The Independent Panel Report

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Outline of the Report

- **1. Executive Summary**
- 2. Background on Suites and Data Used
- **3. Recommendations on Physics Suites**
- 4. Recommendations for the future
- 5. Acknowledgements
- 6. Appendix

PHYSICS SUITES ASSESSED FOR POSSIBLE GFSv16 IMPLEMENTATION

	<u>Suite 1</u> (GFS v15)	<u>Suite 2</u>	<u>Suite 3</u>	<u>Suite 4</u>
Deep convection	sa-SAS	sa-SAS	sa-CS	sa/aa-GF
Shallow convection	sa-MF	sa-MF	sa-MF	MYNN-EDMF and sa GF
Microphysics	GFDL	GFDL	aa-MG3	aa-Thompson
PBL/Turbulence	K-EDMF	sa-TKE-EDMF	K-EDMF	MYNN-EDMF
Land Surface Model	Noah	Noah	Noah	RUC

*aa = aerosol aware

From MEG Presentation

Basis for our recommendation

- Four physics parameterization suites were tested over a large number of cases (every 5 days for 1 year and 16 case studies). A report on the GMTB test setup can be found <u>here</u>.
- The independent panel recommendation is based on a substantial set of verification and evaluation metrics reported from the Environmental Modeling Center (EMC) Model Evaluation Group (MEG), the Global Model Test Bed (GMTB) group in the Developmental Testbed Center (DTC), and EMC's Verification Statistics DataBase (VSDB):
 - MEG presentation: <u>https://drive.google.com/file/d/1Fe-lk6egjxQ5ynZ_xF-</u> <u>TfqjQPlp8h119/view?ts=5c93cc43</u>
 - **GMTB report:**

https://docs.google.com/document/d/1Vyo1zL5N6GowugDCEWOVFlrK83JcOzWK CCSwGvGe_74/edit?ts=5c89156e#heading=h.8d00ooc534fb

• VSDB website:

https://www.emc.ncep.noaa.gov/gmb/wx24fy/NGGPS/phys_cmp/

Executive Summary

- Overall none of the 3 developmental suites were clearly superior to the control GFSv15 physics Suite 1.
- The performance of suite 2 was closest to suite 1 even improving some aspects of the forecasts.
- We encourage work to continue on other suites and new physics packages for future testing.
- We also encourage a similar testing and independent evaluation process on an annual basis in the future.

Recommendations on Physics Suites

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- Suite 2, which features a more advanced closure in the PBL scheme, was the closest in performance to Suite 1 and exhibited improvements in some important aspects including somewhat better capturing surface-based inversions and some better precipitation statistics over CONUS.
- Although overall Suite 2 did not perform as well as Suite 1, there are enough positive aspects in the Suite 2 performance to consider further experimentation and tuning in the near term (time permitting) to see if Suite 2 can be implemented in GFSv16. The panel believes the more advanced PBL may ultimately provide improved forecasts of the PBL.
- Suites 3 and 4 both showed promising results in a number of aspects. We strongly encourage and recommend that the developers of both Suites 3 and 4 continue development and testing. We also recommend the developers to consider consolidating the best aspects of all suites, so attention can be focused on a single advanced development suite in the future.

Recommendations for the Future

- We are supportive of a continued annual process in which an independent panel provides analysis and recommendations on the evaluation of parameterization suites considered for future operations.
- We encourage the testing and evaluation of other combinations of physics from the existing four suites, in addition to emerging physical parameterizations.
- Adequate time for tuning and evaluation is needed prior to test phase. The panel is aware of some issues related to the setups of suites 3 and 4 that impacted their results in this round and that these suites would have been improved given adequate pre-testing.
- Our recommendation is that a pre-test period of a few weeks should be built into the schedule using some of this year's initial data (but independent of the data in the next test).
- It is recognized that this year was special because the physics framework was being changed at the same time as new physics were added, but the new framework should make implementations easier in the future.
- Data assimilation cycling was not included in the current test suite and it may be useful in the future to include more testing with the data assimilation as part of the evaluations.

Summary of Systematic Performance of the Physics Suites Suite 1 (SAS, MF, GFDL MP, K-EDMF, NOAH)

Positive:

- Overall best anomaly correlation and RMSE of synoptic variables of all suites.
- Overall best day 5 over CONUS precipitation ETS and BIAS scores of all suites.
- Together with suite 2, best track and intensity forecast for Tropical Cyclones.

- Increasing cold bias with increasing lead time at 850 hPa and down to the surface. (Addressed with GFDL MP/radiation update?).
- Increased low bias with lead time for 500 hPa heights.
- Precipitation BIAS (too dry) in the Tropics.
- Does not capture warm season low stratus outside the US west coast.
- Struggles with surface temperature inversions
- CERES OLR shows too little high cloud in tropics (as also for suite 2)

Summary of Systematic Performance of the Physics Suites Suite 2 (SAS, MF, GFDL MP, TKE EDMF, NOAH)

Positive:

- Modest improvement of anomaly correlation for 500 hPa temperature, wind and heights.
- Modest improvements for PBL inversions.
- Improved Tropical Cyclone winds over land (Hurricane Irma).
- Best FSS scores for CONUS precip

- Similar to Suite 1, an increased low bias with lead time for 500 hPa heights.
- Degraded RMSE, bias and anomaly correlation for temperature below 850 hPa.
- Cold bias with increasing lead time at 850 hPa and down to the surface, larger than Suite 1.
- Cold bias with increasing lead time near the Tropopause, larger than Suite 1.
- Degradation of precipitation in the Tropics (too dry).
- Small degradation of ETS and BIAS score, and 6h Frequency bias precipitation scores compared with suite 1 over CONUS.
- Colder 2m T BIAS over CONUS than Suite 1 (vs NAM analysis).
- CERES OLR shows too little high cloud in tropics (as suite 1)

Summary of Systematic Performance of the Physics Suites Suite 3 (CS, MF, MG3 MP, K EDMF, NOAH)

Positive:

- Improved surface inversions compared with suite 1
- Improved 2m T bias over Eastern CONUS (large geographical variations in 2m T and RH).
- CERES OLR shows less tropical bias than suites 1 and 2
- Least wind bias against soundings globally (others have negative bias at high levels)

