Diagnostics and Verification of the Tropical Cyclone Environment in Regional Models

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Also a special thanks to the COAMPS-TC modeling team at NRL for extensive collaboration and feedback

Diagnostic Files

- Condense model run down to 20 kb text file
- Contains analysis and forecast of key vortex-scale data as well as a vertical profile of large-scale environmental data
- Produced and made available in near-real-time since 2008 at CIRA for HWRF and GFDL
- Five-page document made available that details file naming convention, field calculations, etc.
- Uniform format across all models, flexible enough to accommodate different temporal and vertical resolutions, and to include additional custom fields

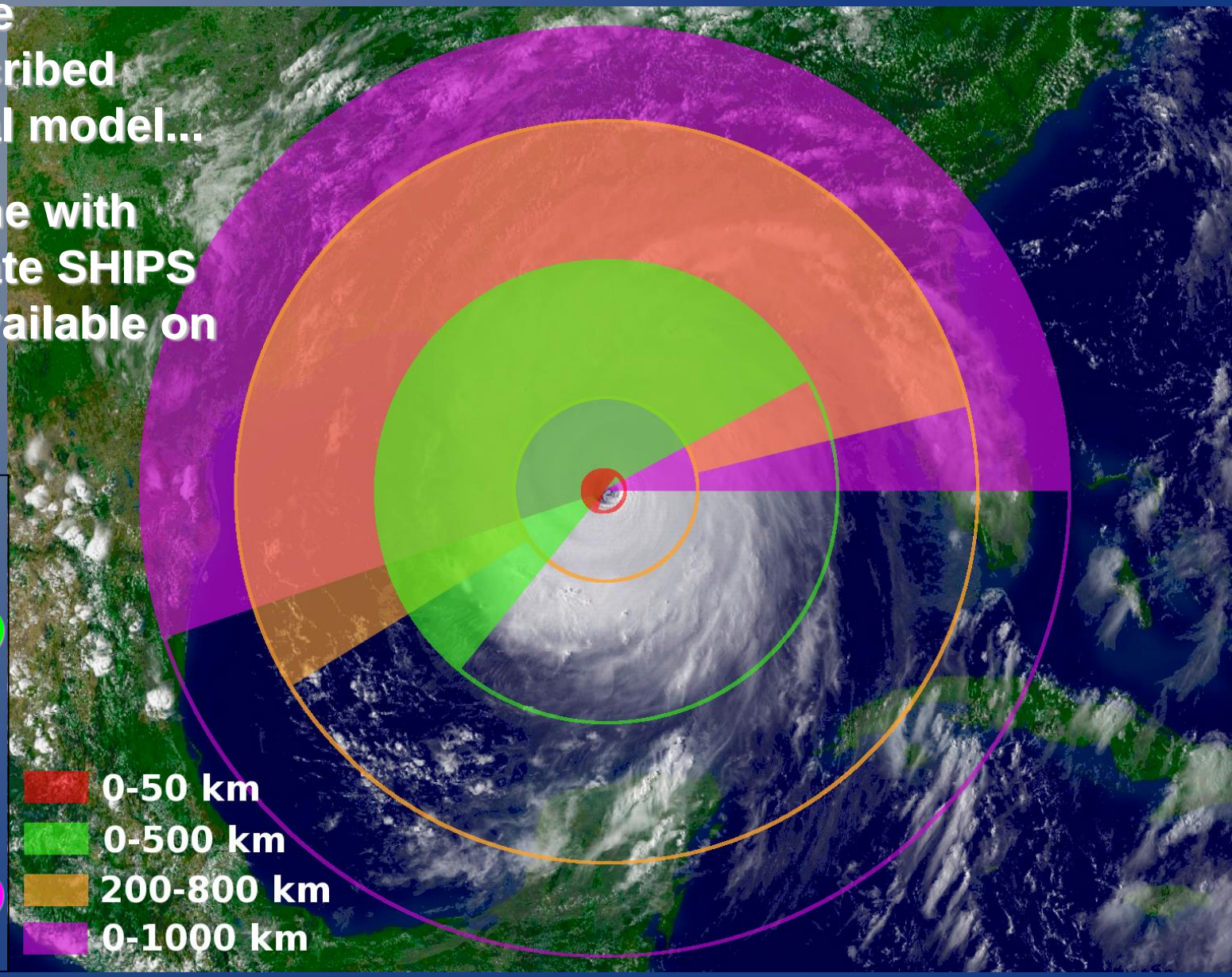
Diagnostic Files, con't

- From 2008-2011, code only existed in IDL
- In mid 2011, CIRA developed and shared Fortran code with interested modeling groups who also produced these files *(NRL-Monterey, Univ at Albany, EMC, GFDL, ESRL, DTC, Univ of Wisconsin)*
  - Part of HFIP Stream 1.5 effort... **SPICE** (SPC3) utilizes these files in real-time
- Updated versions of this code are easy to distribute and implement
- Multi-model collection of these files facilitates convenient comparison of track, intensity, environment over a storm or entire season
  - ~8 Mb / model / season

Standard SHIPS Parameters

Key parameters are calculated in prescribed areas from regional model...

This is already done with GFS output to create SHIPS "predictor" files available on NHC's FTP server



Sea surface temp (RSST)

850-200 mb shear (SHDC)
200 mb zonal wind (U20C)

200 mb temp (T200)
850-700 mb RH (RHLO)
700-500 mb RH (RHMD)
