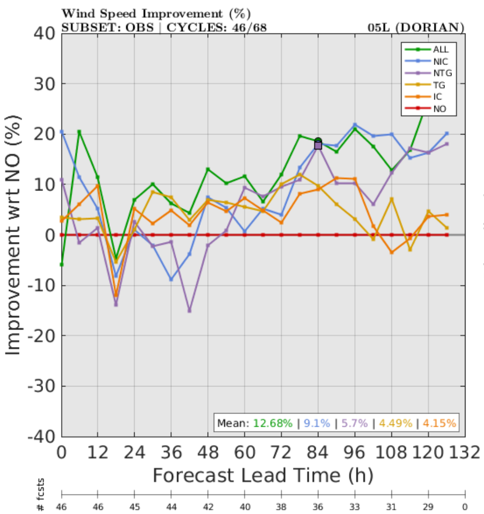
One Storm: Each Cycle | **One Storm: All Cycles** | Composite Graphics

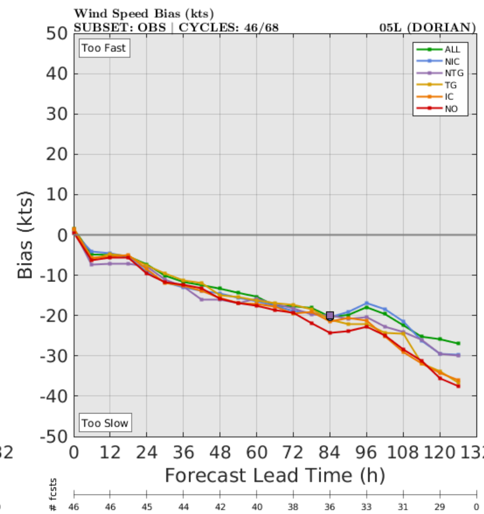
Subsets of Error, Improvement, Bias, & FSP

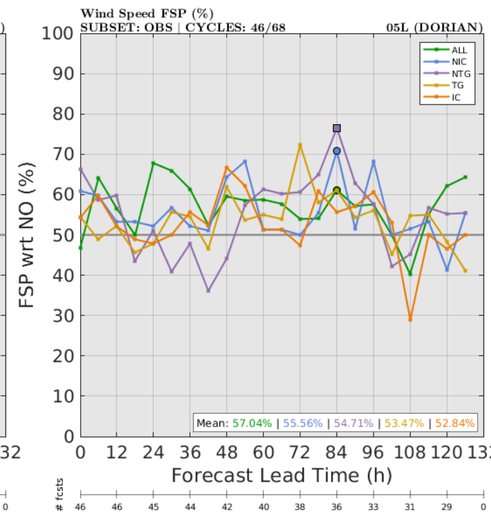
By Forecast Lead Time

The below graphics are generated for Track, Along-Track Error*, Across-Track Error*, Wind Speed, Pressure, R34/R50/R64 (for each the NE, SE, SW, and NW quadrants as well as overall), PO, RO, and RMW.









Error (E) is defined as the absolute value of the difference between the forecast and best track at the forecast verifying time.

$$\mathrm{E} = \mathrm{abs}(\mathrm{exp}_{\mathrm{t=BT}_{\mathrm{t=verif}}} - \mathrm{BT}_{\mathrm{t=verif}})$$

Improvement (I), compares how much better (or worse) an experiment performed over a baseline experiment.

$$\mathrm{I} = 100 * (1 - \frac{\overline{\mathrm{exp}}}{\overline{\mathrm{baseline}}})$$

Bias (B) is defined as the difference between the forecast and best track at the forecast verifying time.

$$\mathrm{B} = \mathrm{exp}_{\mathrm{t=BT}_{\mathrm{t=verif}}} - \mathrm{BT}_{\mathrm{t=verif}}$$

Frequency of Superior Performance (FSP) indicates how often an experiment performed better over a baseline experiment.

$$\mathrm{FSP}_{\mathrm{exp}_{\mathrm{t=fhr}}} = 100 * \frac{\sum_{n=1}^{\# fcsts} \begin{cases} 1, & \text{if } \mathrm{exp_E} < \mathrm{baseline_E} \\ .5, & \text{if } \mathrm{exp_E} = \mathrm{baseline_E} \\ 0, & \text{if } \mathrm{exp_E} > \mathrm{baseline_E} \end{cases}}{\# fcsts}$$

■: 95% sig. | ●: 90% sig. | Paired t-test w/ serial correlation

Also included is a combined error/improvement graphic!

Verification: Consistent with NHC

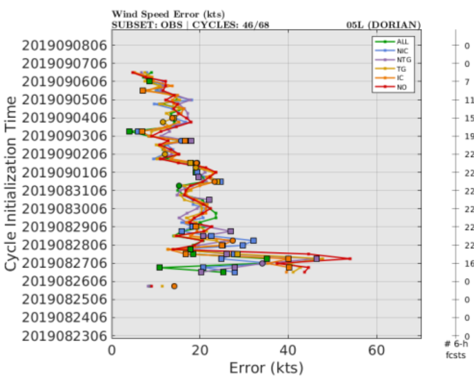
*Since these fields are “bias” fields, only E and I are calculated, as B would be redundant.

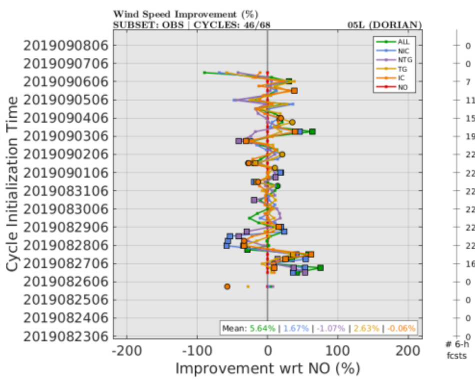
One Storm: Each Cycle | **One Storm: All Cycles** | Composite Graphics

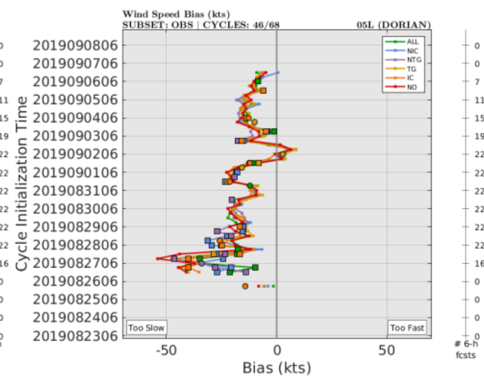
Subsets of Error, Improvement, Bias, & FSP

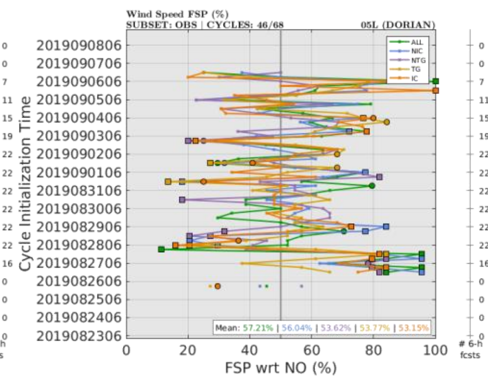
By Cycle

The below graphics are generated for Track, Along-Track Error*, Across-Track Error*, Wind Speed, Pressure, R34/R50/R64 (for each the NE, SE, SW, and NW quadrants as well as overall), PO, RO, and RMW.









Error (E) is defined as the absolute value of the difference between the forecast and best track at the forecast verifying time.

$$E = \mathrm{abs}(\mathrm{exp}_{t=\mathrm{BT}_{t=\mathrm{verif}}} - \mathrm{BT}_{t=\mathrm{verif}})$$

Improvement (I), compares how much better (or worse) an experiment performed over a baseline experiment.

$$I = 100 * \left(1 - \frac{\overline{\mathrm{exp}}}{\overline{\mathrm{baseline}}}\right)$$

Bias (B) is defined as the difference between the forecast and best track at the forecast verifying time.

$$B = \mathrm{exp}_{t=\mathrm{BT}_{t=\mathrm{verif}}} - \mathrm{BT}_{t=\mathrm{verif}}$$

Frequency of Superior Performance (FSP) indicates how often an experiment performed better over a baseline experiment.

$$\mathrm{FSP}_{\mathrm{exp}_{t=\mathrm{fhr}}} = 100 * \frac{\sum_{n=1}^{\#\,fcsts} \begin{cases} 1, & \text{if } \mathrm{exp}_E < \mathrm{baseline}_E \\ .5, & \text{if } \mathrm{exp}_E = \mathrm{baseline}_E \\ 0, & \text{if } \mathrm{exp}_E > \mathrm{baseline}_E \end{cases}}{\#\,fcsts}$$

■ : 95% sig. | ● : 90% sig. | Paired t-test w/ serial correlation

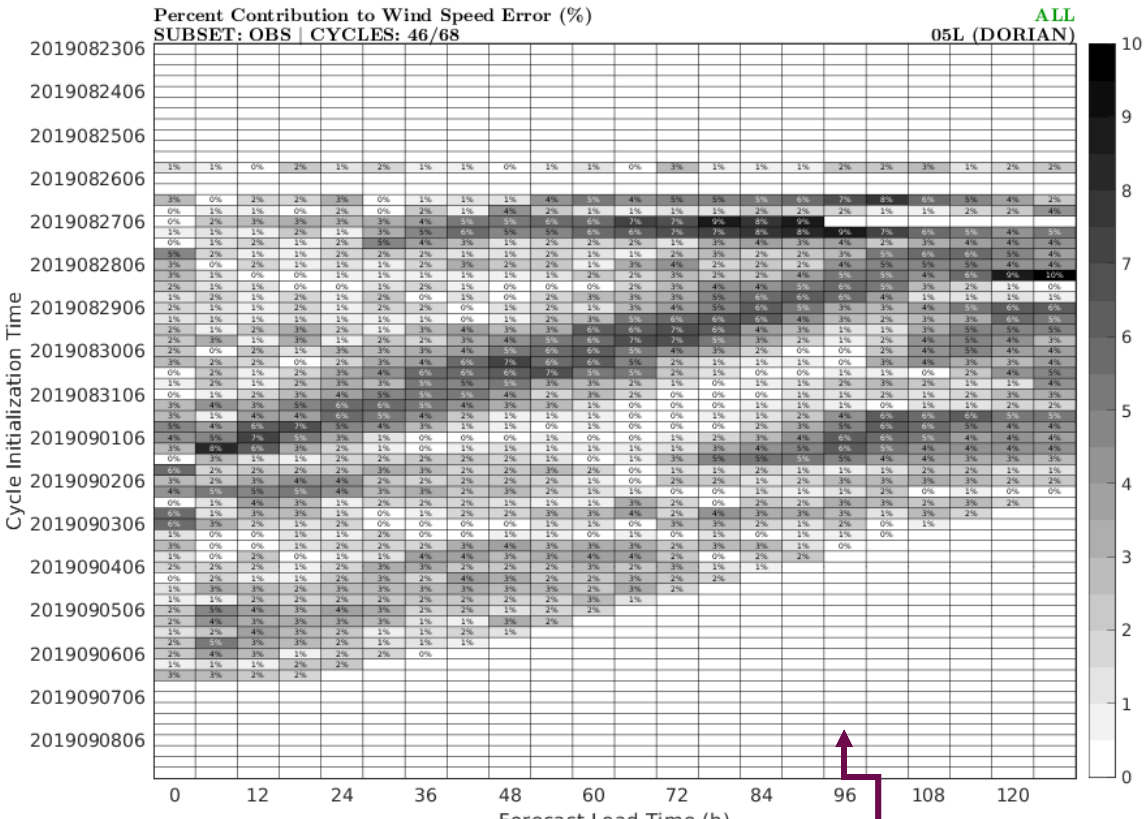
Verification: Consistent with NHC

One Storm: Each Cycle | **One Storm: All Cycles** | Composite Graphics

Percent Contribution to Error

By Forecast Lead Time

The below graphic is generated for each experiment, subset, and variable so the user can gauge each cycle's contribution to the errors and, therefore, which cycles might be dominating the sample.



Rounded to the nearest integer – while most columns add up to 100%, some will add up to 100 $\pm$1-5% .

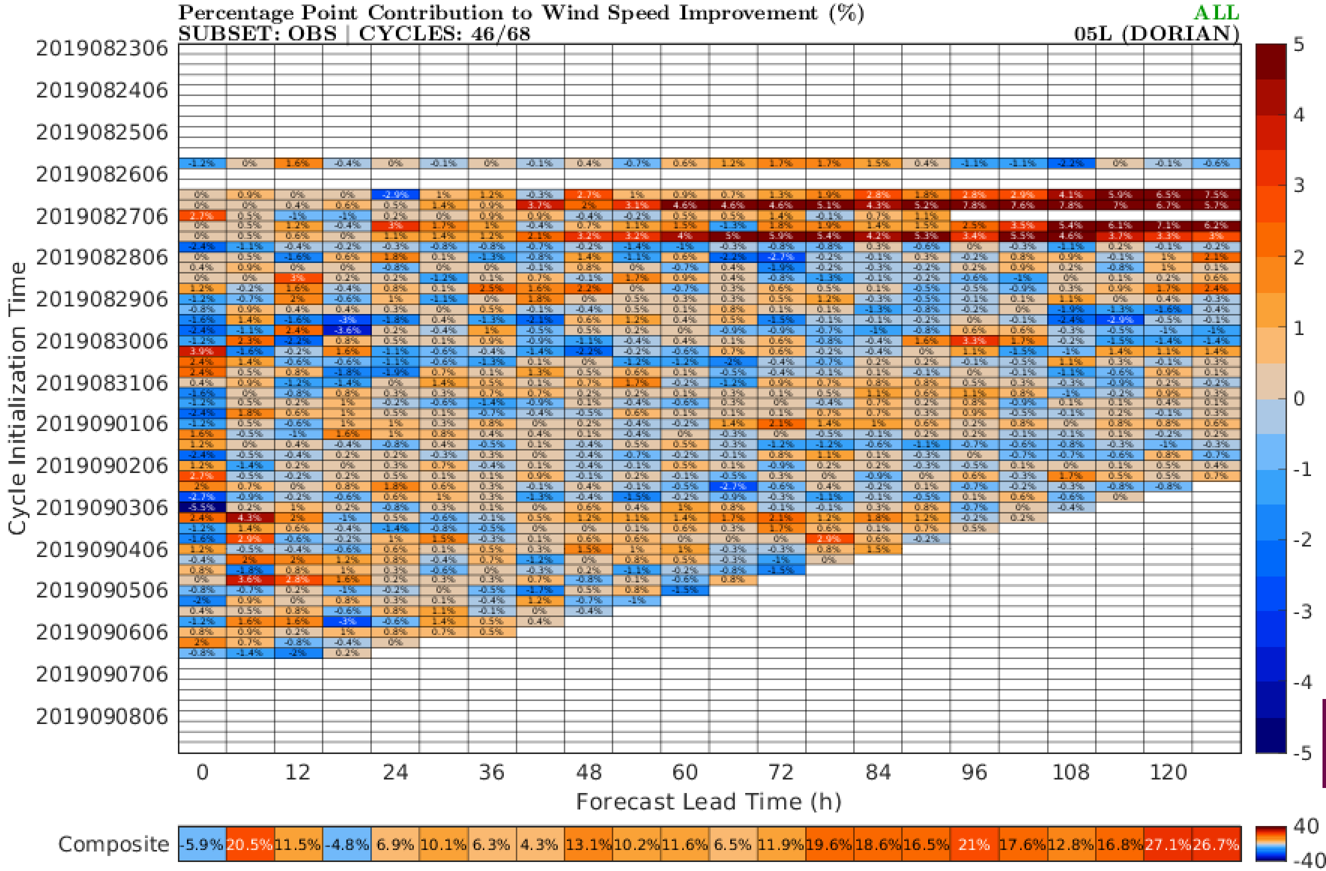
Verification: Consistent with NHC

One Storm: Each Cycle | **One Storm: All Cycles** | Composite Graphics

Relative Contribution to Improvement

By Forecast Lead Time

The below graphic is generated for each experiment, subset, and variable so the user can gauge each cycle's contribution to the improvement and, therefore, which cycles might be dominating the sample.