- Degradation of the anomaly correlation of all variables at all verified levels.
- 500 hPa high height bias increasing with forecast lead time.
- Warm temperature bias increasing with forecast lead time in most of the troposphere.
- Very large warm and dry bias in the Tropics (compared with soundings).
- Driest precipitation bias and lowest FSS of all suites in the Tropics.
- Lowest ETS precipitation scores over CONUS compared with all suites.
- Highest bias at heavy rain categories (esp. 6h at 00Z) over CONUS
- Degradation of Tropical Cyclone tracks and intensity compared with suite 1.
- CERES TOA SW too little cloudiness over oceans (more bias than other suites)
- Some unusual soundings noted by MEG

Summary of Systematic Performance of the Physics Suites Suite 4 (GF, MYNN EDMF/GF, Thompson MP, MYNN EDMF, RUC LSM)

Positive:

- Improved precipitation forecasts in the Tropics.
- Encouraging improvements for PBL inversions. In many cases better than suites 1 and 2 as shown by MEG.
- Improved relationship between surface precipitation and total precipitable water in the tropics.
- Locally much improved 2m T and RH over CONUS, but large geographical variations (sometimes locally much degraded 2m RH).
- Improved 850 hPa temperature BIAS and 500 hPa geopotential height BIAS compared with all other suites.
- Only suite consistently able to capture warm season low stratus along west coast (also seen with CERES SW JJA verification off S. America and S African west coasts and generally less biased cloud cover over oceans) 2m T at southwest coast much better than other suites possibly because of more clouds
- CERES OLR shows less tropical bias than suites 1 and 2
- From SURFRAD sites SW tends to be cloudier than other suites (often better)

- Degradation of the anomaly correlation of all variables at all verified levels.
- 500 hPa high height anomaly correlation scores decreasing with forecast lead time.
- Larger cold bias (compared with suite 1) near the surface and the tropopause.
- Degradation of Tropical Cyclone tracks and intensity.
- Statistically significantly worse precipitation dry bias than other suites for amounts between 10-25 mm/24h over CONUS.
- Extreme precipitation amounts not captured well. Lowest FSS over CONUS.
- Tends to overmix the daytime PBL, not maintaining capping inversions.
- Tends to be drier for 2m Td in central US and more moist on coasts than other suites

Acknowledgements

We would like to thank the following people and organizations for their help, analysis, datasets and collaboration in this process.

- o Jack Kain, Ligia Bernardet, Geoff Manikin
- Fanglin Yang, Ratko Vasic, Linus Magnusson (ECMWF)
- EMC, GMTB, MEG, DTC for providing runs, datasets and analyses
- All who contributed to the development of the physics suites

Appendix

Scorecards

00Z and 12Z Initializations Scored Separately

	EMC Verification Scorecard									
	Symbol Legend									
•	SUITE2 is better than SUITE1 at the 99.9% significance level									
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	No statistically significant difference between SUITE2 and SUITE1									
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	Not statistically relevant									
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00Z RUNS

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	EMC Verification Scorecard
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	EMC Verification Scorecard
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	significance level
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	No statistically significant difference between
	SUITE4 and SUITE1
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	Start Date: 20160101
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RMSE	Vector	200hPa	▼	▼	▼	▼	+		•	▼	▼	▼	▼	•	▼	•	▼	▼	▼	▼	▼	•	▼	▼	•	•				
	wind	500hPa	▼	•	•	•			•	•	▼	•	•	•	•	▼	+	▼	▼	▼	▼	•	▼	•	•	•				
		700hPa	▼	▼	•	▼			•	▼	▼	▼	•	•	•	•	•	▼	▼	•	▼	▼	▼	•	•	•				
		850hPa	▼	▼	▼	▼			•	▼	▼	▼	▼		▼	•	•	▼	▼	•	▼	•	▼	•	•	•				
		1000hPa		▼	▼	▼			•	▼	▼	▼	▼		•	▼	•	▼	▼	+	▼	▼		▼	•	▼				
		10hPa			+													•												
		20hPa			•		►	•			•	►	•	•		•	•					•	•	•						
		50hPa	►					•	•	•	•	•	•	•	•	•	•	▼		►										
		100hPa	•						•	•	•	▼	•	•	•	•	•	▼	•	•	•									
	Temp	200hPa	▼	▼	▼	▼			▼	▼	▼	▼	▼	▼	▼	▼	•	▼	▼	▼	▼	▼								
		500hPa	▼	▼	▼	▼			▼	▼	▼	▼	▼	•	▼	•	•	▼	•	▼	▼	▼	▼			•				
		700hPa	▼	▼	▼	▼	•			▼	▼	▼	▼	•	▼	▼	▼	▼	▼	•	▼	▼	▼			▼				
		850hPa	V	▼	▼	▼		▼	▼	▼	▼	▼	•	▼	•	▼	•	▼	▼	•	▼	•	V			•				
		1000hPa			•			•	•	•			•	•	•	▼	V	▼	▼	V	▼		•			V				