500-300 mb RH (RHHI)

200 mb divergence (D200)
850 mb vorticity (Z850)

* HWRF 2011082306 *
* AL09 IRENE *

* HWRF 2011082306 *
* AL09 IRENE *

--- STORM DATA ---

NTIME 022 DELTAT 006

TIME	(HR)	0	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126
LAT	(DEG)	20.1	20.4	20.7	20.7	21.0	21.6	22.3	23.0	23.9	24.8	25.9	26.9	28.0	29.0	29.9	30.6	31.6	32.5	33.4	34.2	35.1	36.1
LON	(DEG)	290.3	289.3	288.6	287.8	287.3	286.7	285.9	285.2	284.4	283.8	283.4	283.0	282.7	282.5	282.3	282.4	282.3	282.5	282.4	282.6	282.9	283.4
MAXWIND	(KT)	81	81	69	75	83	86	85	96	94	99	101	96	101	98	94	93	100	100	106	91	84	81
RMW	(KM)	46	43	45	45	39	38	46	49	48	50	58	60	64	63	72	79	78	88	85	105	106	108
MIN_SLP	(MB)	965	966	967	962	949	951	949	948	944	942	940	939	936	937	935	936	930	930	927	932	937	943
SHR_MAG	(KT)	22	22	19	14	17	17	12	11	9	6	10	11	10	10	13	14	15	18	16	16	19	19
SHR_DIR	(DEG)	261	268	254	242	265	277	279	273	268	257	246	237	240	220	212	220	217	212	198	196	196	202
STM_SPD	(KT)	10	7	7	6	8	10	10	12	11	12	11	11	10	9	7	10	9	9	8	9	11	9999
STM_HDG	(DEG)	288	295	270	303	317	313	317	321	329	342	340	346	350	349	7	355	11	355	12	15	22	9999
SST	(10C)	292	289	289	289	286	285	287	289	291	292	293	290	287	285	287	285	285	285	289	279	9999	9999
OHC	(KJ/CM2)	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999
TPW	(MM)	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999
LAND	(KM)	49	69	100	98	122	187	202	237	305	359	358	307	297	307	321	321	230	173	76	25	-29	-64
850TANG	(10M/S)	160	166	165	172	171	165	161	167	170	174	183	188	193	205	218	230	237	247	252	256	255	252
850VORT	(/S)	63	62	61	80	93	94	100	114	115	112	102	100	90	94	105	108	105	122	143	143	149	177
200DVRG	(/S)	60	72	57	38	38	28	28	39	50	60	58	40	46	54	66	71	59	55	87	74	63	87