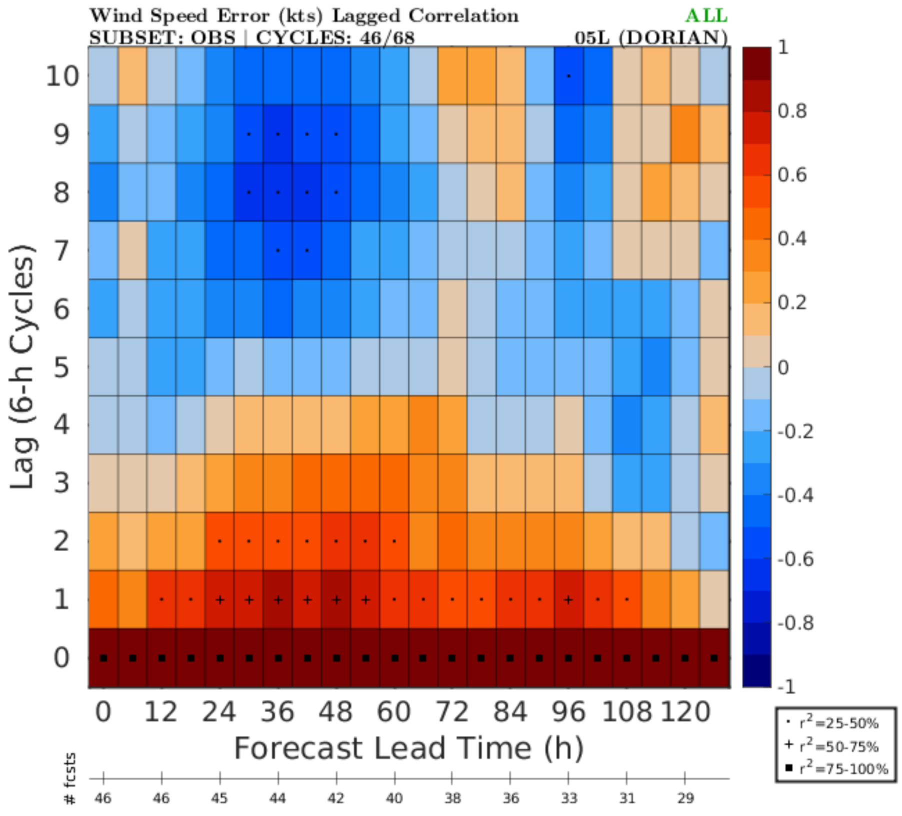
Overall Storm Improvement

Verification: Consistent with NHC

One Storm: Each Cycle | One Storm: All Cycles | Composite Graphics

Lagged Correlation

The below graphic is generated for each experiment, subset, and variable so the user can gauge lagged correlation in the full sample.



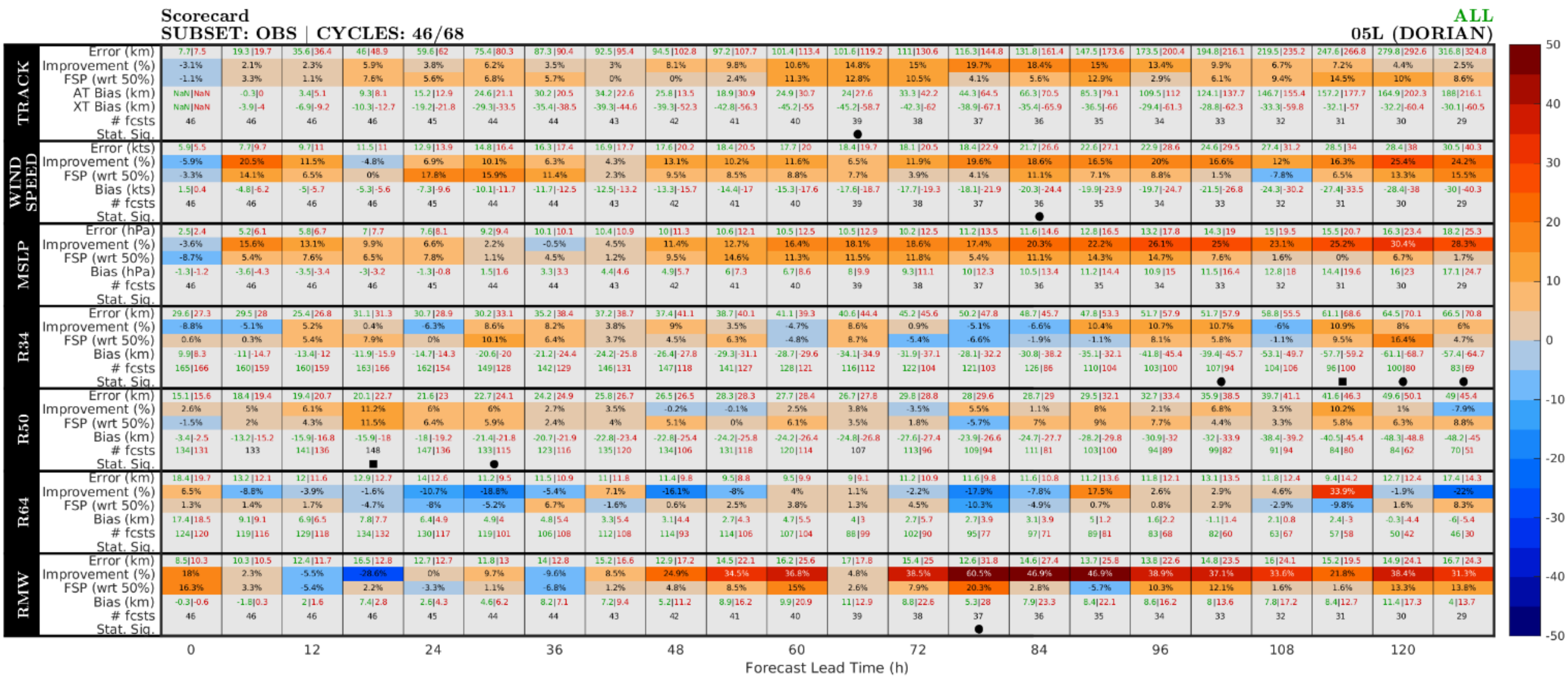
Lagged correlation of a given cycle to subsequent cycles at each forecast hour.

Verification: Consistent with NHC

One Storm: Each Cycle | **One Storm: All Cycles** | Composite Graphics

Scorecard Graphic

The below graphic is generated for each experiment and subset to give an overall snapshot of the model performance.



Credit: Idea & Base Code by Dr. Peter Marinescu

Basin: Individual | Verification: Consistent with NHC

* There is a switch in the namelist to indicate if the model is a basin-scale model.

One Storm: Each Cycle | One Storm: All Cycles | **Composite Graphics**

Subsets Currently Available

Consistent with NHC Verification

All OS(S)Es

#	SUBSET	DEFINITION
0	NONE	Perform no subsets other than NHC verification
1-2	OBS | NOOBS	keeps only the cycles where the obs in question (was | was not) assimilated in a storm
3-4	RECON | PRERECON	keeps (from | before) the 1st cycle where the obs in question was assimilated to the (end | beginning) of the storm
5-8	TD | TS | H12 | H345	cycles with best track intensity of (TD | TS | H12 | H345) at t=0
9-13	RI | IN | SS | WK | RW	For the best track of a storm, calculate the running ± 6 h intensity change to capture what type of intensity change the storm is currently undergoing. Then, for cycles t=0, categorize as follows: (RI: $x \geq 15$ kt | IN: $5 \leq x < 15$ kt | SS: $-5 < x < 5$ kt | WK: $-15 < x \leq -5$ kt | RW: $x \leq -15$ kt)
14-16	LOW | MOD | HIGH	cycles with SHIPS shear* of (LOW | MOD | HIGH) at t=0
17-18	N30 | S30	cycles with best track latitude (≥30 N | <30 N) at t=0
19	CUSTOM	you can input a list of cycles for your own custom subset in the namelist
20	YYYY	cycles that occur in a single year (only runs if >1 year)

Same as before other than this additional subset!

NOTE: #1-4 are run, and #5-8, #14-16, & #17-18 are further subset into OBS and NOOBS *only if* identconv=1 or identsatobs=1 in the namelist which lets the package know that you retrieved the required files and are running the assimilated obs component of the package.

For GROOT-G, an additional subset called OBS-G is included that includes cycles where the obs in question was assimilated anywhere in the global domain. Other than OBS-G, any OBS-related subset considers only the near-storm environment (R<2000 km)

Basin-Scale* OS(S)Es

#	SUBSET	DEFINITION
1	OBS-I	cycles from storms with obs, where that storm was the only one with obs in the parent domain
2	OBS-T	cycles from storms with obs, where that storm was not the only one with obs in the parent domain
3	OBS-O	cycles from storms without obs, where there were other storms with obs in the parent domain
4	OBS-P	cycles where there were obs in a storm somewhere in the parent domain (OBS-P=OBS-I+OBS-T+OBS-O | OBS-P=OBS+OBS-O)
5	NOOBS-P	cycles where there were no obs in any storm anywhere in the parent domain
6	RECON-I	cycles from storms with recon, where that storm was the only one with recon in the parent domain
7	RECON-T	cycles from storms with recon, where that storm was not the only one with recon in the parent domain
8	RECON-O	cycles from storms without recon, where there were other storms with recon in the parent domain
9	RECON-P	cycles where there were recon somewhere in the parent domain (RECON-P=RECON-I+RECON-T+RECON-O | RECON-P=RECON+RECON-O)
10	PRERECON-P	cycles where there were no recon anywhere in the parent domain

NOTE: #1-10 are run *only if* identconv=1 or identsatobs=1 in the namelist which lets the package know that you retrieved the required files and are running the assimilated obs component of the package. Also, #1-5 are further subset by year (YYYY).

* Shear: 850-200 hPa mag (kt) | vortex removed | averaged 0-500 km relative to 850 hPa center

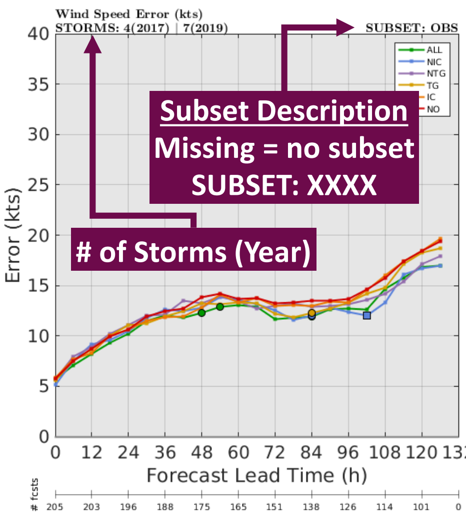
Basin: Individual | Verification: Consistent with NHC

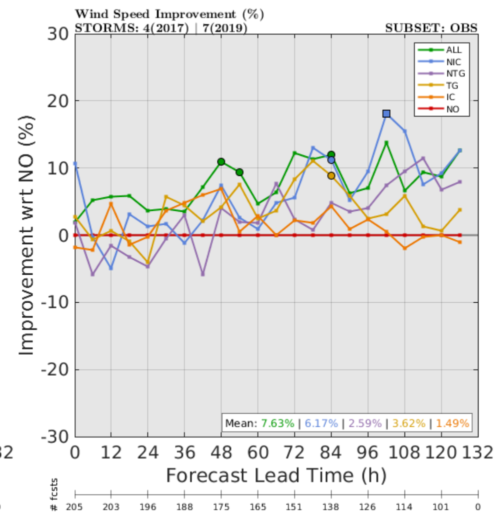
*Since these fields are "bias" fields, only E and I are calculated, as B would be redundant.

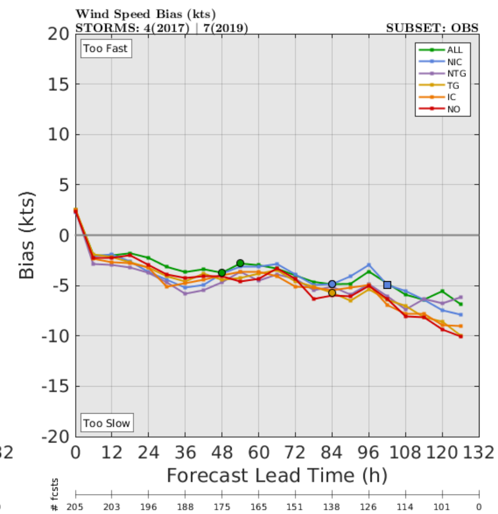
Subsets of Error, Improvement, Bias, & FSP

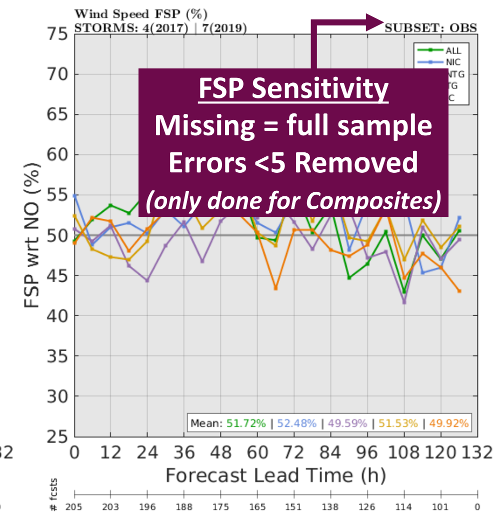
By Forecast Lead Time

The below graphics are generated for Track, Along-Track Error*, Across-Track Error*, Wind Speed, Pressure, R34/R50/R64 (for each the NE, SE, SW, and NW quadrants as well as overall), PO, RO, and RMW.









Error (E) is defined as the absolute value of the difference between the forecast and best track at the forecast verifying time.

$$E = \mathrm{abs}(\mathrm{exp}_{t=\mathrm{BT}_{t=\mathrm{verif}}} - \mathrm{BT}_{t=\mathrm{verif}})$$

Improvement (I), compares how much better (or worse) an experiment performed over a baseline experiment.

$$I = 100 * \left(1 - \frac{\overline{\mathrm{exp}}}{\overline{\mathrm{baseline}}}\right)$$

Bias (B) is defined as the difference between the forecast and best track at the forecast verifying time.

$$B = \mathrm{exp}_{t=\mathrm{BT}_{t=\mathrm{verif}}} - \mathrm{BT}_{t=\mathrm{verif}}$$

Frequency of Superior Performance (FSP) indicates how often an experiment performed better over a baseline experiment.

$$\mathrm{FSP}_{\mathrm{exp}_{t=\mathrm{fhr}}} = 100 * \frac{\sum_{n=1}^{\#\,fcsts} \begin{cases} 1, & \text{if } \mathrm{exp_E} < \mathrm{baseline_E} \\ .5, & \text{if } \mathrm{exp_E} = \mathrm{baseline_E} \\ 0, & \text{if } \mathrm{exp_E} > \mathrm{baseline_E} \end{cases}}{\#\,fcsts}$$

■ : 95% sig. | ● : 90% sig. | Paired t-test w/ serial correlation

Also included is a combined error/improvement graphic!