EMC	Verific	ation	Sco	ore	car	d			SUI	TE2	is be nce l	etter i	than	son	Ela	t the	99.9	%			SU	ITE2	is w	orse	than	SUIT	E1 at th	e 95%	6		
	Symbo	ol Leg	;en (d				. ⊢	SUI	TE2	is be	etter	than	SUIT	E1 a	t the	99%			⊣∟	sig	nifica	nce	level	l						
St	art Dat	te: 201	160	101				· ^	sign	ifica	nce l	level								-	SU	ITE2	is w	orse	than	SUIT	E1 at th	e 99%	6		007
E	nd Dat	e: 201	801	110				· 🗌	SUI	TE2	is be	tter	than	SUIT	E1 a	t the	95%			ᆂ	sig	nifica	nce	leve	1	01117	T 1 of the	- 00.0	10/		002
								· 📕	sign	ifica	nce l	evel								_ •	sig	nifica	nce	orse level	than	5011	El at th	e 99.9	70	ſ	RUN:
	SII	ITF	2						SUI	statis TE2	and	IV SIĮ SUIT	Znifio FE 1	cant o	iller	ence	betw	een			No	t stati	istica	lly r	eleva	int					
			<u> </u>													~															
			D	l D-u	N. Ar	neric	an	D	D	N	. Her	nisph	ere	D	D	S	. Hen	aisph	ere	D	D	D	Tre	pics	D	D	-				
			Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10					
		10hPa	-	- -	V	V	Ť	•		- -	- -	V	V	•	-	- -	- -	V	V	•	-	- -	•	•	V	•	1				
		20hPa		÷.	Ť	Ť	÷	Ť		÷	Ť	Ť	Ť	, T		Ť	÷	Ť	Ť	· •		Ť	Ť	Ť.	Ť	,	1				
		50hPa	•	Ť.	Ť	Ť	Ť	Ť		Ť	Ť	Ť	Ť	Ť		Ť	Ť	Ť	Ť	, ,		Ť	·	×.	Ť	Ť.					
		100hPa		•	▼	▼	•	•		•	•	▼	•	•		•	•	•	•	•			•	▼	•	▼					
	Heights	200hPa					•	•			•	•	•	•			•	•	•	•			▼	▼	•	•					
		500hPa																													
		700hPa	▼	+														•	+	+	•										
		850hPa	▼	•											•	▼	•	•			•					*					
		1000hPa		•	•				•	•	•	•	•		•	•	•	•	•	+											
		10hPa													•						•	•		▼							
		20hPa			•				•		•				•						•	•	•		•	•					
		50hPa							•						•	•	•	•			•	•	•	•	•	•					
		100hPa																			•	•	•	▼	•	▼					
Bias	Wind	200hPa	•	•	•	▼			•	•	•	•	•	•	•	•	•	•	•	•	•	▼	▼	▼	•	•					
	Speed	500hPa	▼	•	▼	▼	•		•	•	•	▼	•	•	•	•	•	•	•		•	▼	▼	▼	•	▼					
		700hPa	▼	•	▼	▼	•	•	•	•	•	▼	•	•		•	•	•			•	▼	▼	▼	•	•					
		850hPa								•	•	▼			•	•	•	•				•	▼	▼	▼	▼					
		1000hPa	▼						•												•	•									
		10hPa	▼	•	•	▼	▼	•	•	•	▼	•	•	•	•	•	▼	▼	•	•			▼								
		20hPa																			•		▼	▼	•	•					
		50hPa		•							•	▼	▼	•			•		•	•		•	▼	▼	▼	▼	1				
		100hPa																			•										
	Temp	200hPa		•	▼	▼	•	▼	▼	▼	▼	▼	▼	•		▼	▼	▼	•	•			V	▼	•	•	1				
		500hPa																				▼	V	▼							
		700hPa													•						▼										
		850hPa	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	•	▼	▼	▼	▼	•	•				•							
		1000hPa						•		•				•						•				•		•					

EMC Verification Scorecard	
Symbol Legend	
Start Date: 20160101	
End Date: 20180110	

SUITE 3

•	SUITE3 is better than SUITE1 at the 99.9% significance level		SUITE3 is worse than SUITE1 at the 95%
٢	SUITE3 is better than SUITE1 at the 99% significance level		SUITE3 is worse than SUITE1 at the 99%
	SUITE3 is better than SUITE1 at the 95% significance level	•	SUITE3 is worse than SUITE1 at the 99.9%
	No statistically significant difference between SUITE3 and SUITE1		significance level Not statistically relevant

				I	l. An	neric	an			N	. Her	nisph	ere			S	. Hen	1isph	ere				Tr	opics		
			Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day
			1	3	5	6	8	10	1	3	5	6	8	10	1	3	5	6	8	10	1	3	5	6	8	10
		10hPa																								
		20hPa																			▼	▼				
		50hPa		▼					•	▼	▼				▼	▼					▼	▼	▼	▼		•
		100hPa							•	•	•				•	•	•				•	•	•	•		
	Heights	200hPa							►	•	•	•		►	▼	►	►	►			►	►	►	►		
		500hPa									•	•		•							•	•	•	•		•
		700hPa						•							▼	▼	▼	▼	•	•	▼					
		850hPa	•					•							▼	▼					•					
		1000hPa	•						•	•	•				•						•	•		•		
		10hPa					•					•		•			•	•	•					•		
		20hPa			•																		•			
		50hPa						•		▼	•	•	•	▼		▼	▼	▼	▼	•				▼		
		100hPa	•	•	•	•	•	•	•	•	•	•	▼	•	•	•	▼	▼	•	•		•	•	•	•	•
Riss	Wind	200hPa																			▼					
Dias	Speed	500hPa					•	•				•	▼	•					▼	•						•
		700hPa	▼				•	▼				•	▼	•				•	•	▼						•
		850hPa						+						+			▼	▼	•	•	•	•	•	•		•
		1000hPa	•	•											▼				▼		▼					▼
		10hPa																								
		20hPa		•				•		•	+	•	▼	+							▼	▼	▼	▼	▼	▼
		50hPa	•										•	▼	+						•	▼	▼	▼	•	•
		100hPa	•	•	•	•	•	•		•	•	•	•	•	▼	•	•	•	•	•			•	▼	•	•
	Temp	200hPa													▼							▼	•	▼	•	▼
		500hPa							▼									▼			▼					
		700hPa																								
		850hPa							•	▼	•										•					•
		1000hPa							▼							▼					•					

EMC Verification Scorecard		SUITE4 is better than SUITE1 at the 99.9%	ŀ	SUITE4 is worse than SUITE1 at the 95%	
Symbol Legend	F	SUITE4 is better than SUITE1 at the 99%	1-	significance level	
Start Date: 20160101	Ĺ	significance level	ŀ	significance level	00Z
End Date: 20180110	L	SUITE4 is better than SUITE1 at the 95%	I,	SUITE4 is worse than SUITE1 at the 99.9%	RUNS
SUITE 4		No statistically significant difference between SUITE4 and SUITE1		significance level Not statistically relevant	Kong

				1	N. Ar	neric	an			Ν	. Her	nisph	ere			S	. Hen	isph	ere				Tre	opics		
			Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day
			1	3	5	6	8	10	1	3	5	6	8	10	1	3	5	6	8	10	1	3	5	6	8	10
		10hPa							•	•					•	•						•				
		20hPa		•					•	•					•	•					•	•				
		50hPa							►						•						•					
		100hPa	•						•						•											
	Heights	200hPa	•						•						•						▼					
		500hPa							•						•											
		700hPa					•								•				•		•					
		850hPa		•					•	•												•				
		1000hPa		•					•	•	•	•	•	•	•	•	•	•								
		10hPa																								
		20hPa																						•		
		50hPa										•	•	+							•		•		+	
		100hPa	▼				•	•	▼						▼						▼	•				
Bias	Wind	200hPa	•						▼						▼						•					
	Speed	500hPa																			▼			•	•	•
		700hPa																			•				•	▼
		850hPa							•												•	•		•		▼
		1000hPa			+	+										•	•	•	•	•						▼
		10hPa			▼	•					•						▼									
		20hPa	▼	▼	▼	•	•		▼	•	▼	▼	▼	▼	▼	▼	▼	•	•	V	▼	▼	▼	•	•	▼
		50hPa	▼	•	•	•	•	•	•	•	▼	▼	▼	•	▼	•	▼	▼	•	•	•	•	•	•	•	▼
		100hPa																			•					
	Temp	200hPa		•	•	•	•		▼	•	►		•	•	•	•		►	•	٠	•	•				
		500hPa								•				•							•	▼				
		700hPa												•												▼
		850hPa	•		*	*			•						•							•				▼
		1000hPa								▼				▼												▼