--- SOUNDING DATA ---

NLEV 020 SURF 1000 0950 0900 0850 0800 0750 0700 0650 0600 0550 0500 0450 0400 0350 0300 0250 0200 0150 0100

TIME	(HR)	0	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126
T_SURF	(10C)	286	286	285	285	284	284	284	283	283	284	285	284	282	277	272	267	259	252	245	239	232	224
R_SURF	(%)	82	82	82	82	82	81	81	81	81	81	80	81	80	80	79	79	77	76	74	73	72	73
P_SURF	(MB)	1010	1009	1008	1009	1007	1009	1007	1008	1007	1009	1007	1009	1007	1009	1006	1007	1005	1006	1003	1003	1001	1002
U_SURF	(10KT)	-103	-131	-122	-103	-105	-105	-93	-93	-92	-74	-69	-59	-55	-48	-35	-25	-9	5	29	38	38	30
V_SURF	(10KT)	-13	0	-14	-19	3	25	35	39	51	48	51	44	55	47	48	52	57	57	71	81	98	105
T_1000	(10C)	279	281	282	282	281	281	284	283	281	280	282	282	277	272	276	276	267	259	263	262	251	242
R_1000	(%)	76	70	72	73	74	74	76	77	78	78	79	81	82	83	82	83	86	86	85	85	86	85
Z_1000	(DM)	9	8	7	8	7	8	6	7	6	8	6	8	6	8	6	6	4	5	2	3	1	2
U_1000	(10KT)	-120	-152	-140	-118	-120	-121	-105	-106	-102	-85	-80	-69	-62	-54	-39	-29	-12	2	28	40	42	37
V_1000	(10KT)	-15	0	-15	-20	5	31	41	46	59	57	58	50	61	51	51	56	54	52	65	73	93	101
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.																							
T_0100	(10C)	-764	-758	-761	-766	-752	-748	-751	-749	-746	-744	-740	-737	-731	-728	-730	-722	-722	-717	-714	-704	-694	-694
R_0100	(%)	45	39	41	43	36	36	40	41	40	41	40	40	37	36	38	34	35	33	34	29	26	28
Z_0100	(DM)	1661	1661	1661	1662	1662	1664	1663	1666	1664	1667	1667	1670	1668	1670	1669	1672	1669	1670	1669	1671	1669	1669
U_0100	(10KT)	-116	-180	-199	-205	-139	-116	-113	-108	-74	-70	-78	-54	-48	-43	-33	3	20	32	70	83	93	123
V_0100	(10KT)	7	-30	-10	26	9	-46	-59	-55	-74	-80	-63	-54	-51	-62	-13	4	9	30	68	75	88	117

--- CUSTOM DATA ---

NVAR 004 GRDWIND GRD_SLP CAPE VERTVEL

GRDWIND	(KT)	82	82	69	75	85	84	86	93	94	101	101	96	100	98	93	93	100	100	108	91	84	81
GRD_SLP	(MB)	964	966	968	963	949	952	950	948	944	942	940	939	936	937	935	935	930	930	927	932	937	943
CAPE	(J/KG)	102	2	52	67	85	45	272	311	315	272	362	452	334	13	310	323	194	6	19	19	3	0
VERTVEL	(100M/S)	497	333	408	423	448	384	699	753	758	698	839	866	782	647	746	767	560	264	324	284	194	156