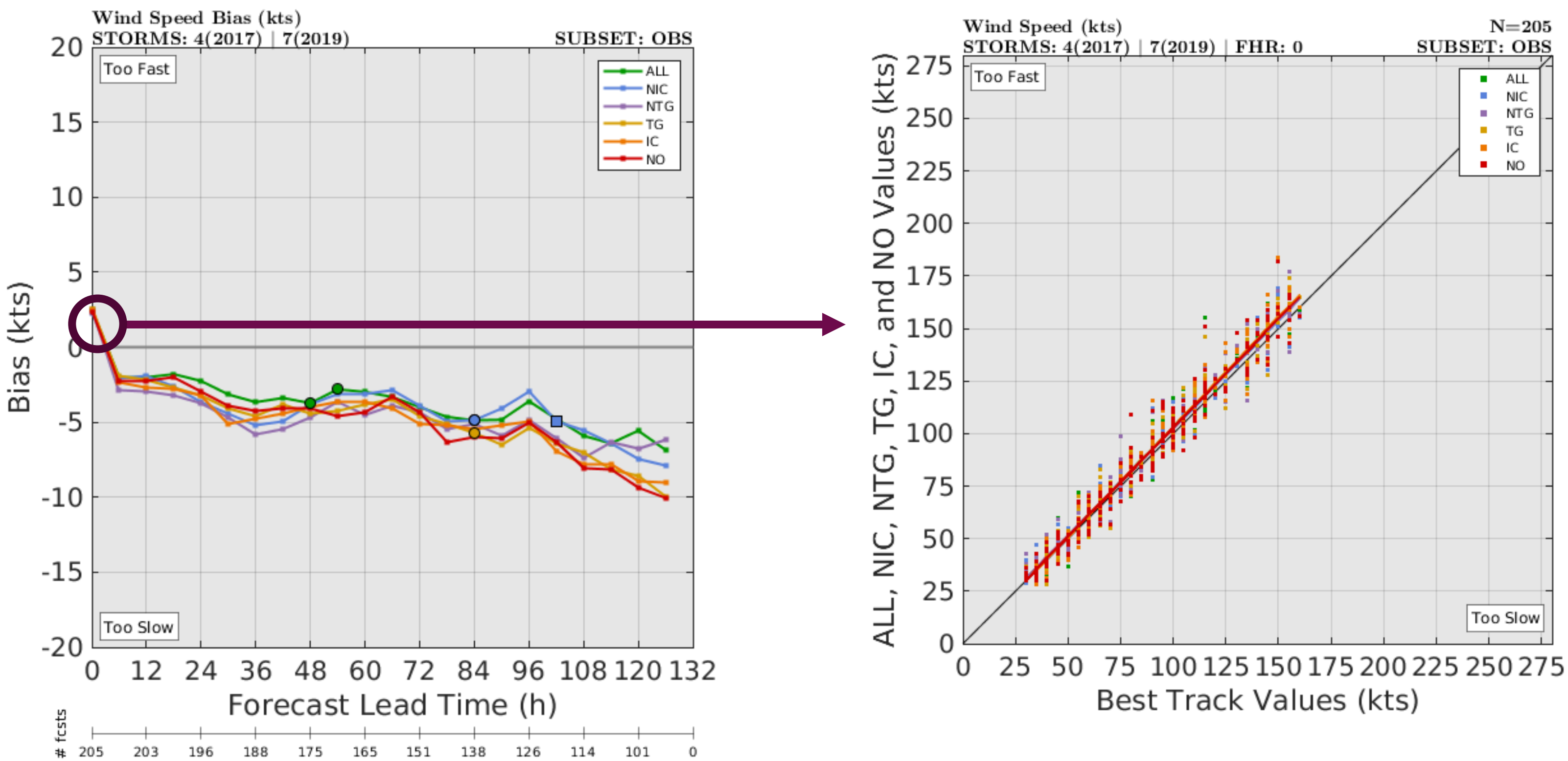
Basin: Individual | Verification: Consistent with NHC

One Storm: Each Cycle | One Storm: All Cycles | **Composite Graphics**

Raw Value Comparison

At Forecast Initialization

The below graphics are generated for Track, Along-Track Error*, Across-Track Error*, Wind Speed, Pressure, R34/R50/R64 (for each the NE, SE, SW, and NW quadrants as well as overall), PO, RO, and RMW.



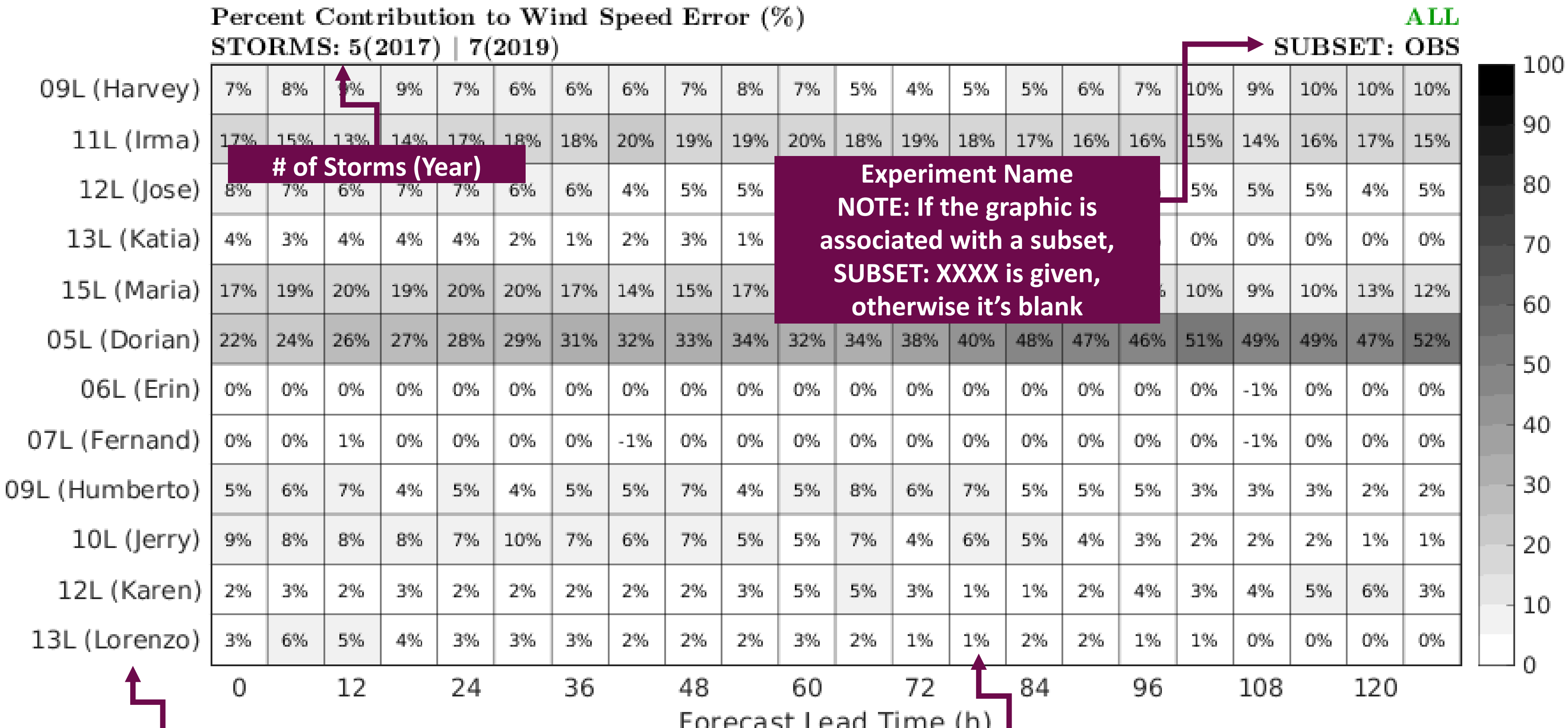
Basin: Individual | Verification: Consistent with NHC

One Storm: Each Cycle | One Storm: All Cycles | **Composite Graphics**

Percent Contribution to Error

By Forecast Lead Time

The below graphic is generated for each experiment, subset, and variable so the user can gauge each storm's contribution to the errors and, therefore, which storms might be dominating the sample.



	0		12		24		36		48		60		72		84		96		108		120	
09L (Harvey)	7%	8%	[illegible]	9%	7%	6%	6%	6%	7%	8%	7%	5%	4%	5%	5%	6%	7%	10%	9%	10%	10%	10%
11L (Irma)	17%	15%	13%	14%	17%	18%	18%	20%	19%	19%	20%	18%	19%	18%	17%	16%	16%	15%	14%	16%	17%	15%
12L (Jose)	8%	7%	6%	7%	7%	6%	6%	4%	5%	5%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5%	5%	5%	4%	5%
13L (Katia)	4%	3%	4%	4%	4%	2%	1%	2%	3%	1%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0%	0%	0%	0%	0%
15L (Maria)	17%	19%	20%	19%	20%	20%	17%	14%	15%	17%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10%	9%	10%	13%	12%
05L (Dorian)	22%	24%	26%	27%	28%	29%	31%	32%	33%	34%	32%	34%	38%	40%	48%	47%	46%	51%	49%	49%	47%	52%
06L (Erin)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	-1%	0%	0%	0%
07L (Fernand)	0%	0%	1%	0%	0%	0%	0%	-1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	-1%	0%	0%	0%
09L (Humberto)	5%	6%	7%	4%	5%	4%	5%	5%	7%	4%	5%	8%	6%	7%	5%	5%	5%	3%	3%	3%	2%	2%
10L (Jerry)	9%	8%	8%	8%	7%	10%	7%	6%	7%	5%	5%	7%	4%	6%	5%	4%	3%	2%	2%	2%	1%	1%
12L (Karen)	2%	3%	2%	3%	2%	2%	2%	2%	2%	3%	5%	5%	3%	1%	1%	2%	4%	3%	4%	5%	6%	3%
13L (Lorenzo)	3%	6%	5%	4%	3%	3%	3%	2%	2%	2%	3%	2%	1%	1%	2%	2%	1%	1%	0%	0%	0%	0%

Sorted by Year then Alphabetical

Rounded to the nearest integer – while most columns add up to 100%, some will add up to 100 ±1-5% .

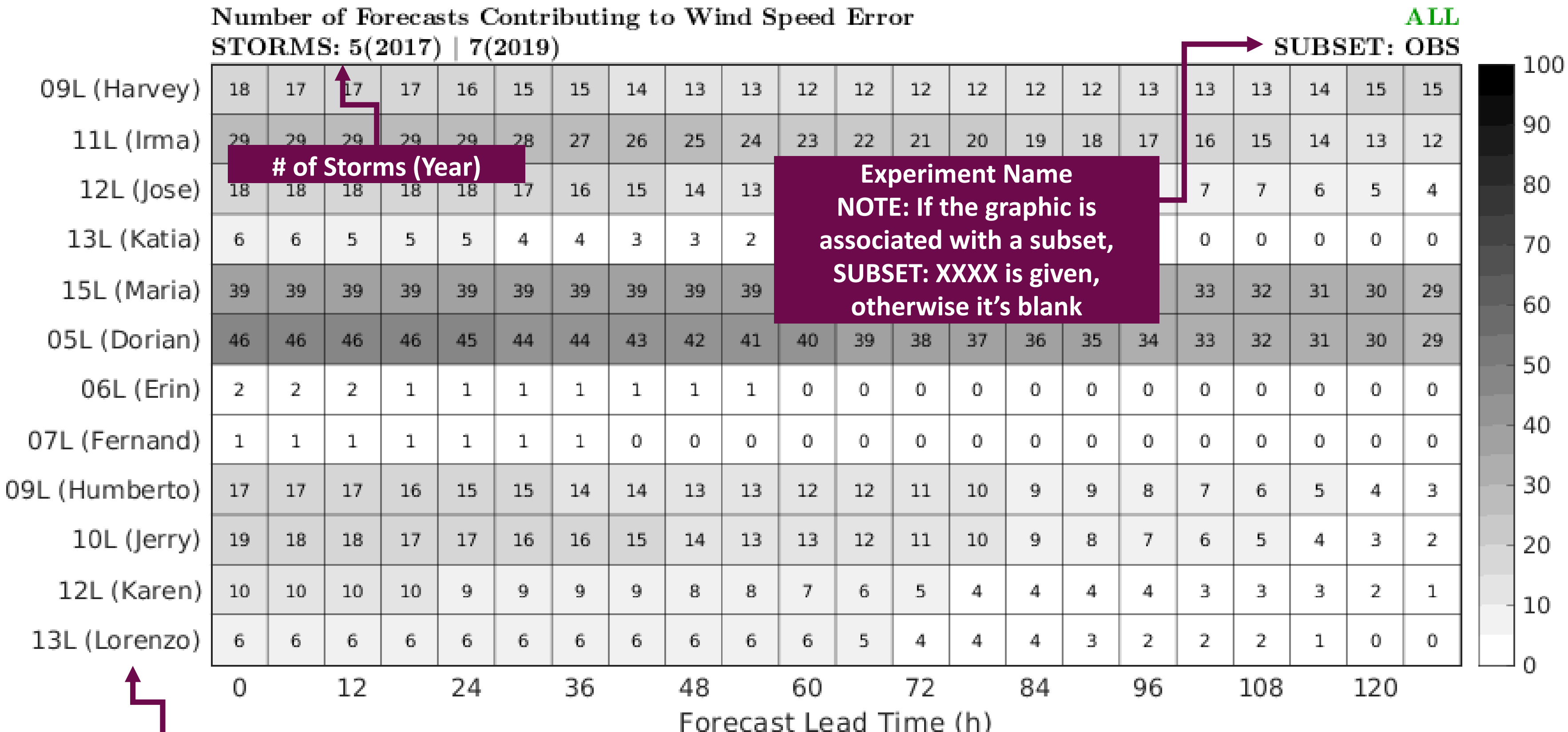
Basin: Individual | Verification: Consistent with NHC

One Storm: Each Cycle | One Storm: All Cycles | **Composite Graphics**

Number of Forecasts Contributing to The Error

By Forecast Lead Time

The below graphic is generated for each experiment, subset, and variable so the user can gauge each storm's contribution to the errors and, therefore, which storms might be dominating the sample.



Sorted by Year then Alphabetical

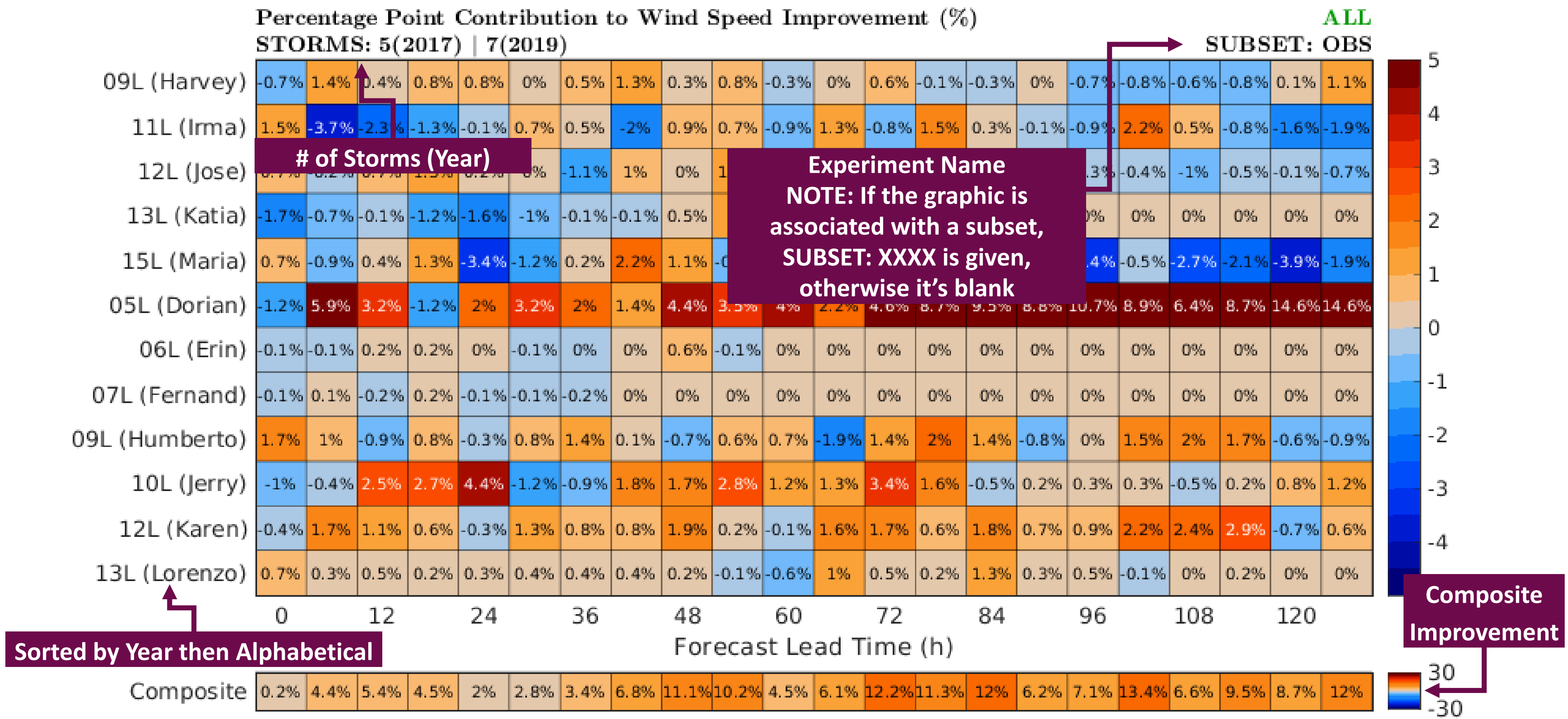
Basin: Individual | Verification: Consistent with NHC

One Storm: Each Cycle | One Storm: All Cycles | **Composite Graphics**

Relative Contribution to Improvement

By Forecast Lead Time

The below graphic is generated for each experiment, subset, and variable so the user can gauge each storm's contribution to the errors and, therefore, which storms might be dominating the sample.