	EMC Verification Scorecard
	Symbol Legend
•	SUITE2 is better than SUITE1 at the 99.9% significance level
•	SUITE2 is better than SUITE1 at the 99% significance level
	SUITE2 is better than SUITE1 at the 95% significance level
	No statistically significant difference between SUITE2 and SUITE1
	SUITE2 is worse than SUITE1 at the 95% significance level
•	SUITE2 is worse than SUITE1 at the 99% significance level
•	SUITE2 is worse than SUITE1 at the 99.9% significance level
	Not statistically relevant
	Start Date: 20160101
	End Date: 20180110

12Z RUNS

				N	l. An	ieric	an			N.	. Hen	nisph	ere			S.	Hem	isph	ere				Tro	pics		
			Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10
		250hPa							▼				▼	+	▼											
	Heighte	500hPa																								
	rieigins	700hPa												•	•											
		1000hPa	►						•						•	•	•		•	•						
	Vector	250hPa																								
Anomaly	Wind	500hPa																								
Correlation		850hPa																								
		250hPa					•						•													
	Temp	500hPa											•													
		850hPa	►	•		•	•			•	•	•		•	•	•	•		•							
	MSLP	MSL								•					•		•	•	•	•						

	EMC Verification Scorecard
	Symbol Legend
	SUITE3 is better than SUITE1 at the 99.9%
	significance level
	SUITE3 is better than SUITE1 at the 99%
	significance level
	SUITE3 is better than SUITE1 at the 95%
	significance level
	No statistically significant difference between
	SUITE3 and SUITE1
	SUITE3 is worse than SUITE1 at the 95%
	significance level
	SUITE3 is worse than SUITE1 at the 99%
	significance level
•	SUITE3 is worse than SUITE1 at the 99.9%
	significance level
	Not statistically relevant
	Start Date: 20160101
	End Date: 20180110

12Z RUNS

				Ν	V. An	aeric	an			N	. Hen	nisph	ere			S.	. Hen	isph	ere				Tro	opics		
			Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10
		250hPa	•		•	•		•	•	▼	▼	•	►	•	•	•	•	•	•	►						
	Heighte	500hPa	•		•	•		•	•		•	•	•	•	•	•	•	•								
	rieignis	700hPa	•		•	•	•		•		•	•	►	•	•	•		•		•						
		1000hPa	•		•	•			•			•	►	•	•	•		•		•						
	T.	250hPa				•	•	►	•		•	•	►	▼	•	•		►		►						
Anomaly	Wind	500hPa	•	•	•	•	•	•	•	•	•	•	•	•	•	•			•	•						
Correlation	Willia	850hPa	•		•	•			•	•	•	•	►	•	•	•	•	•		►						
		250hPa	•		•	•	•	•	•		•	•	•	•	•	•		•		•						
	Temp	500hPa	•		•	•	•		•		•	•	►	•	•	•				►						
		850hPa																								
	MSLP	MSL				•			•		•	•		•	•	•			•							

	EMC Verification Scorecard
	Symbol Legend
	SUITE4 is better than SUITE1 at the 99.9%
	significance level
	SUITE4 is better than SUITE1 at the 99%
	significance level
	SUITE4 is better than SUITE1 at the 95%
	significance level
	No statistically significant difference between
	SUITE4 and SUITE1
	SUITE4 is worse than SUITE1 at the 95%
	significance level
	SUITE4 is worse than SUITE1 at the 99%
	significance level
,	SUITE4 is worse than SUITE1 at the 99.9%
	significance level
	Not statistically relevant
	Start Date: 20160101
	End Date: 20180110

12Z RUNS

				ľ	V. An	aeric	an			N	. Hen	nisph	ere			S.	. Hen	ıisph	ere				Tro	opics		
			Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10
		250hPa			►	•		•	▼	•		•	•	•	▼	•	•	▼		•						
	Unights	500hPa			•	•		•	•	•		•	•	•	•		•	•		•						
	rieignis	700hPa			►	•		•	•	•		•	•	•	•	•	•	•		▼						
		1000hPa			►	•		•	•	•		•	V	•	•	•	V	•		►						
Anomalia	Vector	250hPa			►			•	•	•		•		•	•			•								
Correlation	Wind	500hPa			►			•	▼	•		•	•	•	•	•	•	•								
Correlation	WING	850hPa			►	•		•	•	•		•	•	•	•	•	•	•								
		250hPa			►	•		•	•	•		•	V	•	•	•	V	•		►						
	Temp	500hPa			►	•		•	•	•		•	•	•	•		•	•		►						
		850hPa												•												
	MSLP	MSL						•						•												

EMC Verification Scorecard
Symbol Legend
Start Date: 20160101
End Date: 20180110

SUITE 2

	SUITE2 is better than SUITE1 at the 99.9% significance level		SUITE2 is worse than SUITE1 at the 95%
•	SUITE2 is better than SUITE1 at the 99% significance level	-	significance level SUITE2 is worse than SUITE1 at the 99%
	SUITE2 is better than SUITE1 at the 95% significance level	-	SUITE2 is worse than SUITE1 at the 99.9%
	No statistically significant difference between SUITE2 and SUITE1		significance level Not statistically relevant