--- COMMENTS ---

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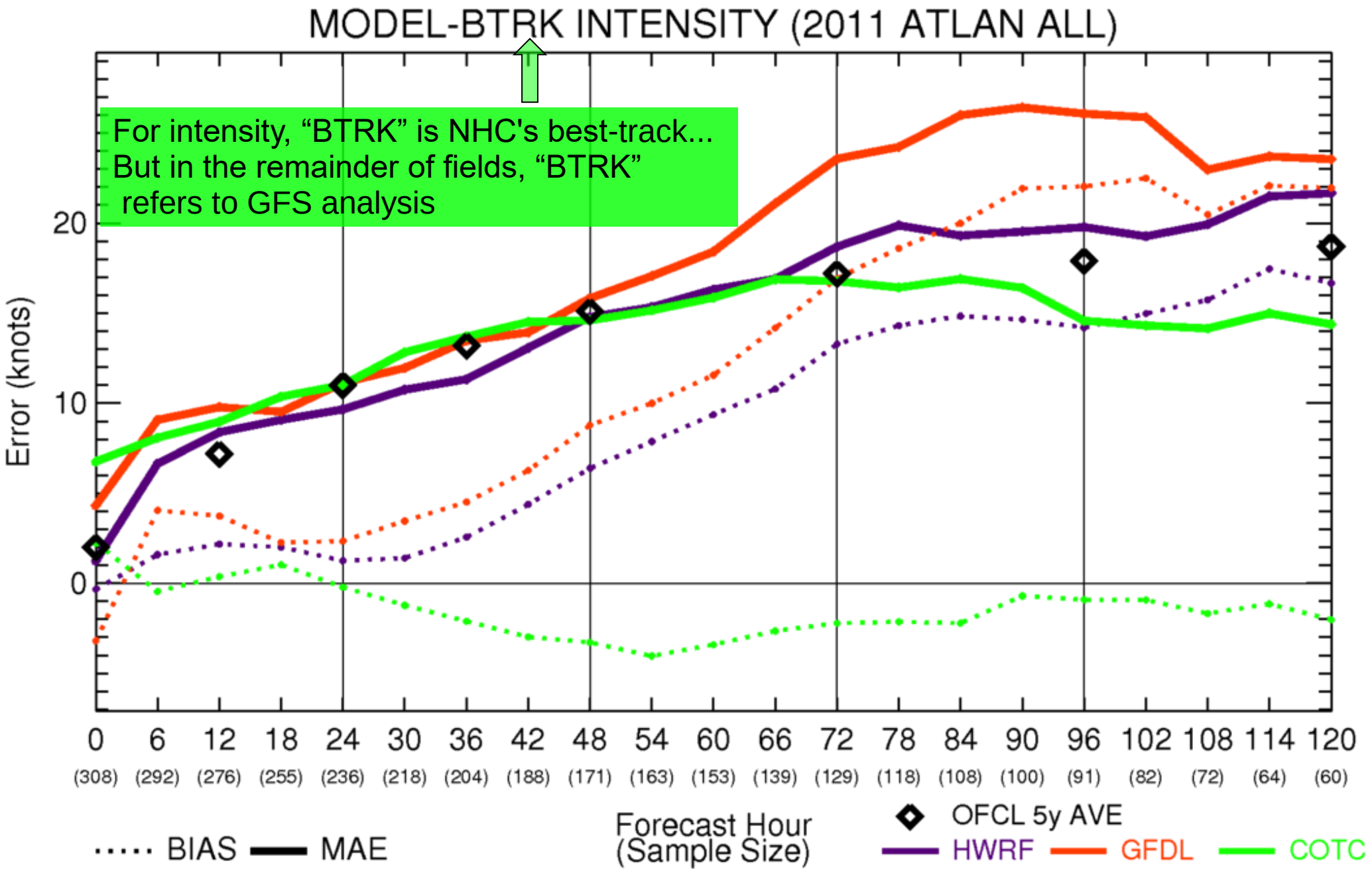
*   SST, OHC averaged in five closest points under storm center [x10 C, kJ/cm2]   *
*   RMW, TPW, GRDWIND, GRD_SLP within 0-200km around storm center [km, mm, kt, mb]   *