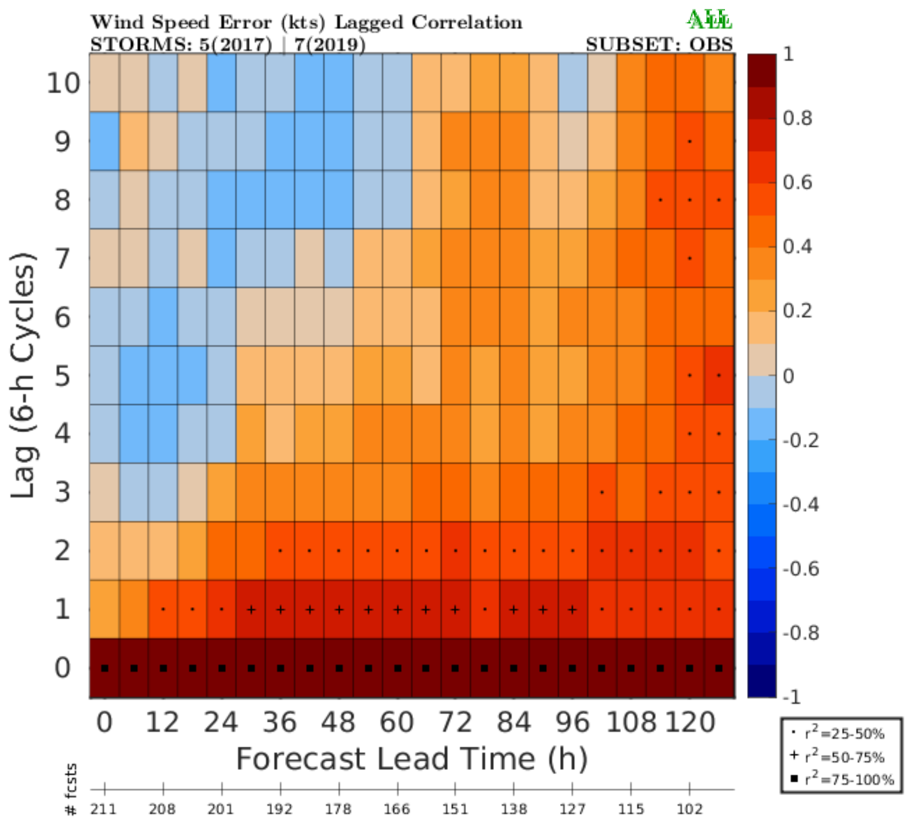


Basin: Individual | Verification: Consistent with NHC

One Storm: Each Cycle | One Storm: All Cycles | Composite Graphics

Lagged Correlation

The below graphic is generated for each experiment, subset, and variable so the user can gauge lagged correlation in the full sample.



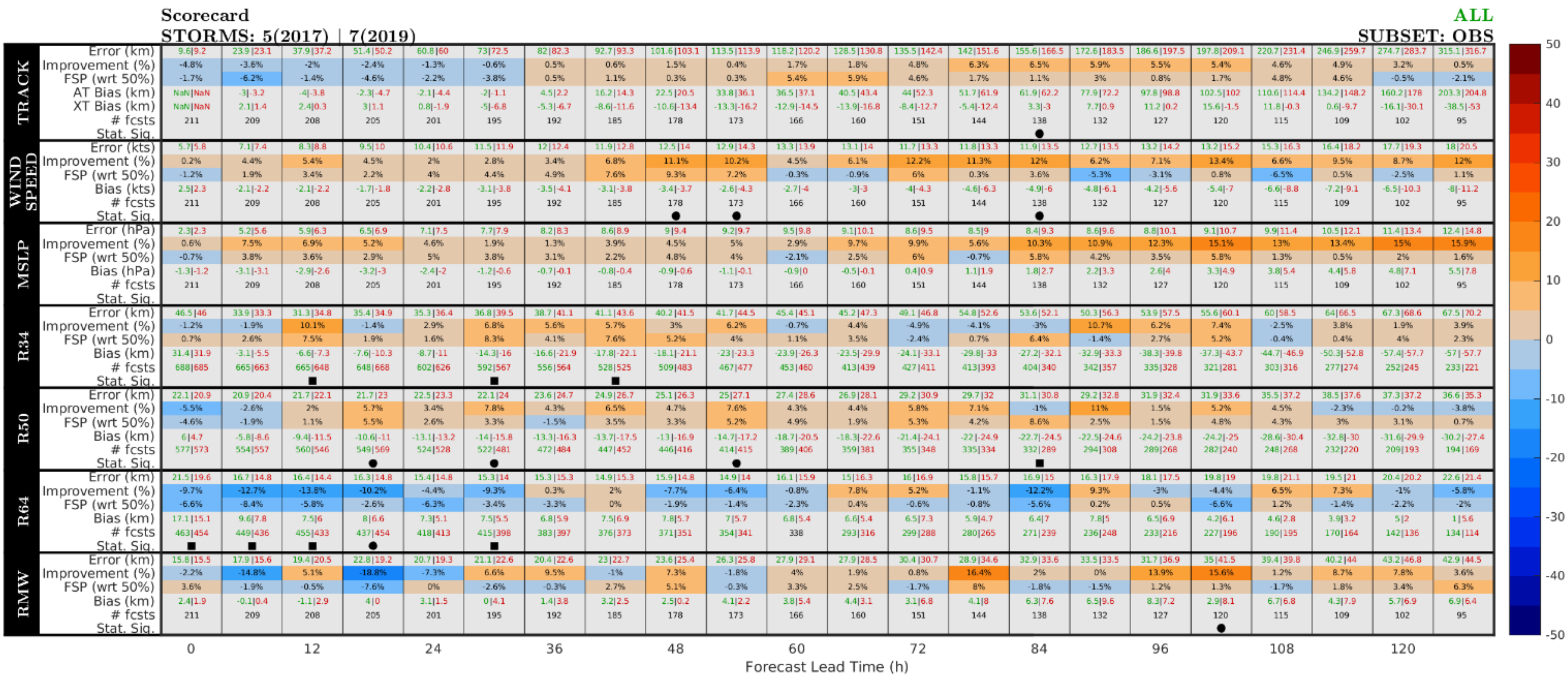
Lagged correlation of a given cycle to subsequent cycles at each forecast hour.

Basin: Individual | Verification: Consistent with NHC

One Storm: Each Cycle | One Storm: All Cycles | **Composite Graphics**

Scorecard Graphic

The below graphic is generated for each experiment and subset to give an overall snapshot of the model performance.



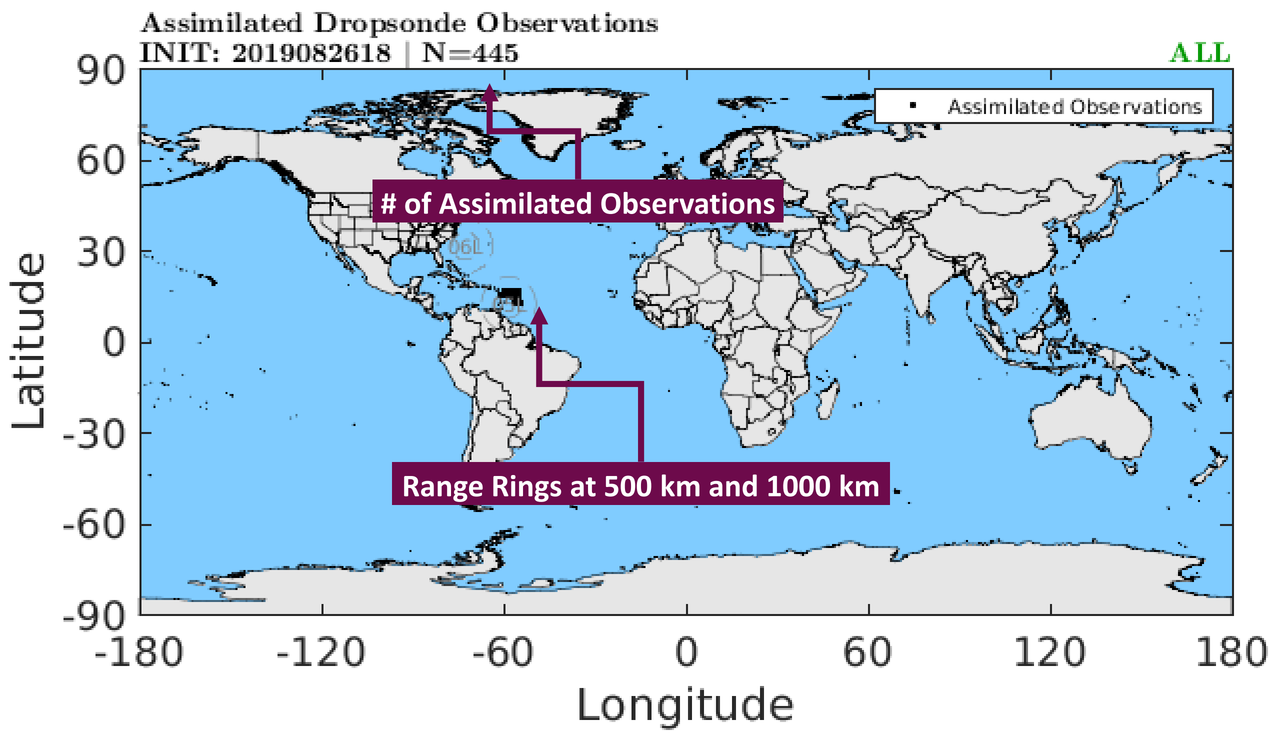
Credit: Idea & Base Code by Dr. Peter Marinescu

*Works with observation subtypes – each get their own color/name in namelist!

One Storm: Each Cycle | One Storm: All Cycles | Composite Graphics

Basin View

The below graphic is generated for each experiment. It shows the number of storms run at each cycle time. For HWRF, this graphic will show only 1 storm. For the basin-scale HWRF and the global component, this graphic will show all storms run at this cycle time.



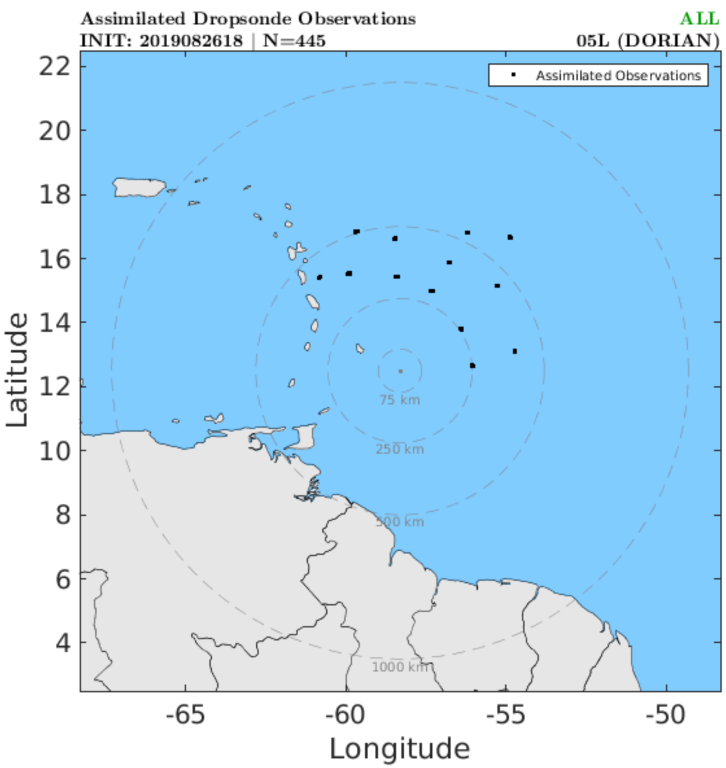
*Works with observation subtypes – each get their own color/name in namelist!

One Storm: Each Cycle | One Storm: All Cycles | Composite Graphics

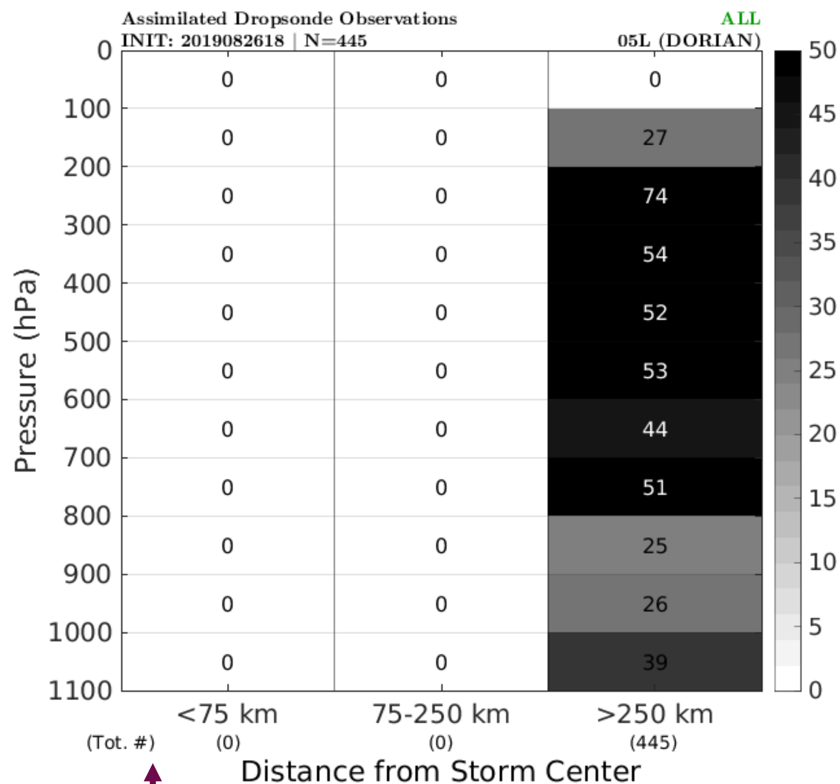
Plan View & Radial View

The below graphics are generated for each experiment and each storm. For OBS-related subsets in GROOT-G (other than OBS-G) it will take into account observations within 2000 km of the storm – this will be indicated on the graphic.