12Z RUNS

				ľ	V. An	ierica	an			N.	. Hen	nisph	ere			S.	Hem	isph	ere				Tro	pics		
			Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day
		10bDa	1	3	2	6	8	10		3		6	8	10		3	2	6	8	10		3		6	8	10
		1011Fa	-	÷	÷	÷	-	÷		-	÷	÷	-			÷	-	÷	÷	-		-	÷	÷	÷	-
		20nPa	-	<u> </u>	<u></u>	-	<u> </u>	<u> </u>	-		-	<u> </u>	-	<u> </u>	<u>·</u>	<u> </u>		-	<u> </u>	-	<u> </u>	<u> </u>				
		JOnPa	•	÷	-				•	-	÷	÷	-		•	÷			÷	<u> </u>		×				
	TT : 1.	200hDa			•	•	•			•		•	÷	-		•	•	•	•	•			-	-	÷	-
	Heights	20011Pa						-			<u>^</u>		÷	•		^ _							•	•	· ·	•
		700hDa											•		-						-					
		700IIFa	-			-		-	-					•	-	-	-	-			· ·			_	-	-
		850nPa	-		-	^	-		<u> </u>			-			-	-	-	-	-	-		-	-		-	
		1000hPa	-				<u>^</u>		<u> </u>		_	<u>^</u>	_	_	•	•	•	•	•		_					
		10hPa	•				•	•	•		•	•	•	•							•				•	
		20hPa						•	•		•		▼	•							•	•	•		▼	
		50hPa							•				•		•	•					•	•				
	Vector	100hPa				•			•	•					•	•	•	•			•	•			•	
RMSE	Wind	200hPa					*														•					
		500hPa																								
		700hPa																								
		850hPa																								
		1000hPa																								•
		10hPa										•								•						
		20hPa				4		►																		
		50hPa	•	•	•	•			•	•	•	•	•	•			•	•			•	•	•	•	•	•
		100hPa	▼	▼					▼	▼	•				▼	▼		•			▼	•	▼	•		
	Temp	200hPa	•	•			+		•	•	•	•	•	•	•	•	•	▼	+				▼	•	•	•
		500hPa																					▼	▼	▼	▼
		700hPa											•		▼	•	•	▼	▼		•			•		
		850hPa	V	▼	▼	•	V	•	•	V	▼	▼	▼	V	▼	•	▼	▼	▼	V	▼	•	V	▼	•	•
		1000hPa	•	•	▼	•	•	▼	▼	▼	▼	▼	•	V	▼	•	•	▼	▼	V	•	•	•	▼	▼	•

EMC Verification Scorecard
Symbol Legend
Start Date: 20160101
End Date: 20180110

SUITE 3

	SUITE3 is better than SUITE1 at the 99.9% significance level		SUITE3 is worse than SUITE1 at the 95%
•	SUITE3 is better than SUITE1 at the 99% significance level		SUITE3 is worse than SUITE1 at the 99%
	SUITE3 is better than SUITE1 at the 95% significance level	-	SUITE3 is worse than SUITE1 at the 99.9%
	No statistically significant difference between SUITE3 and SUITE1		significance level Not statistically relevant

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EMC Verification Scorecard
Symbol Legend
Start Date: 20160101
End Date: 20180110

SUITE 3

•	SUITE3 is better than SUITE1 at the 99.9% significance level		SUITE3 is worse than SUITE1 at the 95%
•	SUITE3 is better than SUITE1 at the 99% significance level	•	SUITE3 is worse than SUITE1 at the 99%
	SUITE3 is better than SUITE1 at the 95% significance level	•	SUITE3 is worse than SUITE1 at the 99.9%
	No statistically significant difference between SUITE3 and SUITE1		significance level Not statistically relevant

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			Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day
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		10hPa		A	A	A			A									A				A	A			A
		20hPa		A	A	A			A		A							A			<u> </u>	_	_		-	_
		50hPa		A		A			-		-				A	<u> </u>		A			-	-	-	-	<u> </u>	<u> </u>
		100hPa							-	<u> </u>	-	-	-		A				A	-	<u> </u>	-	•	•	•	
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		200hPa									•		•						-	-	-	•	•	•	•	
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		850hPa							▼	▼	▼			•							▼		•	▼	•	•
		1000hPa																							•	•

EMC Verification Scorecard		SUITE4 is better than SUITE1 at the 99.9%	-	SUITE4 is worse than SUITE1 at the 95%	
Symbol Legend	⊢	significance level		significance level	
Start Date: 20160101	Ĺ	significance level	-	SUITE4 is worse than SUITE1 at the 99%	127
End Date: 20180110	Γ	SUITE4 is better than SUITE1 at the 95%	Ŀ	SUITE4 is worse than SUITE1 at the 99.9%	PLIN
SUITE 4	F	No statistically significant difference between SUITE4 and SUITE1	Ŀ	significance level Not statistically relevant	
					-

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			Day	Day	Day	Day	Day	Day	Day	Day																
			1	3	5	6	8	10	1	3	5	6	8	10	1	3	5	6	8	10	1	3	5	6	8	10
		10hPa	<u> </u>	<u> </u>					<u> </u>	•					<u> </u>	•					-	-	•	•	•	
		20hPa	<u> </u>	•			A		<u> </u>		A	A	A	A	<u> </u>		A	A	A		-	•	A	A		
		50hPa	<u> </u>				A		<u> </u>						<u> </u>	A	A				-	A	A	A	A	
		100hPa	-	A							A					A	A	A			-		A	A	A	
	Heights	200hPa		A	A	A	A		•	A	A				•	A	A	A	A		•	A	A	A	A	
		500hPa					A	A	^	A	A	A	A	A	· -	A	A					A	A	A	A	
		700hPa	_						_			A	A	A	•	A	A		•	-	-					
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ļ		1000hPa	•	•	•	•	•	•							▼	•	•	•	•	•		•	•	•	•	•
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VSDB output (20160106-20171226 12 UTC inits)

for SUITE2 and SUITE1

2016-01-06 12:00:00 - 2017-12-26 12:00:00

				N	EC			A	PL			M	DW			LI	мv			G	мс			SI	EC	
			Day 1	Day 3	Day 5	Day 7	Day 1	Day 3	Day 5	Day 7	Day 1	Day 3	Day 5	Day 7	Day 1	Day 3	Day 5	Day 7	Day 1	Day 3	Day 5	Day 7	Day 1	Day 3	Day 5	Day 7
DWSE	2m Temp	SFC		•	•	•		•	•		•	•	•	•			•	•								
RNISE	2m RH	SFC																								
RMSE	10m Vector Wind	SFC																								
ME	2m Temp	SFC	•	•	▼	•	•	•	•		•	•	•	•	•	•	•	•								
MIL	2m RH	SFC					•	•	•	•		•	•													
Bias	10m Wind Speed	SFC						•																		
SUI	TE2 is better than TE2 is better than TE2 is better than Statistically signifi	SUI SUI SUI	FE1 at FE1 at FE1 at differe	the 99 the 99 the 95 nce be	9.9% si 9% sig 16% sig 16% sign	ignifica nificano nificano SUITE	nce leve ce leve ce leve 22 and	vel 1 1 SUITH	31																	
SU	TE2 is worse than	SUI	TE1 at	the 95	5% sig	nifican	ce leve	l																		

SUITE2 is worse than SUITE1 at the 99% significance level
 SUITE2 is worse than SUITE1 at the 99.9% significance level
 Not statistically relevant

Figure SC1. Scorecard documenting performance of Suite 2 as compared to Suite 1 over the subregions across the eastern portions of the CONUS for RMSE and mean error (also referred to as bias) of 2-m temperature, 2-m RH, and 10-m winds by forecast lead time 12 UTC initializations during the entire test

temperature, 2-m RH, and 10-m winds by forecast lead time 12 UTC initializations during the entire test period (20160101-20171231). Green (red) marks indicate Suite 2 (Suite 1) is better than Suite 1 (Suite 2). Statistical significance is represented by the type of marks: shading, small arrows, and large arrows indicate 95%, 99%, and 99.9% significance, respectively.