*   U, V, SHR averaged from 0-500km around storm center [x10 kt, x10 kt, kt]   *
*   850VORT, 200DVRG averaged from 0-1000km around storm center [x10^7 /s, x10^7 /s]   *
*   850TANG is 0-600km average symmetric wind [x10 m/s]   *
*   T, R, Z, P averaged from 200-800km around storm center [x10 C, %, dm, mb]   *
```

Post-season Environmental Verification

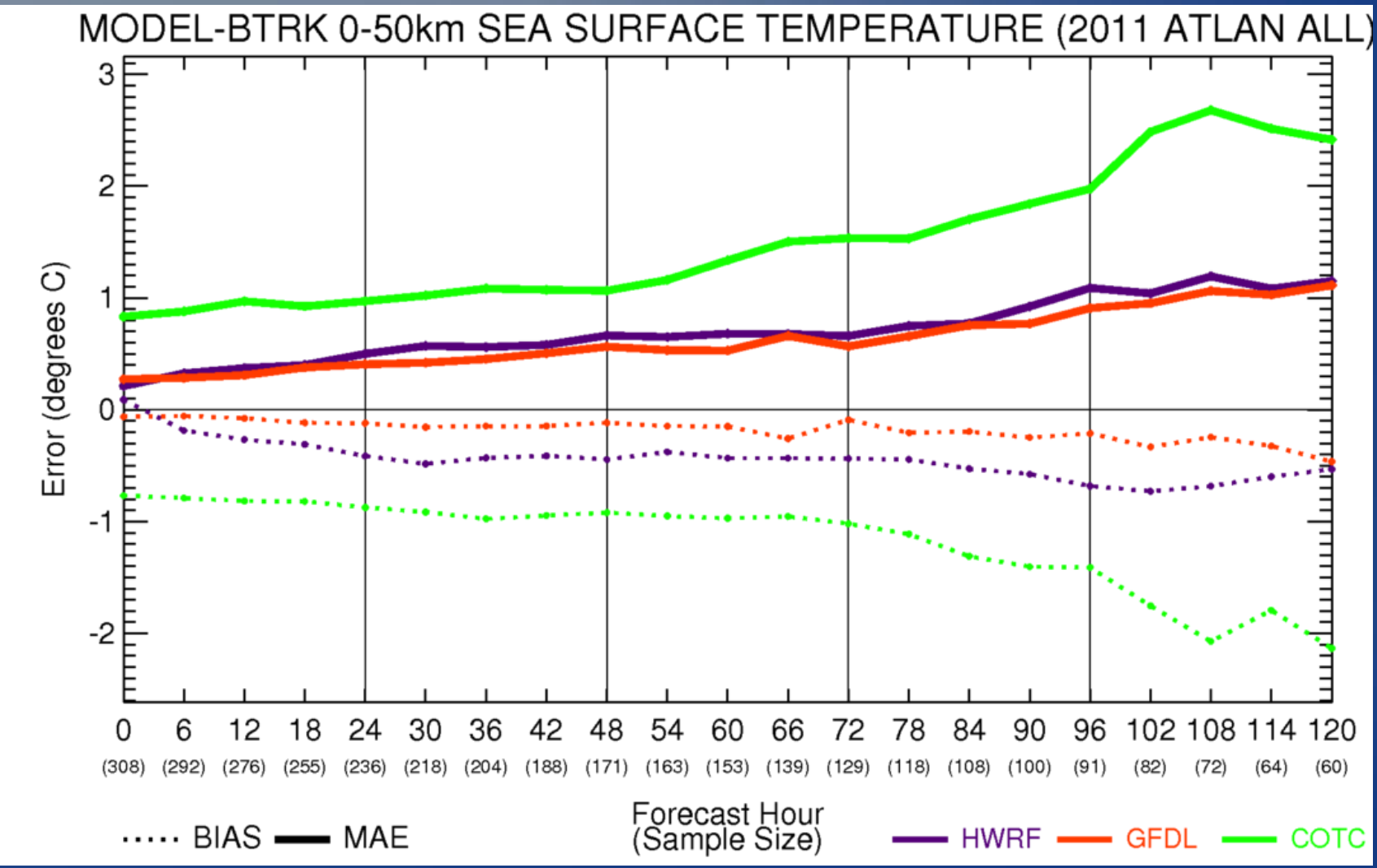
- 2011 Atlantic season
- Storms of at least TD intensity
- Bias (dotted) and MAE (solid) plotted as function of forecast hour