Plan View



Radial View

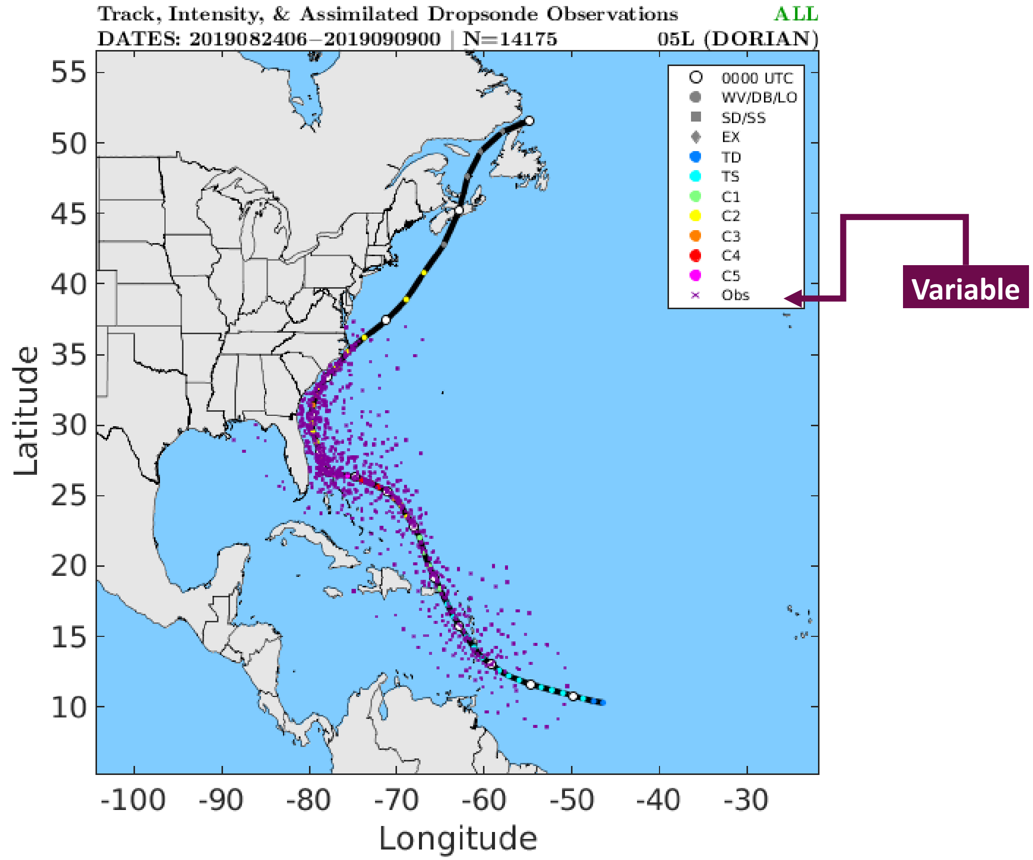


*Works with observation subtypes – each get their own color/name in namelist!

One Storm: Each Cycle
One Storm: All Cycles
Composite Graphics

Best Track Graphic

The below graphic is generated for each experiment and shows the along-track assimilated observations. For OBS-related subsets in GROOT-G (other than OBS-G) it will take into account observations within 2000 km of the storm – this will be indicated on the graphic.

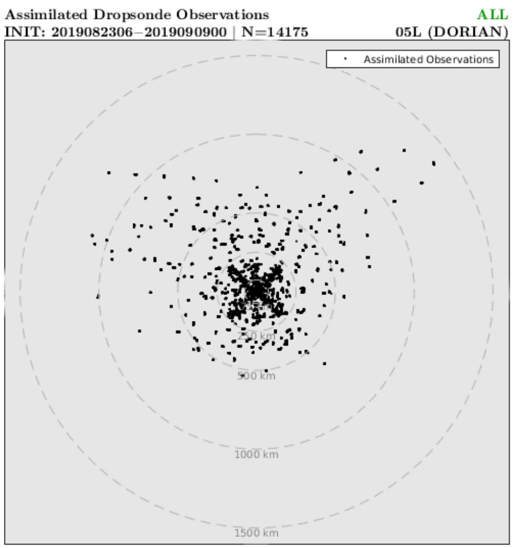


*Works with observation subtypes – each get their own color/name in namelist!

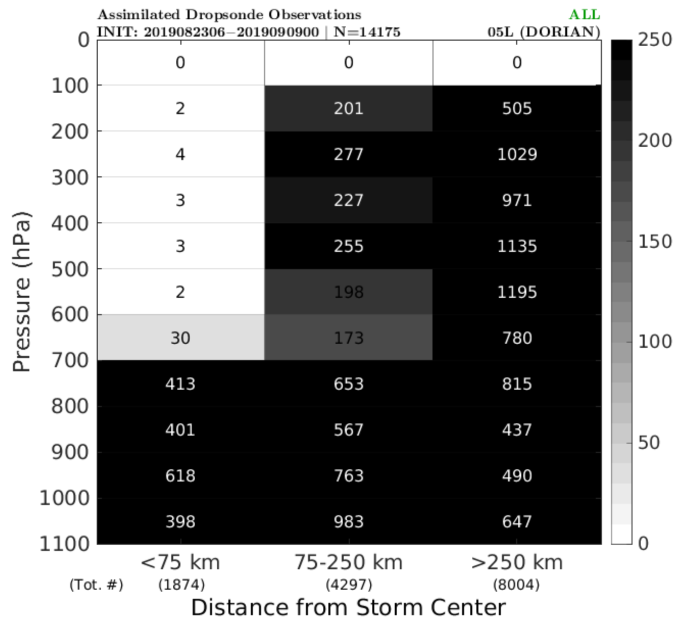
Plan, Radius-Pressure, & Radial View

The below graphic is generated for each experiment. For OBS-related subsets in GROOT-G (other than OBS-G) it will take into account observations within 2000 km of the storm – this will be indicated on the graphic.

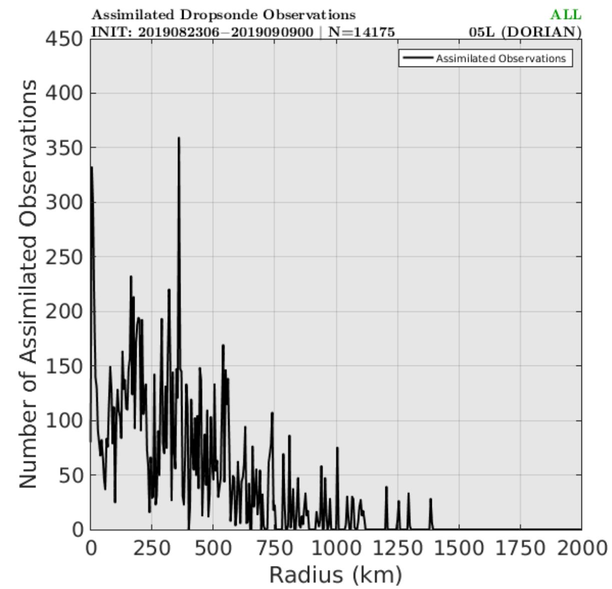
Plan View



Radius-Pressure View



Radial View



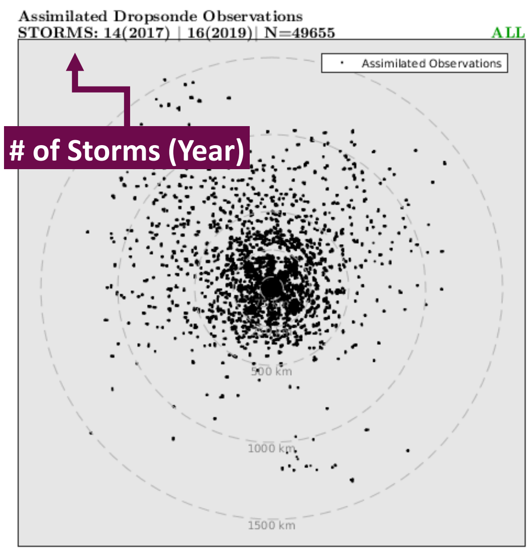
*Works with observation subtypes – each get their own color/name in namelist!

One Storm: Each Cycle | One Storm: All Cycles | **Composite Graphics**

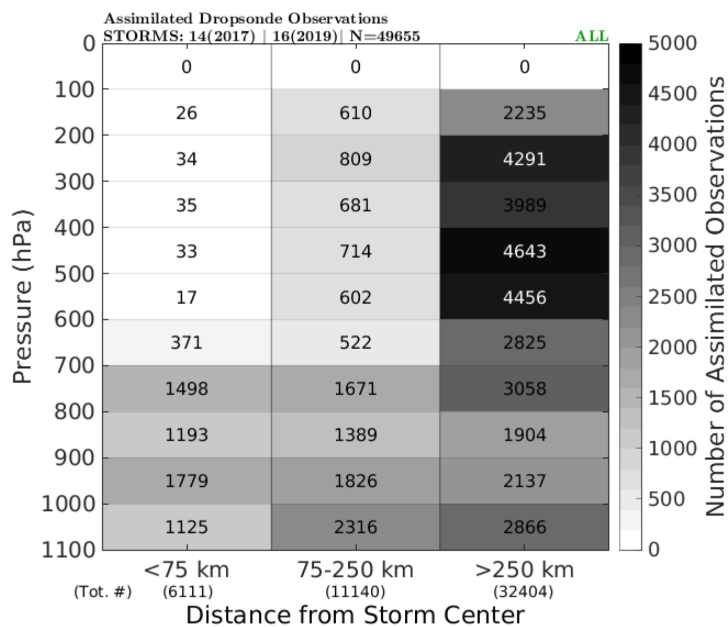
Plan, Radius-Pressure, & Radial View

The below graphic is generated for each experiment. For OBS-related subsets in GROOT-G (other than OBS-G) it will take into account observations within 2000 km of the storm – this will be indicated on the graphic.

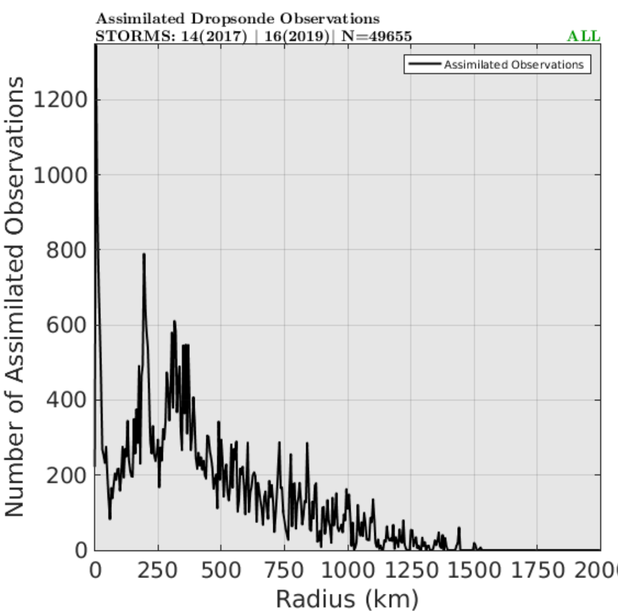
Plan View



Radius-Pressure View



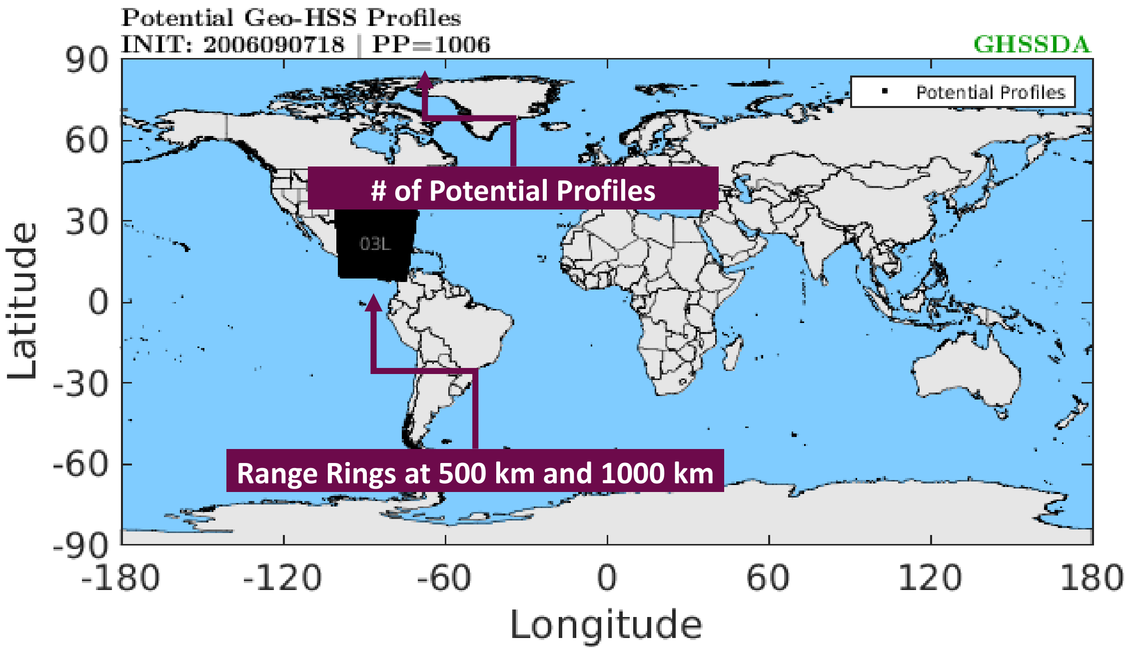
Radial View



One Storm: Each Cycle | One Storm: All Cycles | Composite Graphics

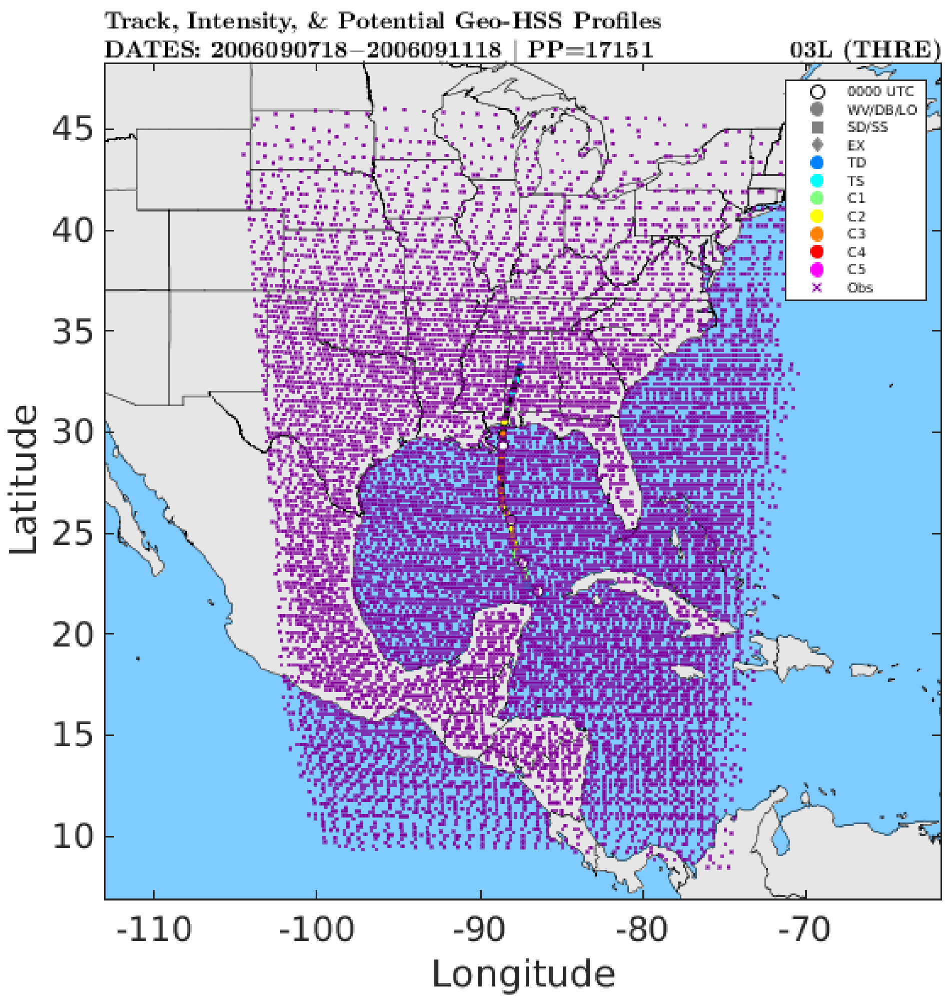
Basin View

The below graphic is generated for each experiment. It shows the number of storms run at each cycle time. For HWRF, this graphic will show only 1 storm. For the basin-scale HWRF and the global component, this graphic will show all storms run at this cycle time.