VSDB output (20160101-20171231 00 UTC inits) for SUITE3 and SUITE1

2016-01-01 00:00:00 - 2017-12-31 00:00:00



▲ SUITE3 is better than SUITE1 at the 99.9% significance level
 △ SUITE3 is better than SUITE1 at the 99% significance level
 SUITE3 is better than SUITE1 at the 95% significance level
 SUITE3 is worse than SUITE1 at the 95% significance level
 ○ SUITE3 is worse than SUITE1 at the 99% significance level
 ○ SUITE3 is worse than SUITE1 at the 99% significance level
 ○ SUITE3 is worse than SUITE1 at the 99% significance level
 ○ SUITE3 is worse than SUITE1 at the 99% significance level

Not statistically relevant

Figure SC2. Scorecard documenting performance of Suite 3 as compared to Suite 1 over the NH, SH, and Tropics for RMSE and bias of temperature, RH, and winds at various pressure levels by forecast lead time for 00 UTC initializations during the entire test period (20160101-20171231). Green (red) marks indicate Suite 3 (Suite 1) is better than Suite 1 (Suite 3). Statistical significance is represented by the type of marks: shading, open arrows, and filled arrows indicate 95%, 99%, and 99.9% significance, respectively.

PRECIP SCORECARDS

ETS for NH, SH, & Tropics. All symbols are relative to Suite 1

MET output (20160101-20171231 00 UTC inits) for GFS_suite2_0p25_FCST and GFS_suite1_0p25_FCST

2016-01-01 00:00:00 - 2017-12-31 00:00:00

						N	H								SI	H								TR	OP			
		f36	f60	f84	f108	f132	f156	f180	f204	f228	f36	f60	f84	f108	f132	f156	f180	f204	f228	f36	f60	f84	f108	f132	f156	f180	f204	f228
	>=0.254														\square													
	>=0.508		\bigtriangledown								$ \bigtriangleup $													\sim	•	-		
	>=1.270	•	•	•		\sim					\sim	•	-	•	\sim					•	•	•	•	•	•	•	•	•
	>=2.540	•	•								\bigtriangledown	•								•	•	•	•	•	•	•	•	•
GSS 24-h Accum Pcp	>=3.810	•	•																	•	•	•	-	-	-	-	-	-
	>=6.350	\bigtriangledown																		•	•	•	•	•	•	•	•	•
	>=8.890																	\triangleleft		-	•	-	-	-	•	•	•	-
	>=12.700																	\sim		•	•	•	-	-	-	-	-	-
	>=25.400												•					\triangleleft			•	•	-	•	•	\sim		-

MET output (20160101-20171231 00 UTC inits) for GFS_suite3_0p25_FCST and GFS_suite1_0p25_FCST

2016-01-01 00:00:00 - 2017-12-31 00:00:00

							N	н								SI	I								TR	OP			
			f36	f60	f84	f108	f132	f156	f180	f204	f228	f36	f60	f84	f108	f132	f156	f180	f204	f228	f36	f60	f84	f108	f132	f156	5 f180	f204	f22
		>=0.254		\triangleleft	•	•	•	•				•	•	-	•	•	•												
		>=0.508	-	-	•	•	•	•				•	•	-	•	•													
		>=1.270	•	•	•	•	-	•	•	•		•	•	-	•	•	•				•	•	•	•	•	•	•	•	•
		>=2.540	•	•	-	-	-	-	\sim	\sim		•	•	-	-	-	-	\sim	\sim		•	•	•	-	-	-	-	-	-
GSS	24-h Accum Pcp	>=3.810	•	•	-	-	-	-	\sim			•	•	-	-	-	-	\sim	\sim		•	•	•	-	-	-	-	-	-
		>=6.350	•	•	•	-	•	-				•	•	•	-	-	-	-	\sim	-	•	•	•	•	-	•	-	-	-
		>=8.890	•	•	•	•	•	•				•	•	•	•	•	•	•	-	-	•	•	•	•	•	•	•	•	-
		>=12.700	•	•	•	-	•	-				•	•	•	-	•	-	-	-	-	•	•	•	-	-	•	-	-	-
		>=25.400	-	-	•	-	•	•	•			-	-	-	•	-	-	•	-		-	-	-	•	•	•	•	•	•

MET output (20160101-20171231 00 UTC inits)

for GFS_suite4_0p25_FCST and GFS_suite1_0p25_FCST

2016-01-01 00:00:00 - 2017-12-31 00:00:00

							N	e C								SI	I								TR	ор			
			f36	f60	f84	f108	f132	f156	f180	f2041	f228	f36	f60	f84	f108	f132	f156	f180	f204	f228	f36	f60	f84	f108	f132	f156	f180	f204	f228
		>=0.254					\sim	\sim								\sim			$ \land $									-	
		>=0.508	\bigtriangledown	•	\bigtriangledown		\sim	•							\sim														
		>=1.270	•	•	•	-	•	•	\sim			•	•	•	•	\sim	•				\bigtriangledown								
		>=2.540	•	•	•	-	-	•	\sim			•	•	•	•	-	-	•		\diamond	•	\sim		•	-				
GSS	24-h Accum Pcp	>=3.810	•	•	•	-	-	•	\sim			•	•	•	•	-	•	•	\diamond	\diamond		\bigtriangledown	\bigtriangledown	•	-	•	•	\sim	
		>=6.350	•	•	•	•	•	•				•	•	•	•	•	•	•	\triangleleft			•	•	•	-	•	•	•	•
		>=8.890	•	•	•	-	-	•				•	•	•	•	\sim	-					-	•	•	-	•	-	-	-
		>=12.700	•	•	•	-	-	•				$\overline{}$	\sim	\bigtriangledown	\sim		\sim				•	-	•	•	-	•	-	-	•
		>=25.400	•	•	\sim	\sim	\sim	•				•		\sim		•					•	-	•	•	-	•	•	\sim	•