- Homogeneous sample size shown below forecast hour
- 308 HWRF/GFDL/COTC cases at t=0 (60 at t=120h)

Post-season Environmental Verification



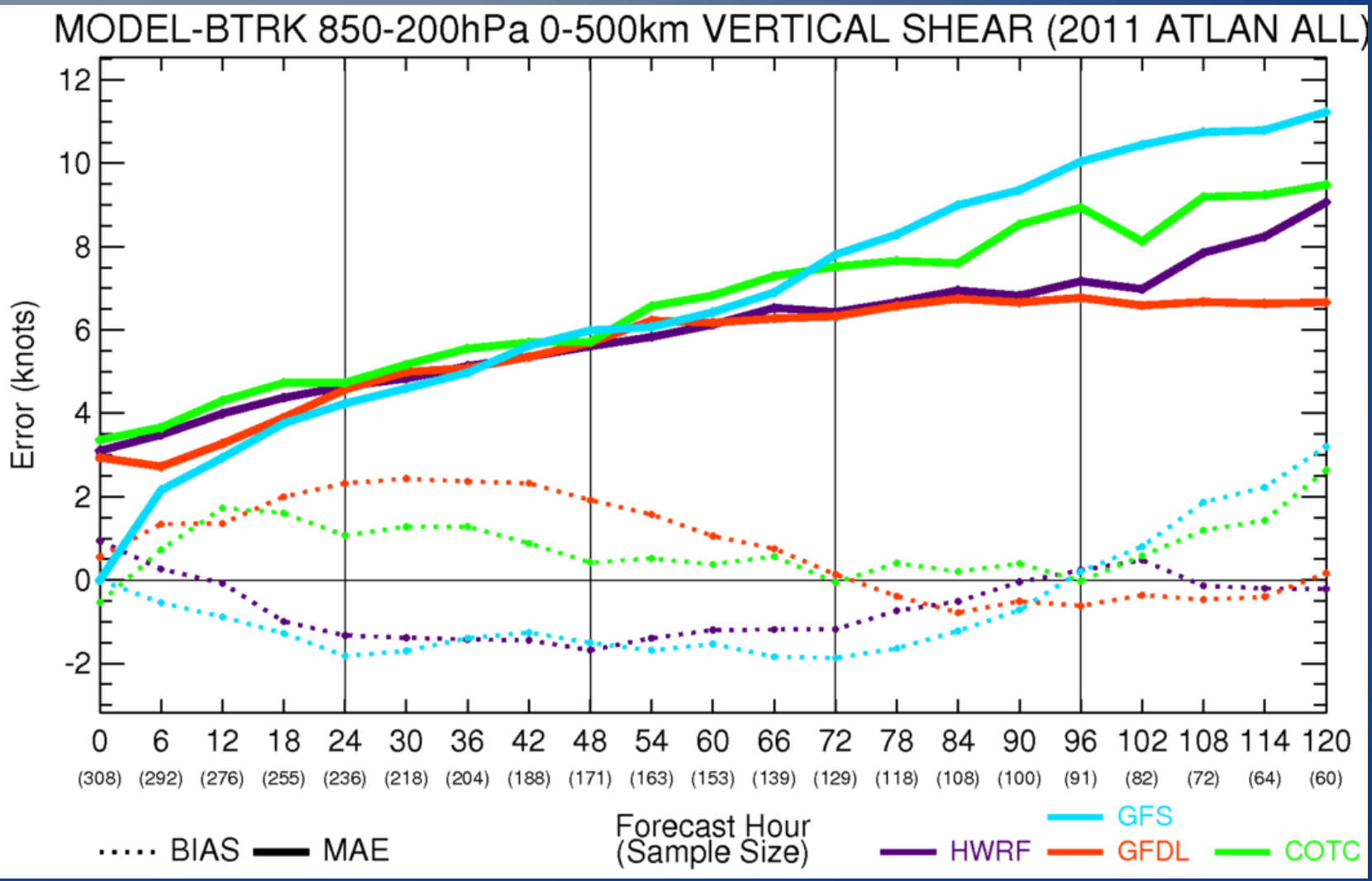
Sea Surface Temperature

- Slight cool bias, more so in COTC (2 deg by 120h)
- Intimately linked to track errors