One Storm: Each Cycle | One Storm: All Cycles | Composite Graphics

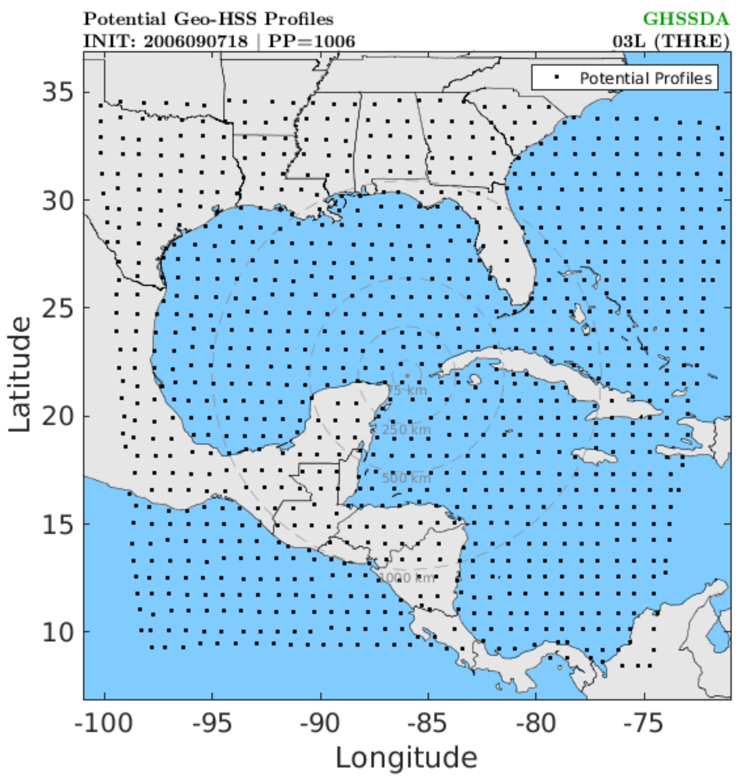
Best Track Graphic



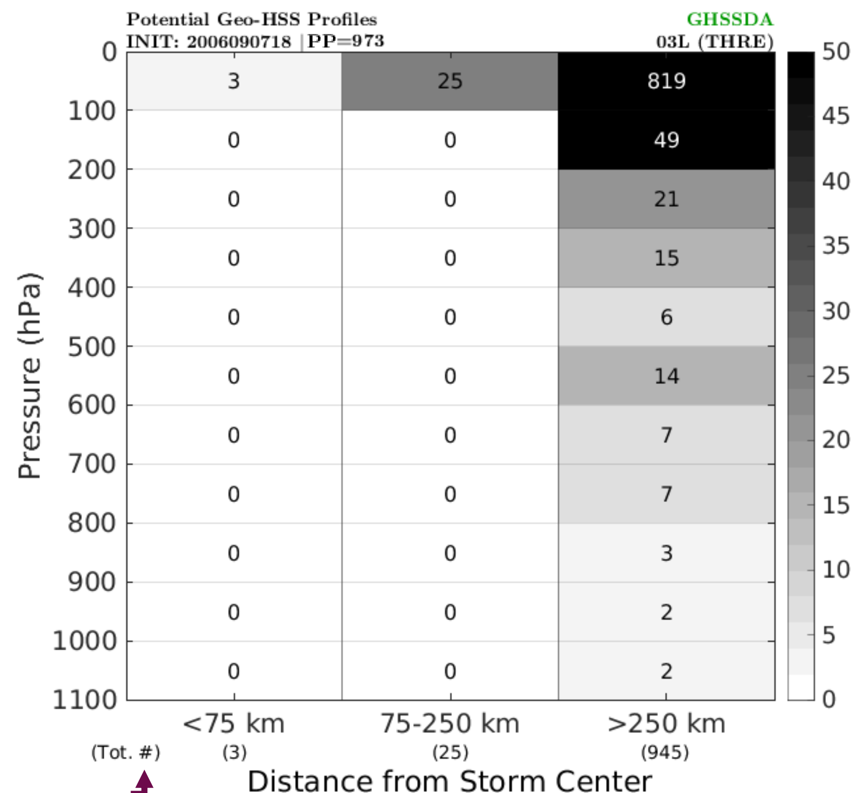
One Storm: Each Cycle | One Storm: All Cycles | Composite Graphics

Plan View & Radial View

Plan View



Radial View

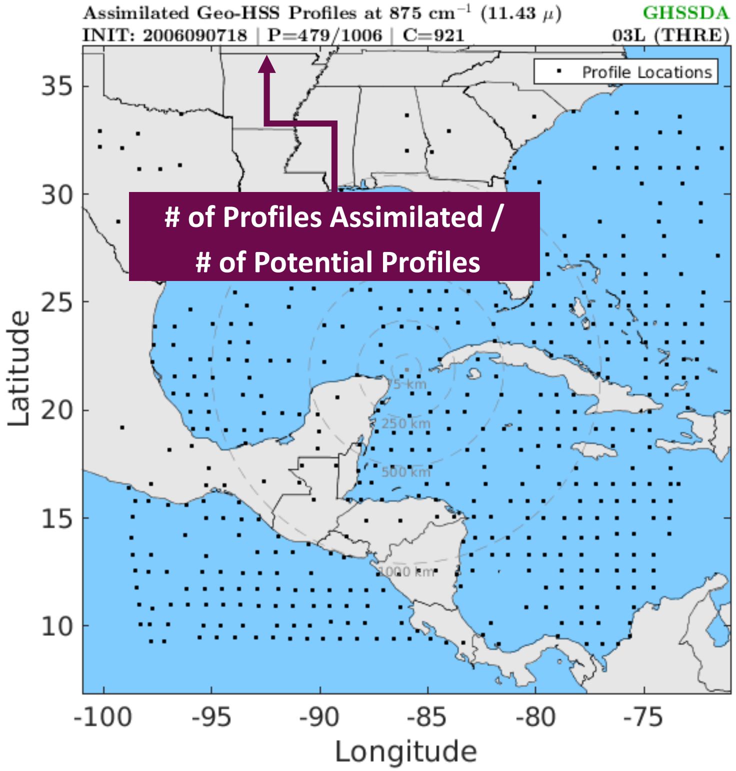


Column Sum

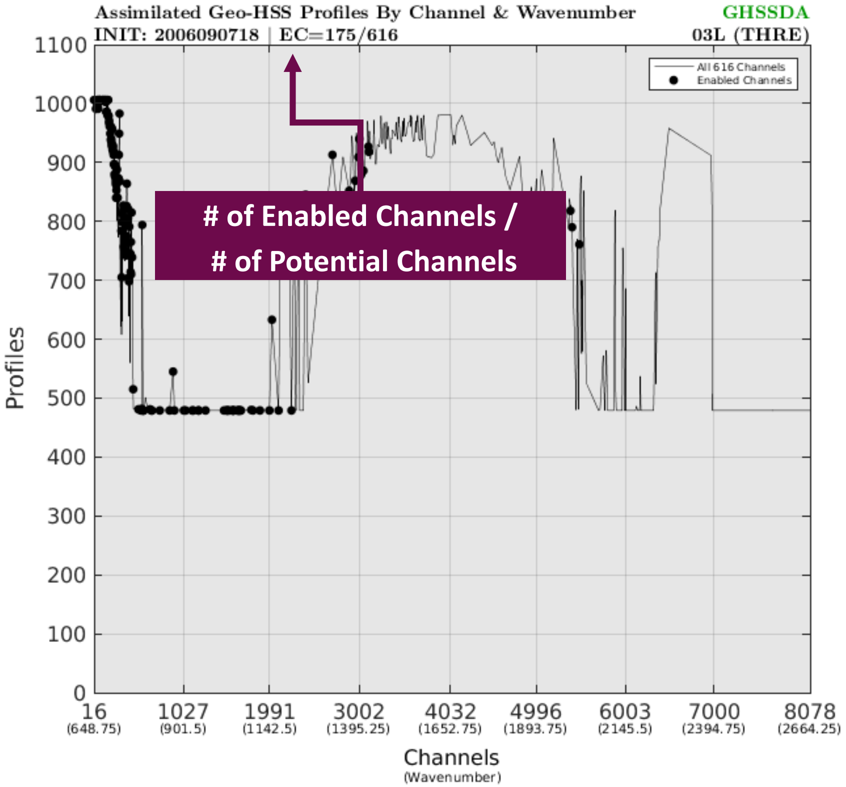
One Storm: Each Cycle | One Storm: All Cycles | Composite Graphics