	GFS_suite4_0p25_FCST is better than GFS_suite1_0p25_FCST at the 99.9% significance level
$ \bigtriangleup $	GFS_suite4_0p25_FCST is better than GFS_suite1_0p25_FCST at the 99% significance level
	GFS_suite4_0p25_FCST is better than GFS_suite1_0p25_FCST at the 95% significance level
	GFS_suite4_0p25_FCST is worse than GFS_suite1_0p25_FCST at the 95% significance level
	GFS_suite4_0p25_FCST is worse than GFS_suite1_0p25_FCST at the 95% significance level
\sim	GFS_suite4_0p25_FCST is worse than GFS_suite1_0p25_FCST at the 99% significance level
•	GFS_suite4_0p25_FCST is worse than GFS_suite1_0p25_FCST at the 99.9% significance level
	Not statistically relevant

SUITE 2

SUITE 3

SUITE 4

Statistics provided by GMTB

PRECIP SCORECARDS

MET output (20160101-20171231 00 UTC inits) for GFS_suite2_0p25_G218 and GFS_suite1_0p25_G218



MET output (20160101-20171231 00 UTC inits)

for GFS_suite3_0p25_G218 and GFS_suite1_0p25_G218

2016-01-01 00:00:00 - 2017-12-31 00:00:00

																								CC	NUS																	
			f06	f12	f18	5f24	f30	f36	f42 f	48 f	54 f	60 f	f661	f72	f78	f84	f90	f96	f102	f 10	8f114	f120	f120	5f13	2f138	8f14	4f15	50 f150	f16	2 fl 68	8 f174	f180)f186	5 f192	2 f198	8 f204	4f21	10 f216	5f222	f228	8 f23	4 f240
		>=0.254	\bigtriangledown	۲	•	•				•			∇	۲	•			•			∇					V					\bigtriangledown	1										
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		>=1.270	•	۲	∇				1	∇	•		¥	V	•		1	T	∇	T		T			∇	∇				2						8					1	
	(1 A	>=2.540	•	۷			V		1	$\overline{\nabla}$		V	∇	۲	•			∇	∇	Y		۷	∇			1	8				V	1	Ű.			сс - с						
GSS	6-n Accum	>=3.810	۲	۲			۲			•		V	۷	۲	∇	∇			\bigtriangledown	Y		۲	\bigtriangledown																			
	rep	>=6.350	•		∇		V					V			∇		∇			∇		•	∇				1			1						Ĩ.						
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		>=12.700			∇							•										∇	∇														8					
		>=25.400			∇																						1	Δ								1	1					

MET output (20160101-20171231 00 UTC inits) for GFS_suite4_0p25_G218 and GFS_suite1_0p25_G218

2016-01-01 00:00:00 - 2017-12-31 00:00:00

																							CO	NUS																	
			f06	12	18	24 f	30 f	36 f-	42 f4	48 f.	54 f (0 f6	6f7	2 f7	8 f8	4 f9	0 f96	f102	f108	8 f114	f120	f126	f132	f138	f144	f150	f156	f162	f168	f174	f180	f186	f192	f19	8 f20-	4f21	0 f210	5 f222	f228	f234	f240
		>=0.254			•	•	\bigtriangledown			7	1 2	7 7		7 7	7		∇	∇	∇	۲																					
		>=0.508			•	5	∇		•	•		7 7		7 7	7		∇		∇	\bigtriangledown					•																
		>=1.270								•	•	1	7						∇					∇	∇																
		>=2.540			\triangle							7			1	7	1		∇					1	1									49 							
GSS	6-h Accum	>=3.810							2	7		7							1																						
	гер	>=6.350	•							7	7 5	7																1						1							
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		>=12.700	•	∇																		\bigtriangledown	∇		∇																
		>=25.400													7	7																									

GSS for CONUS All symbols are relative to Suite 1

SUITE 2

SUITE 3

SUITE 4

Statistics provided by GMTB

CERES TOA SW JJA 5-day









less JJA NH cloud bias over oceans in suite 4 especially off west coasts - similar for SH DJF (not shown)

STATISTICS (from MEG slides)

500-hPa Geopotential Height Anomaly Correlation (AC) Scores



SUITE 1SUITE 3ECMWFSUITE 2SUITE 4

- Suites 1 and 2 have statistically significantly better AC scores than Suites 3 and 4 well into medium range
- Suites 1 and 2 have nearly identical AC scores
- Suite 4 is slightly better than Suite 3

500-hPa Geopotential Height Bias



SUITE 1SUITE 3ECMWFSUITE 2SUITE 4

- Suites 1 and 2 have a nearly identical low bias that increases with forecast lead time
- Suite 3 has a high bias that increases with forecast lead time
- Suite 4 has the smallest average 500-hPa height bias at almost all forecast hours

850-hPa Temperature Bias



SUITE 1SUITE 3ECMWFSUITE 2SUITE 4

- Suites 1 and 2 have a cold bias that increases with lead time
- Suite 2 has a larger cold bias than Suite 1, potentially due to PBL scheme
- Suites 3 has a warm bias that increases with lead time, while Suite 4 has the smallest temperature bias
- The suites without GFDL microphysics do not show a cold bias increasing w time



Vertical Profile of Temp. Bias

- Suites 1 and 2 have a low-level cold bias that increases with lead time
- Suites 2 and 4 have a worse cold bias than Suite 1 near tropopause and near sfc.
- Suites 3 has a warm bias that increases with lead time throughout most of the troposphere

Grid-to-Obs: 2-m Temperatures

OBS

SUITE 1

SUITE 2

SUITE 3

SUITE 4

CONUS East



- All suites except Suite 3 have a near-surface cold bias that increases with forecast lead time

Northern Great Plains

T SFC, Northern Great Plains, 00Z Cycle, 20160101-20171231 Mean



Suite 4 has the largest near-surface warm bias on the Plains, but all suites are warmer than east

Grid-to-Obs: 2-m Relative Humidity

OBS

Northeast Coast

RH SFC, Northeast Coast, 00Z Cycle, 20160101-20171231 Mean



Southwest Coast



Suite 4 has RH values that are far too high -

Suite 4 has the best RH values

Temperature Profiles compared to RAOBs

F072





Suites 1 and 2 have the least bias at F072

Pressure (hPa)

926

Suite 2 is has a larger cold bias at 200 hPa and near surface, while Suite 3 has a warm bias

- Cold bias in Suites 1 and 2 increases with forecast lead time
- Warm bias in Suite 3 increases with lead time

Track Performance – Composite Track Errors



- For many of the 8 TCs examined by the MEG, track forecasts were fairly comparable
- Track errors for Suites 1 and 2 were nearly identical
- Incorrect outlier track solutions were largely limited to forecasts from Suites 3 and 4
- Composite stats for all TCs in all basins show that beyond Day 3, Suites 3 and 4 did have larger track errors than Suites 1 and 2