Specific Channel & Profiles by Channel

Specific Channel

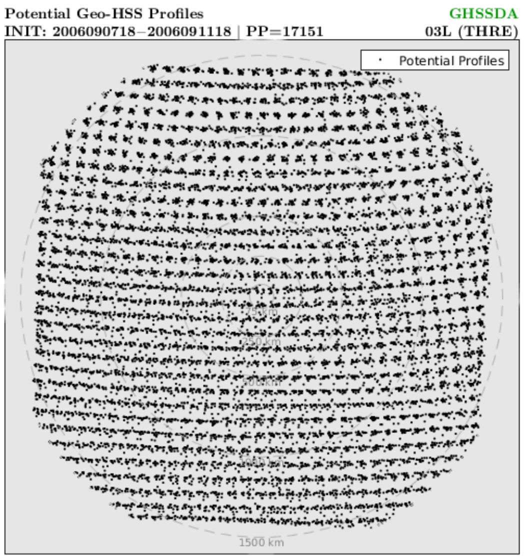


Profiles by Channel

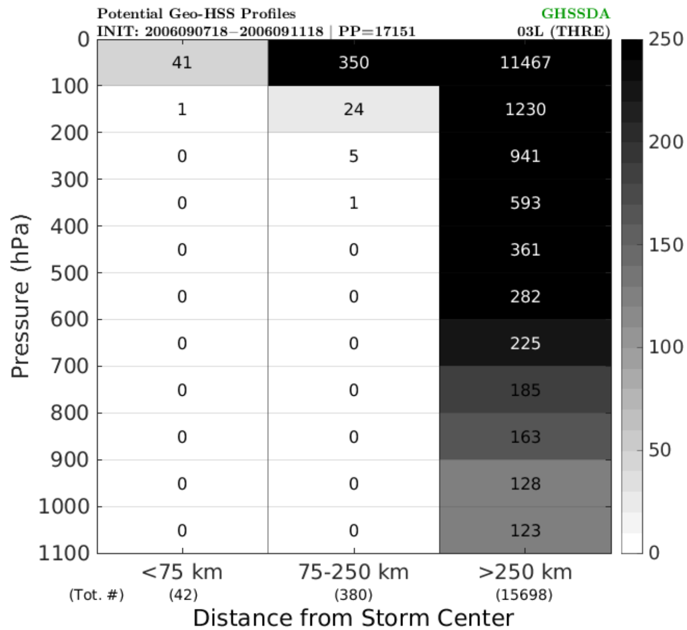


Plan, Radius-Pressure, & Radial View

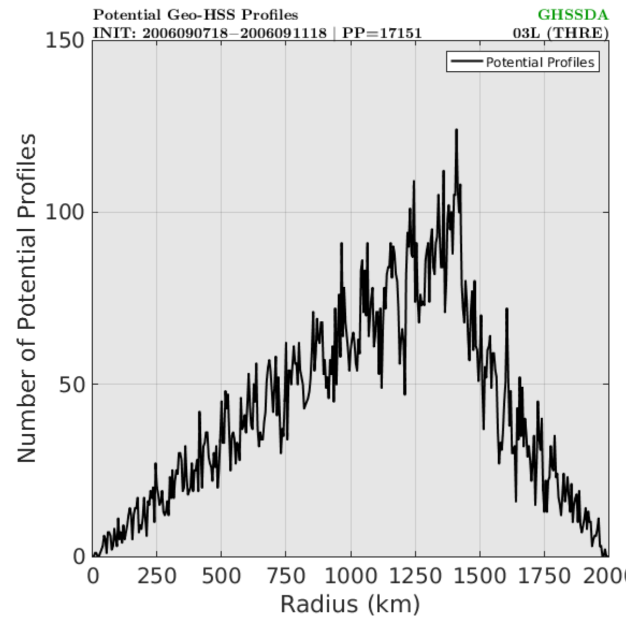
Plan View



Radius-Pressure View

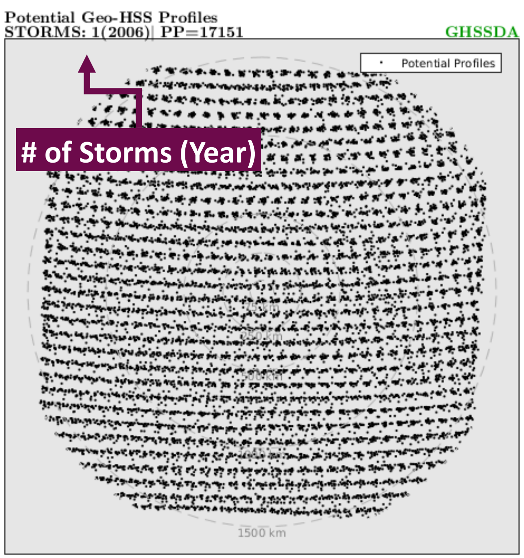


Radial View

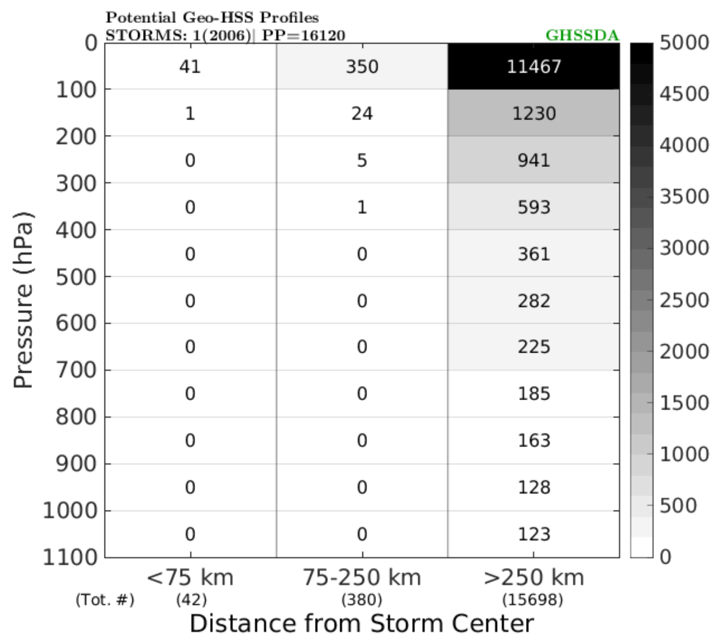


Plan, Radius-Pressure, & Radial View

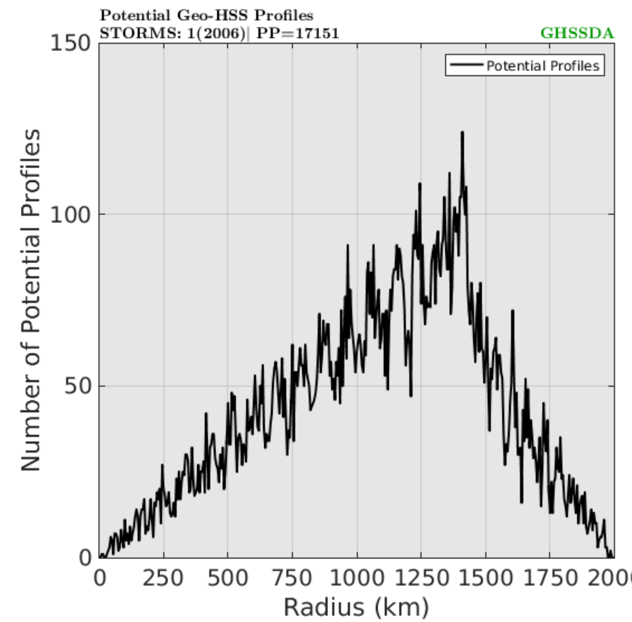
Plan View



Radius-Pressure View



Radial View



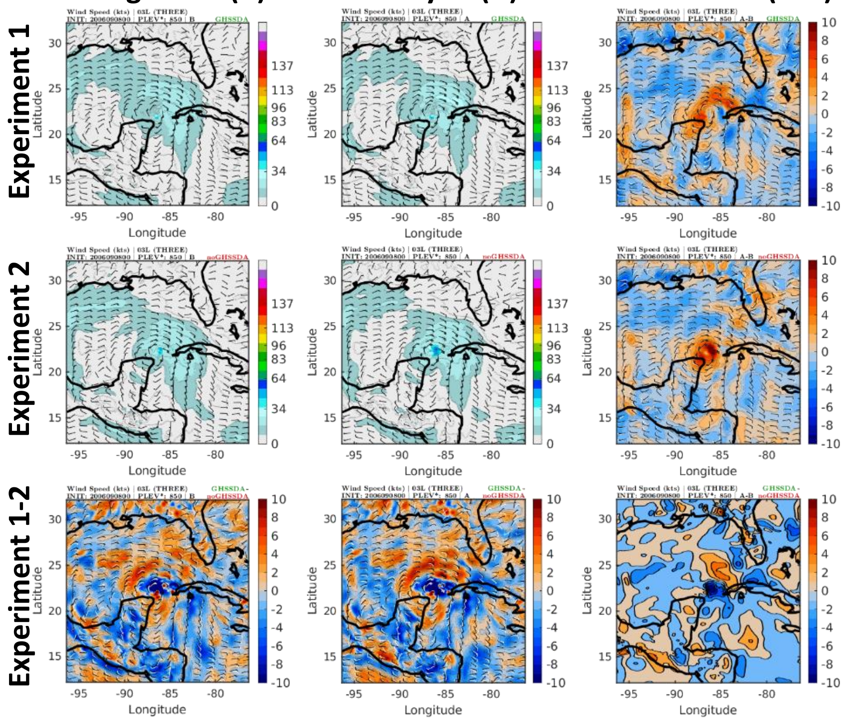
Pre- and Post- GSI Graphics

If you want to plot pre- and post- GSI fields to further understand the impact of your observations, you need to setup the HWRFDA.ksh script in the retrievalscripts/ folder *before* starting your experiments, since HWRF doesn't save the pre- and post- GSI files.

Plan View

The below graphics are generated for Divergence, Pressure, Specific Humidity, Relative Humidity, Relative Vorticity, Temperature, Zonal Wind, Meridional Wind, and Wind Speed at 850 hPa, 500 hPa, and 200 hPa for both D02 and D03.

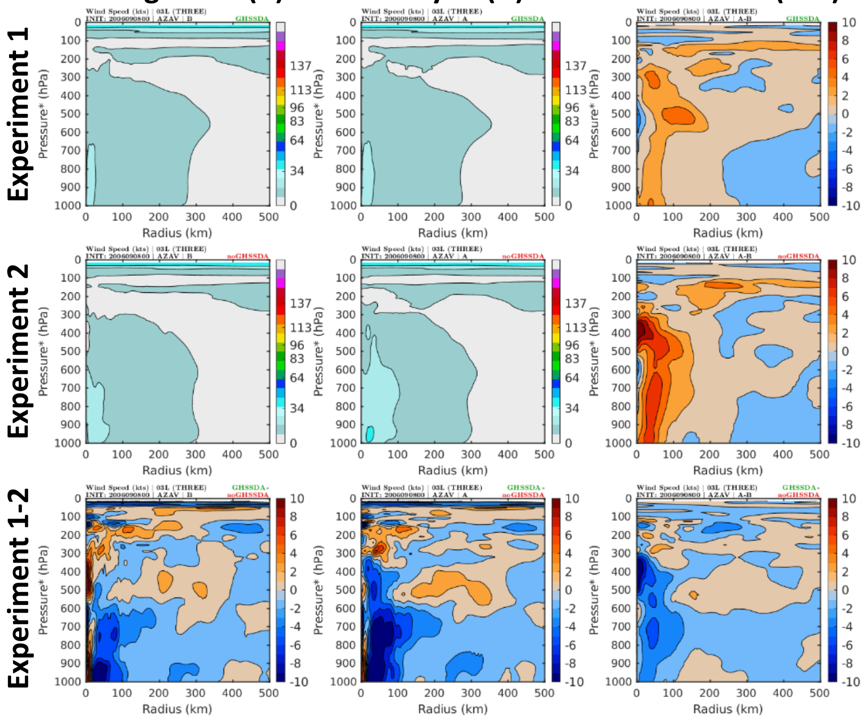
Background (B) | **Analysis (A)** | **Increments (A-B)**



Azimuthal Averages

The below graphics are generated for Divergence, Specific Humidity, Radial Wind, Relative Humidity, Relative Vorticity, Tangential Wind, Temperature, and Wind Speed for both D02 and D03

Background (B) | **Analysis (A)** | **Increments (A-B)**



Credit: Idea by Dr. Peter Marinescu

Storm Grid & Synoptic Grid Graphics

Variables Available

User Options & Guidance

Full List of Available Variables

Absolute Vorticity (Isobaric) | Cloud Ice (Isobaric) | Cloud Mixing Ratio (Isobaric) | Maximum/Composite Radar Reflectivity (2D) | Convective Available Potential Energy (Surface) | Convective Inhibition (Surface) | Convective Accumulated Precipitation (Water; Surface) | 2 Metre Dewpoint Temperature (2D) | Dew Point Temperature (Isobaric) | Downward Long-Wave Radiation Flux (Surface) | Downward Long-Wave Radiation Flux Hour Average (Surface) | Downward Short-Wave Radiation Flux (Surface) | Downward Short-Wave Radiation Flux Hour Average (Surface) | Drag Coefficient | Geopotential Height (Isobaric) | Geopotential Height (Surface) | Orography (2D) | Land-Sea Mask (Surface) | Non-Convective Accumulated Precipitation (Large-Scale; Surface) | Latent Heat Net Flux (Surface) | Momentum Flux, U Component (Surface) | Momentum Flux, V Component (Surface) | Planetary Boundary Layer Height (2D) | Potential Temperature (Tropopause) | Precipitable Water (2D) | Precipitation Rate (Surface) | Pressure Reduced To MSL (Surface) | Surface Pressure (Surface) | Pressure (Tropopause) | Rain Mixing Ratio (Isobaric) | Radar Reflectivity (Isobaric), | Relative Humidity (2D) | Relative Humidity (Isobaric) | Rime Factor (Isobaric) | Sensible Heat Net Flux (Surface) | Snow Mixing Ratio (Isobaric) | Specific Humidity (2D) | Specific Humidity (Isobaric) | Storm Relative Helicity (2D) | Surface Roughness (Surface) | Temperature (2D) | Temperature (Isobaric) | Temperature (Surface) | 2 Metre Temperature (2D) | Total Column Integrated Rain (2D) | Total Column Integrated Snow (2D) | Total Column-Integrated Cloud Ice (2D) | Total Column-Integrated Cloud Water (2D) | Total Column-Integrated Condensate (2D) | Total Condensate (Isobaric) | Total Accumulated Precipitation (Surface) | Upward Long-Wave Radiation Flux (Surface) | Upward Long-Wave Radiation Flux Hour Average (Surface) | Upward Short-Wave Radiation Flux (Surface) | Upward Short-Wave Radiation Flux Hour Average (Surface) | Heat Exchange Coefficient (2D) | Vertical Speed Shear (Tropopause) | Vertical Velocity (Isobaric) | Sea Surface Temperature (Surface) | 10 Metre U/V Wind Component (2D) | U/V Component Of Wind (Isobaric) | U/V Component Of Wind (Tropopause)

Commonly-Selected Variables

Absolute Vorticity (Isobaric) | Geopotential Height (Isobaric) | Precipitable Water (2D)
Pressure Reduced to MSL (Surface) | Relative Humidity (Isobaric) | U/V Component of Wind (Isobaric)

Additional Variables Computed

Relative Vorticity (Isobaric): from absolute vorticity, if selected
Radial & Tangential Wind (Isobaric): from u/v component of wind, if selected
Wind Speed (Isobaric): from u/v component of wind, if selected

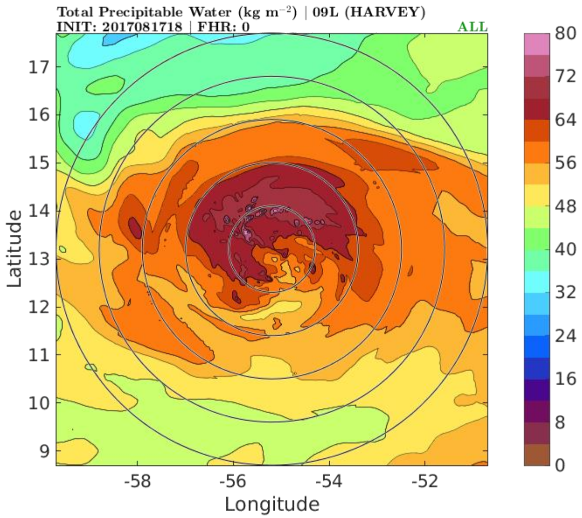
*These graphics are not generated for zonal, meridional, radial, or tangential wind.

Storm Grid

Plan View

2D Field

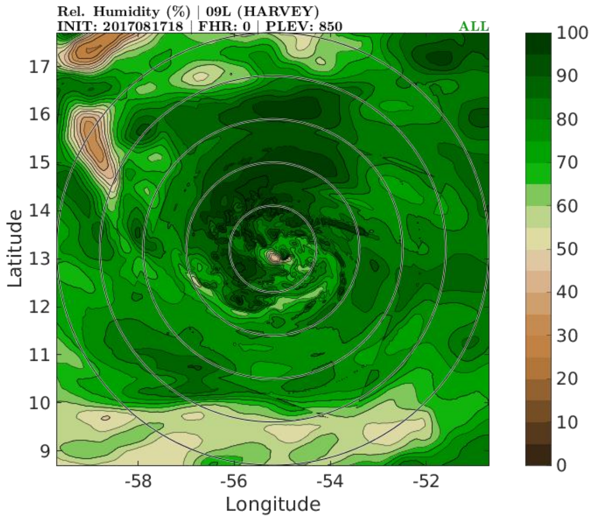
1 CYCLE | 1 FHR | 1 PLEV | ALL RAD | 1 STORM



This graphic is generated for every cycle and forecast hour for every experiment. Difference graphics are also created.

3D Field*

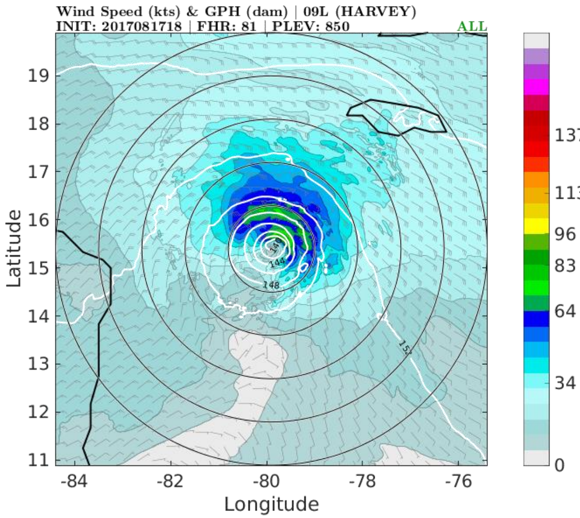
1 CYCLE | 1 FHR | 1 PLEV | ALL RAD | 1 STORM



This graphic is generated for every cycle and forecast hour for every experiment for user-specified PLEVS. You can turn off 3D plan-view graphics in the namelist to save time. Difference graphics are also created.

Layered Field

1 CYCLE | 1 FHR | 1 PLEV | ALL RAD | 1 STORM



When GPH or U/V is chosen, this graphic depicting wind speed (shading according to intensity), wind direction (vectors), and GPH (white contours) is created. Difference graphics are also created.

Range Rings: every 100 km from 100-500 km

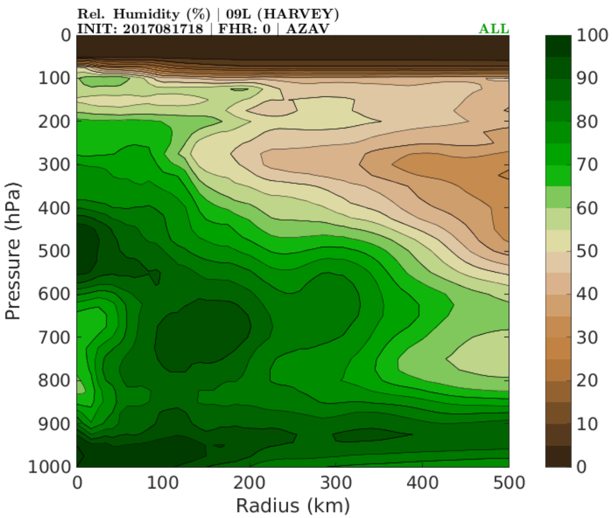
*These graphics are not generated for zonal or meridional wind.

Storm Grid

Azimuthal Averages

Radius-Pressure*

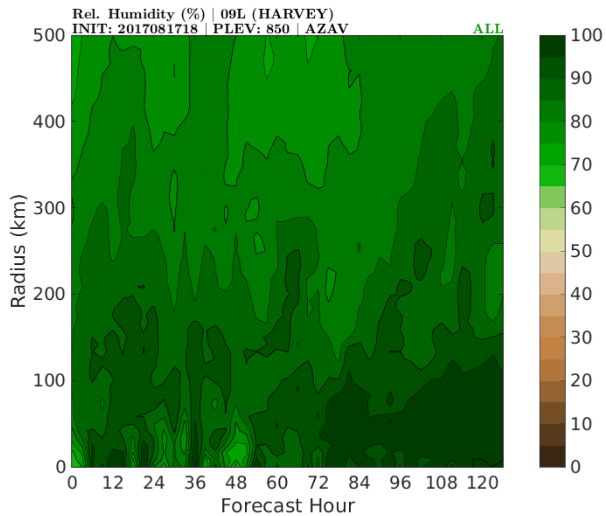
1 CYCLE | 1 FHR | ALL PLEV | ALL RAD | 1 STORM



This graphic is generated for every cycle and forecast hour for every experiment. Difference graphics are also created.

FHR-Radius*

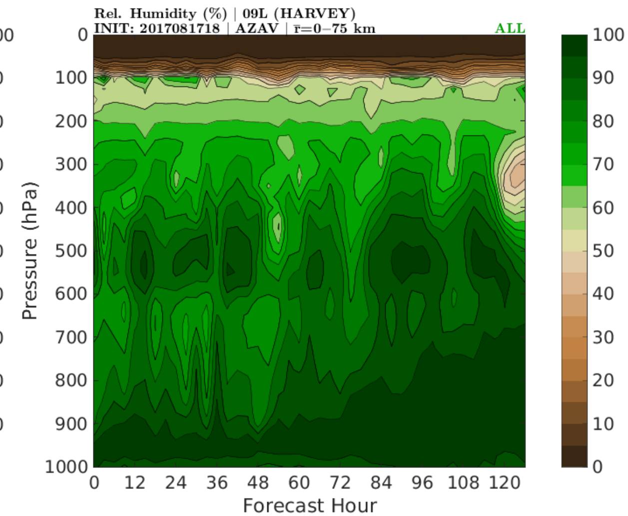
1 CYCLE | ALL FHR | 1 PLEV | ALL RAD | 1 STORM



This graphic is generated for every cycle for every experiment for user-specified PLEVS. Difference graphics are also created.

FHR-Pressure*

1 CYCLE | ALL FHR | ALL PLEV | ALL RAD | 1 STORM



This graphic is generated for every cycle for every experiment for the Inner-Core region (0-75 km), TS Gales region (0-250 km) and the Outer Vortex (250-500 km) region. Difference graphics are also created.

Range Rings: every 100 km from 100-500 km

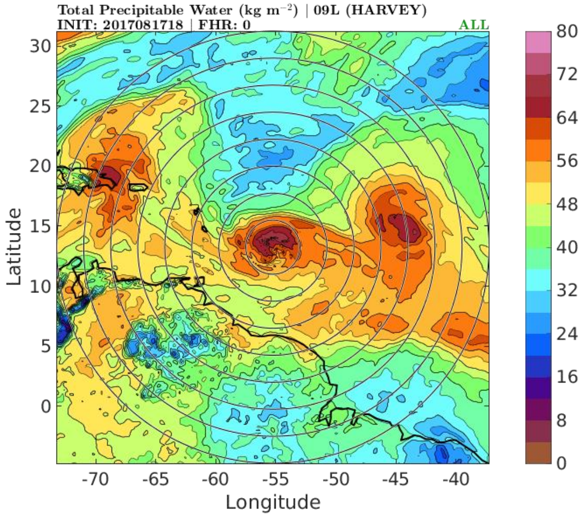
*These graphics are not generated for zonal, meridional, radial, or tangential wind.

Synoptic Grid

Plan View

2D Field

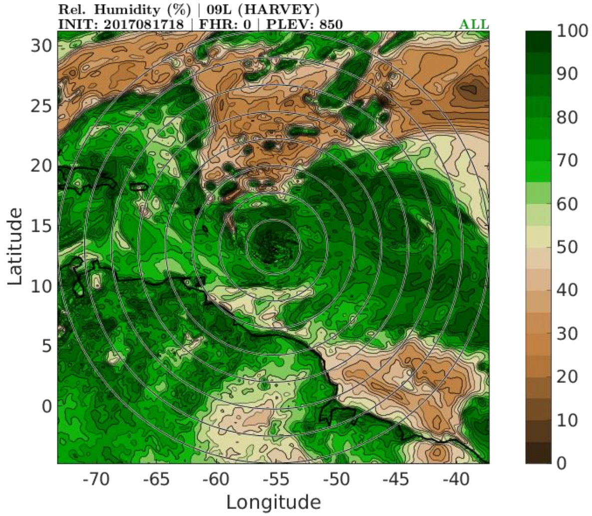
1 CYCLE | 1 FHR | 1 PLEV | ALL RAD | 1 STORM



This graphic is generated for every cycle and forecast hour for every experiment. Difference graphics are also created.

3D Field*

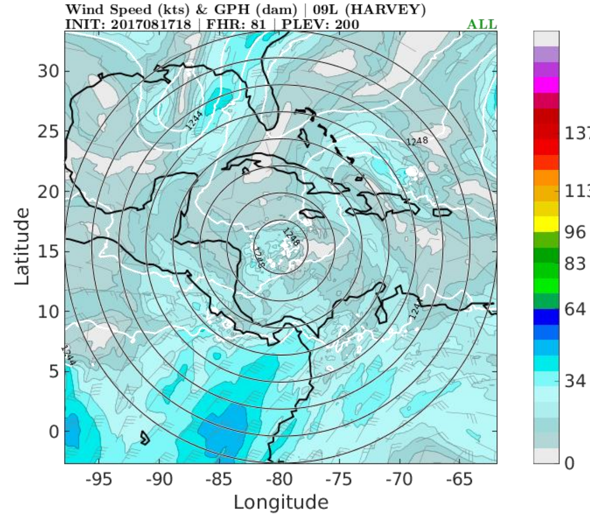
1 CYCLE | 1 FHR | 1 PLEV | ALL RAD | 1 STORM



This graphic is generated for every cycle and forecast hour for every experiment for user-specified PLEVS. You can turn off 3D plan-view graphics in the namelist to save time. Difference graphics are also created.

Layered Field

1 CYCLE | 1 FHR | 1 PLEV | ALL RAD | 1 STORM



When GPH or U/V is chosen, this graphic depicting wind speed (shading according to intensity), wind direction (vectors), and GPH (white contours) is created. Difference graphics are also created.

Range Rings: every 250 km from 250-2000 km

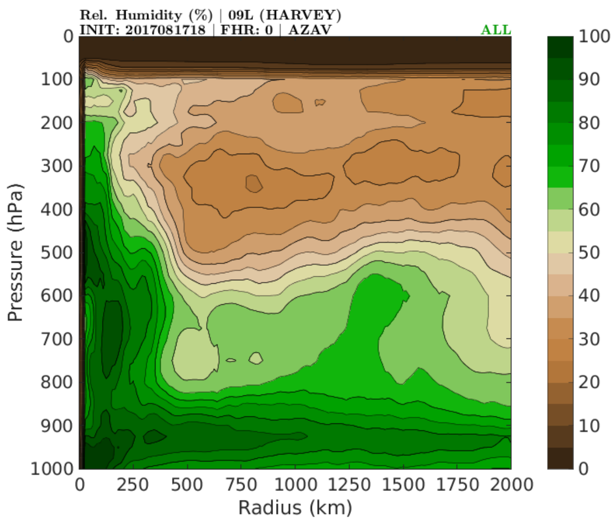
*These graphics are not generated for zonal or meridional wind.

Synoptic Grid

Azimuthal Averages

Radius-Pressure*

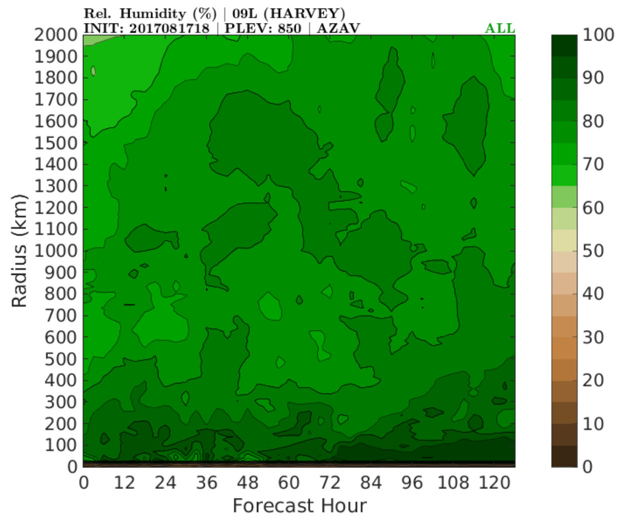
1 CYCLE | 1 FHR | ALL PLEV | ALL RAD | 1 STORM



This graphic is generated for every cycle and forecast hour for every experiment. Difference graphics are also created.

FHR-Radius*

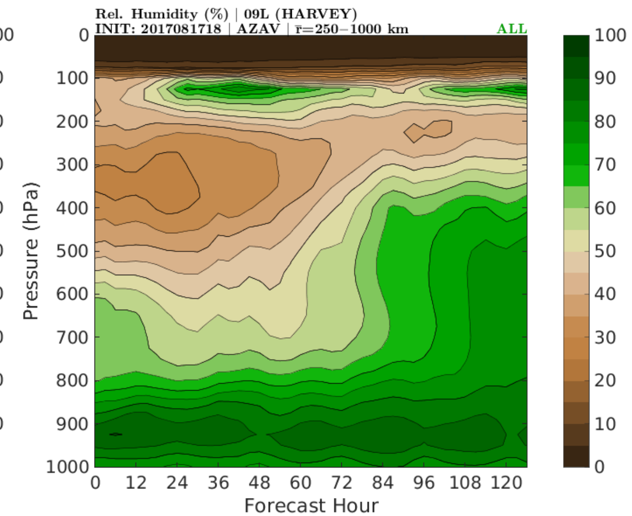
1 CYCLE | ALL FHR | 1 PLEV | ALL RAD | 1 STORM



This graphic is generated for every cycle for every experiment for user-specified PLEVS. Difference graphics are also created.

FHR-Pressure*

1 CYCLE | ALL FHR | ALL PLEV | ALL RAD | 1 STORM

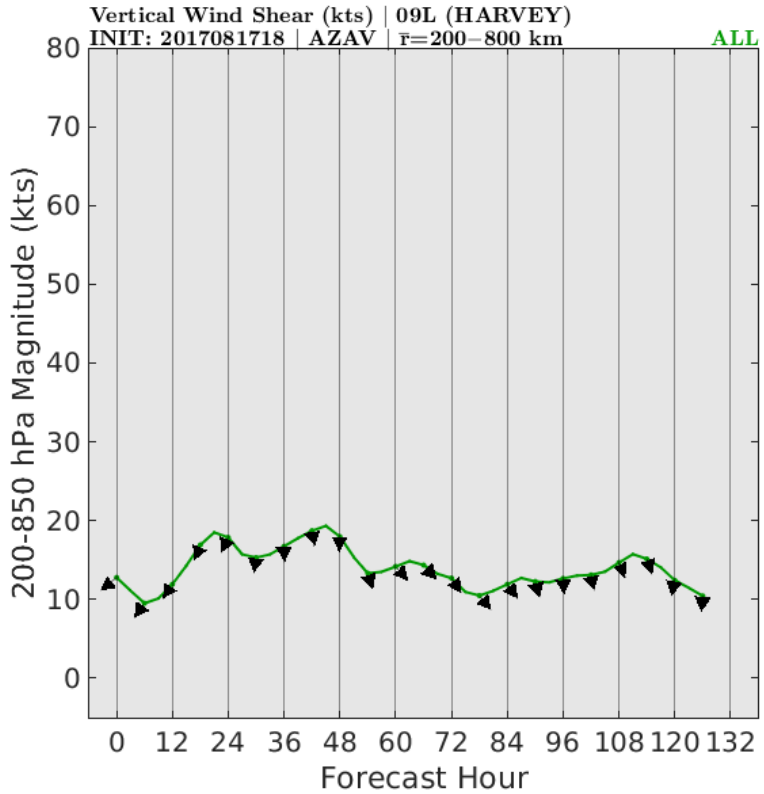


This graphic is generated for every cycle for every experiment for only the 250-1000 km region (Outer Vortex).
Difference graphics are also created.

Synoptic Grid

Vertical Wind Shear

1 CYCLE | ALL FHR | 200-850 hPa PLEV | 200-800 km RAD | 1 STORM



This graphic is generated for every cycle for every experiment. It depicts the vertical wind shear magnitude (line) and direction (arrow).

Edit this text to point to the top-level directory where you want GROOT/ to sit!

Do you want GROOT-H or GROOT-G? Edit all instances with H or G.

*For GROOT-G, place your atcf files for all cycles desired in 1 folder, named according to the experiment run. Do the same treatment for all assimilated observations files for the variable you're testing.

Getting Started

Edit all instances of Jul-26-21 below with the date in the most current file in my /GROOT/package directory

Follow Along

Step 1: Which component do you need, GROOT-H or GROOT-G?

You can checkout the code from GitHub (https://github.com/sditchek/GROOT) or follow the below on Hera…

cd /scratch1/AOML/aoml-osse/Sarah.D.Ditchek/ && mkdir -p GROOT/GROOT-H/ && cp /scratch1/BMC/qosap/Sarah.D.Ditchek/GROOT/package/GROOT-H_graphicspackage-Jul-26-21.tar.gz GROOT/GROOT-H/ && cd GROOT/GROOT-H/ && gunzip GROOT-H_graphicspackage-Jul-26-21.tar.gz && tar -xvf GROOT-H_graphicspackage-Jul-26-21.tar && rm GROOT-H_graphicspackage-Jul-26-21.tar

Step 2: View Your Files

Not in GROOT-G

Not in GROOT-G

```
README   bdeck   editgrb.m   editverif.m   nctoolbox-1.1.3   retrievalscripts   rungrb.ksh   runverif.ksh   scripts
```

Step 3: Read the README!

Step 4: Steps to Run

VERIFICATION CAPABILITY: FULL-STORM GRAPHICS & GRAPHICS THAT ARE CONSISTENT WITH NHC VERIF | VARIOUS STRATIFICATIONS ARE ALSO TAKEN.

1) If you had scrubbing turned ON, run the retrieval scripts in retrievalscripts/ directory to download files needed by the package (read the README)
2) Edit the user settings section of editverif.m for the cases you want to include
3) Edit the user settings section of runverif.ksh - follow the instructions carefully or it won't run
4) Load the matlab module (module load matlab) - this isn't included in the batch scripts in case there is an issue/conflict with your other loaded modules
5) Submit runverif.ksh to batch: sbatch ./runverif.ksh

Step 5: Be Patient!

Kick back and relax – a watched script never finishes! Thousands (tens of thousands if many storms) of graphics are being generated.

If something is not working, do a cat slurm* in your GROOT-H/ or GROOT-G/ directory. Failures typically occur due to user errors in the namelist or since the required files were not retrieved.

Step 6: View Your Results

When the package finishes, you'll receive an email. Go to your directory and there will be a new text file pointing you to the finished results!

NOTE: Script Updates/Bugs

- When there are major script updates, I'll push them to GitHub and will generate a new tarred file on Hera.

The README

Sections
Summary Description of the package
Files and Directories Describes the files included in the package
How To Run The Package Description of the steps you need to take to run the package
Location and Description of Various Results Details the directory structure of where results are located
Key Points A few key points that you should be aware of
New Additions A history of new additions to the package starting from today onward
Issues My contact information in case you have difficulty running or find any bugs!

Required Files By Component

GROOT-H: scripts in the retrievalscripts/ directory are set up to retrieve all required files
GROOT-G: only the Error Statistics and Assimilated Observations component are working currently; ATCF files for all cycles should be placed in 1 folder, named according to the experiment run; do the same treatment for all assimilated observations files for the variable you're testing.

Component	GROOT-H (for each cycle)	GROOT-G (for each cycle)
Error Statistics	*trak.hwrf.atcfunix	*atcfunixp.gfs* *(Note: if you run your global experiments without archiving *atcfunixp.gfs* files, you will not be able to run this component)*
Assimilated Observations	*storm_vit	*storm_vit *(Note: GROOT-G has code to extract tcvitals files since some global workflows do not archive *storm_vit files)*
	*gsi_d02.diag_conv_anl.gz	*anl*.gz or already-unzipped *anl*.nc4 files – either work!
GRB Graphics	*hwrfprs.storm.0p015.f*.grb2	*hwrfprs.storm.0p015.f*.grb2
	hwrfprs.synoptic.0p125.f.grb2	*hwrfprs.synoptic.0p125.f*.grb2

Acknowledgements

Publications

If using output from this graphics package in PUBLICATIONS,
please include the following in the acknowledgements section:

"The GRaphics for OSEs and OSSEs on TCs (GROOT) verification package developed by Dr. Sarah Ditchek and funded by the Quantitative Observing System Assessment Program (QOSAP) and the FY18 Hurricane Supplemental (NOAA Award ID #NA19OAR0220188) was used to generate graphics for this publication."

Presentations

If using output from this graphics package in PRESENTATIONS,
please indicate the following verbally:

"Graphics were made using GROOT – a verification package developed by Dr. Sarah Ditchek and funded by QOSAP and the FY18 Hurricane Supplemental."

THANK YOU FOR YOUR INTEREST IN GROOT!

Dr. Sarah D. Ditchek
Email: sarah.d.ditchek@noaa.gov