Intensity Performance – Composite Vmax Errors



Suite 2

Suite 4

- As expected, all suites had a weak intensity bias compared to Best Track data
- Intensity errors for Suites 1 and 2 were nearly identical
- Intensity forecasts from Suites 3 and 4 were significantly weaker beyond Day 1, while Suites 1 and 2 reduced the intensity errors with time

Statistics provided by GMTB

Highlighted Comparative Evluation: PBL Inversion

FORMAT of SOUNDINGS SLIDES



MOST COMMON INVERSION FINDING: Suite 4 handles inversions the best, Suite 1 struggles the most, Suite 2 offers some level of improvement over 1, and Suite 3 sometimes offers modest improvement over 1



MOST COMMON INVERSION FINDING: Suite 4 handles inversions the best, Suite 1 struggles the most, Suite 2 offers some level of improvement over 1, and Suite 3 sometimes offers modest improvement over 1



MOST COMMON INVERSION FINDING: Suite 4 handles inversions the best, Suite 1 struggles the most, Suite 2 offers some level of improvement over 1, and Suite 3 sometimes offers modest improvement over 1



There are examples, however, of Suite 4 predicting low-level inversions that are too strong



There are also examples in which Suite 4 overall handles an inversion the best but is significantly too warm at the top of the inversion



MOST COMMON AFTERNOON FINDING: Suite 4 often overmixes the PBL, leading to the lower levels being too hot and too dry



MOST COMMON AFTERNOON FINDING: Suite 4 often overmixes the PBL, leading to the lower levels being too hot and too dry







CAPPING INVERSIONS: Suite 4 often mixes out capping inversions which are critical features in pre-convective environments

- The process begins during early afternoon
 - By early evening, the inversion is too weak in all suites, but it's completely gone in Suite 4

- The temperatures around the inversion level in Suite 3 looks odd by 00z as well

SUITE 2 LOW-LEVEL 00z COLD BIAS: Indications of early decoupling??



SUITE 3 OCCASIONALLY SHOWS SOME ODD FEATURES IN PROFILES



Extremely unrealistic inversion

Odd low-level moisture structure

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Precipitation

Day-5 CONUS Precipitation ETS and Bias (0000 UTC)

Bias

<u>ETS</u>



SUITE 1SUITE 3SUITE 2SUITE 4

KEY POINTS:

- Suites 1 and 2 have the highest ETSs, while Suite 3 has the lowest ETS

All four suites have a wet bias at low thresholds & dry bias at mid-thresholds

Suite 4 has a statistically significantly worse dry bias than other suites for amounts between 10-25 mm/24h

Day-5 CONUS Precipitation ETS and Bias (1200 UTC)

Bias



<u>ETS</u>

SUITE 1SUITE 3SUITE 2SUITE 4

- ETSs increase across all four suites
- Suites 1 and 2 have the highest ETSs, while Suite 3 has the lowest ETS
- All four suites have a wet bias at low thresholds that decreases at middle thresholds (Suites 1-3 = no dry bias)

CONUS Precipitation Bias (0000 UTC)



- At lower precipitation thresholds, a wet bias exists at all lead times in all suites
- All four suites have an increasing dry bias with time at middle thresholds
- Suite 4 has the largest dry bias that increases with time at middle and high precipitation thresholds

00 UTC

12 UTC



6-h Accumulated Precipitation Frequency Bias CONUS (20160101-20171231) 04 02 >=0.254 >=0.508 >=1.270 >=2.540 >=3.810 >=6.350 >=8.890 >=12.700 >=25.400 CI=95% OBS=CCPA INIT=12 UTC Threshold (mm) Suite3 (172)
 Suite3 (120)
 Suite3 (120)
 Suite4 (120)
 Suite3 (1240)
 Suite4 (1240) Suite1 (f72)
 Suite1 (f120)
 Suite1 (f120) Suite2 (f72) Suite2 (f120) Suite2 (f240)

DJF

MAM



JJA

>=0.254



6 h Frequency bias, CONUS



6-h Accumulated Precipitation Frequency Bias CONUS (2016/17 SON)

SON



6h acc. Fraction Skill Score, CONUS

https://docs.google.com/do cument/d/1Vyo1zL5N6Gow ugDCEWOVFlrK83JcOzWKCC SwGvGe 74/edit?ts=5c8915 6e#



Figure 3. FSS of 6-h accumulated precipitation (mm) for Suite 1 (black), Suite 2 (red), Suite 3 (green), and Suite 4 (blue) aggregated over the CONUS domain for the entire test period (20160101-20171231) for all 12 UTC initializations using a neighborhood size of 49 (7 x 7 grid squares). The 72-h, 120-h, and 240-h forecasts are represented by the solid, dashed, and dotted lines, respectively. The vertical bars surrounding the aggregate value represent the 95% CIs.



Summary from	POSITIVES for SUITE 1	NEGATIVES for SUITE 1
the Model	overall the best synoptic scores	really struggles with inversions
(MEG).	overall good tropical cyclone tracks and intensity	underdoes instability
		low-level cold bias increases with time
	POSITIVES for SUITE 2	NEGATIVES for SUITE 2
	synoptic scores overall match Suite 1	underdoes instability (maybe more than Suite 1)
	matches Suite 1 for tropical tracks/intensity	larger low-level cold bias than suite 1
	improved handling of inversions	even drier than Suite 1 with tropical precip
	POSITIVES for SUITE 3	NEGATIVES for SUITE 3
	some improvement on inversions	synoptic scores not as good as Suite 1
	more representative instability magnitudes	increasing warm bias with time
		tropical cyclone tracks and intensity are worse
	POSITIVES for SUITE 4	NEGATIVES for SUITE 4
	shows the most promise for dealing with inversions	worse synoptic scores
	shows promise for improving instability	tends to overmix PBL, leading to hot and dry on plains
	more tropical precipitation	too light on extreme precipitation events and lowest precip bias scores
	has the smallest low-level temperature bias	struggles with tropical cyclone intensity and track

Some Caveats and Thoughts

All of the runs were with 64 levels; with plans for 96 or 128 levels in GFSv16. How will this change the results?

Data assimilation cycling was not included and it is not clear how this will impact the results.

The cause of the cold bias increasing w time in suites with GFDL MP, along with the increased cold bias since the radiation fix, is still is not well understood and the physics testing does not address this issue

Some Material Drawn from the MEG Presentation

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