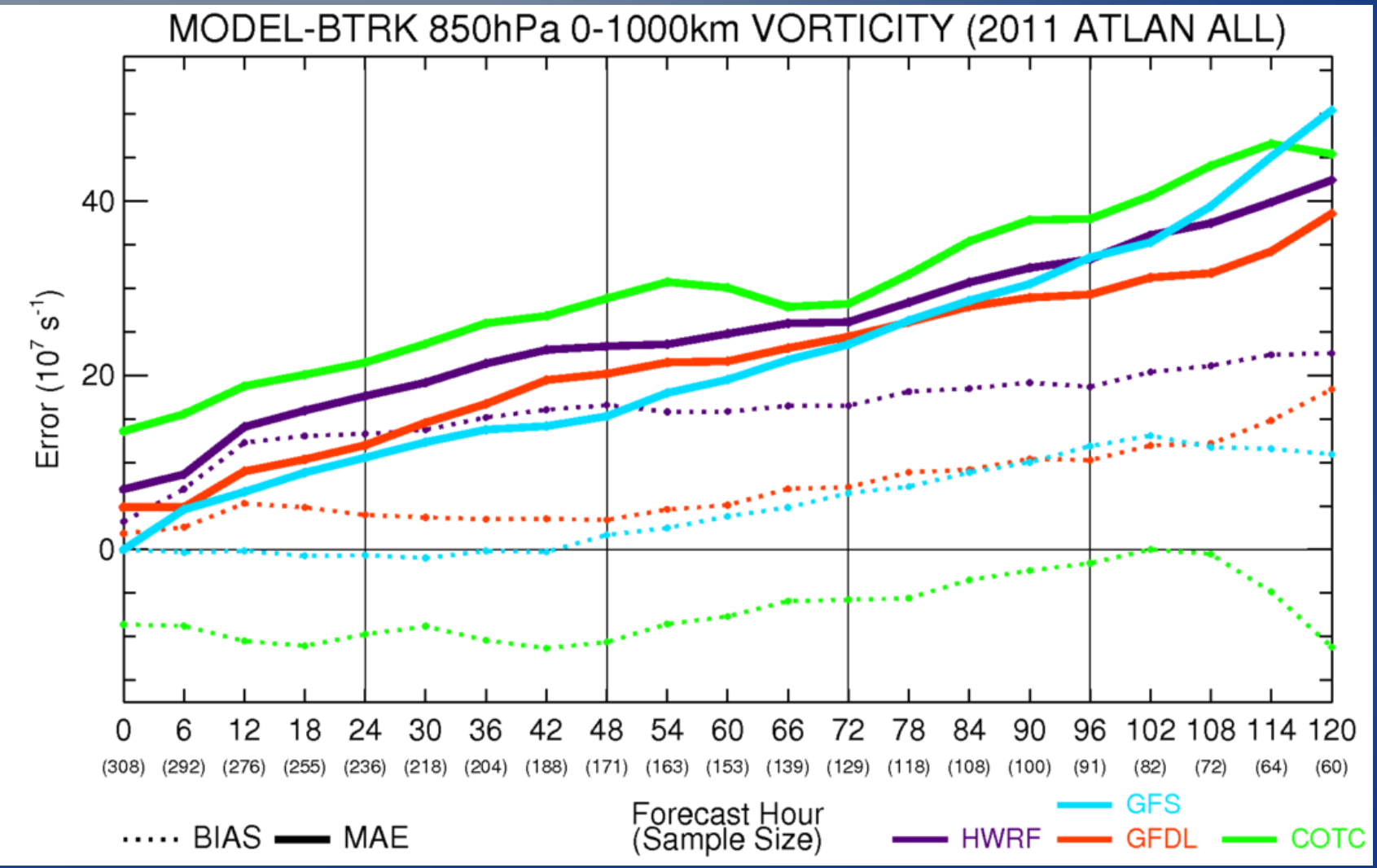
Vertical Shear

- ~5kt error at 36h, then GFS reaches 11kt at 120h while GFDL reaches 6.5kt at 120h



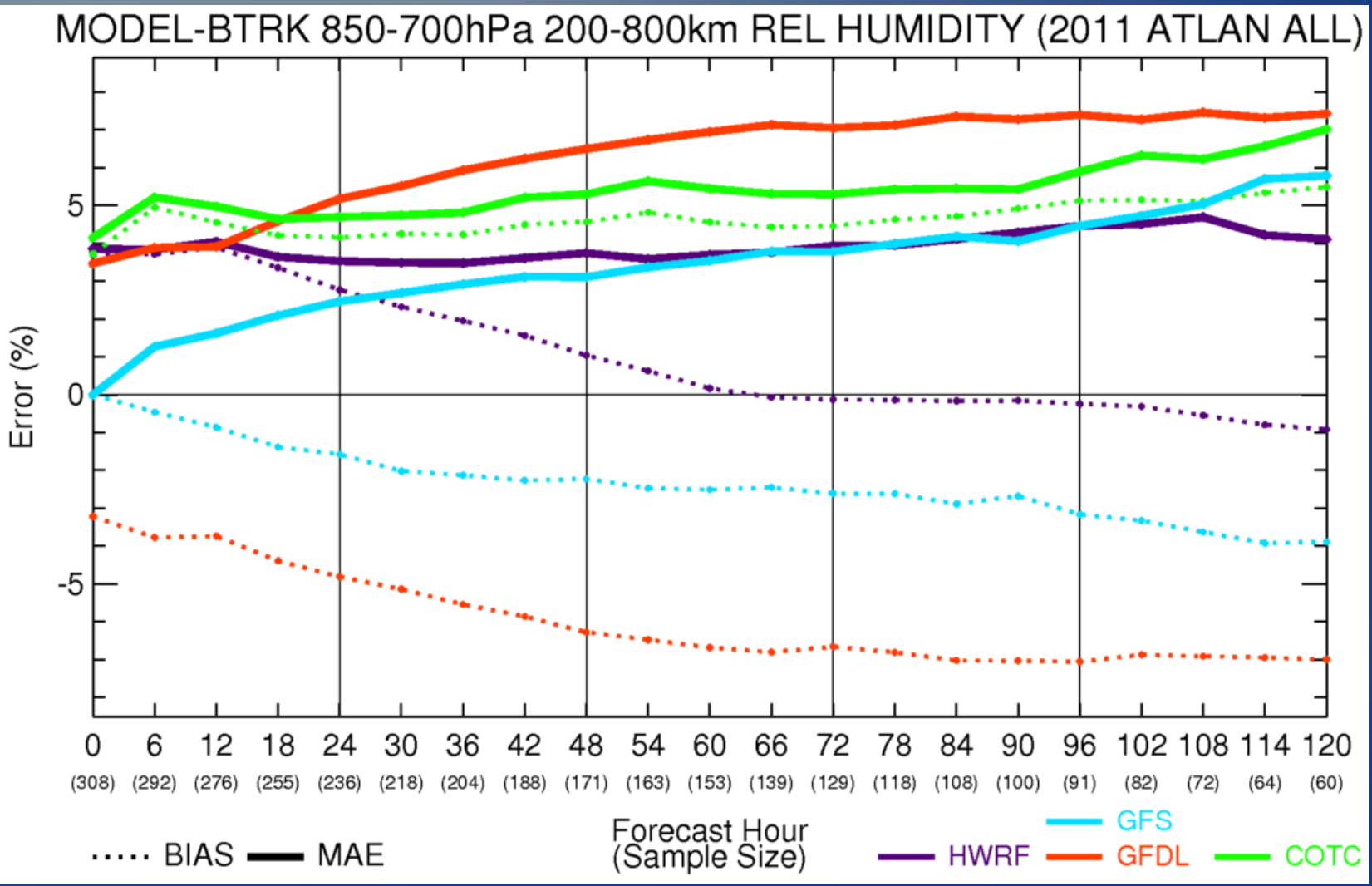
850mb Vorticity

- Similar errors among all models, most bias in HWRF



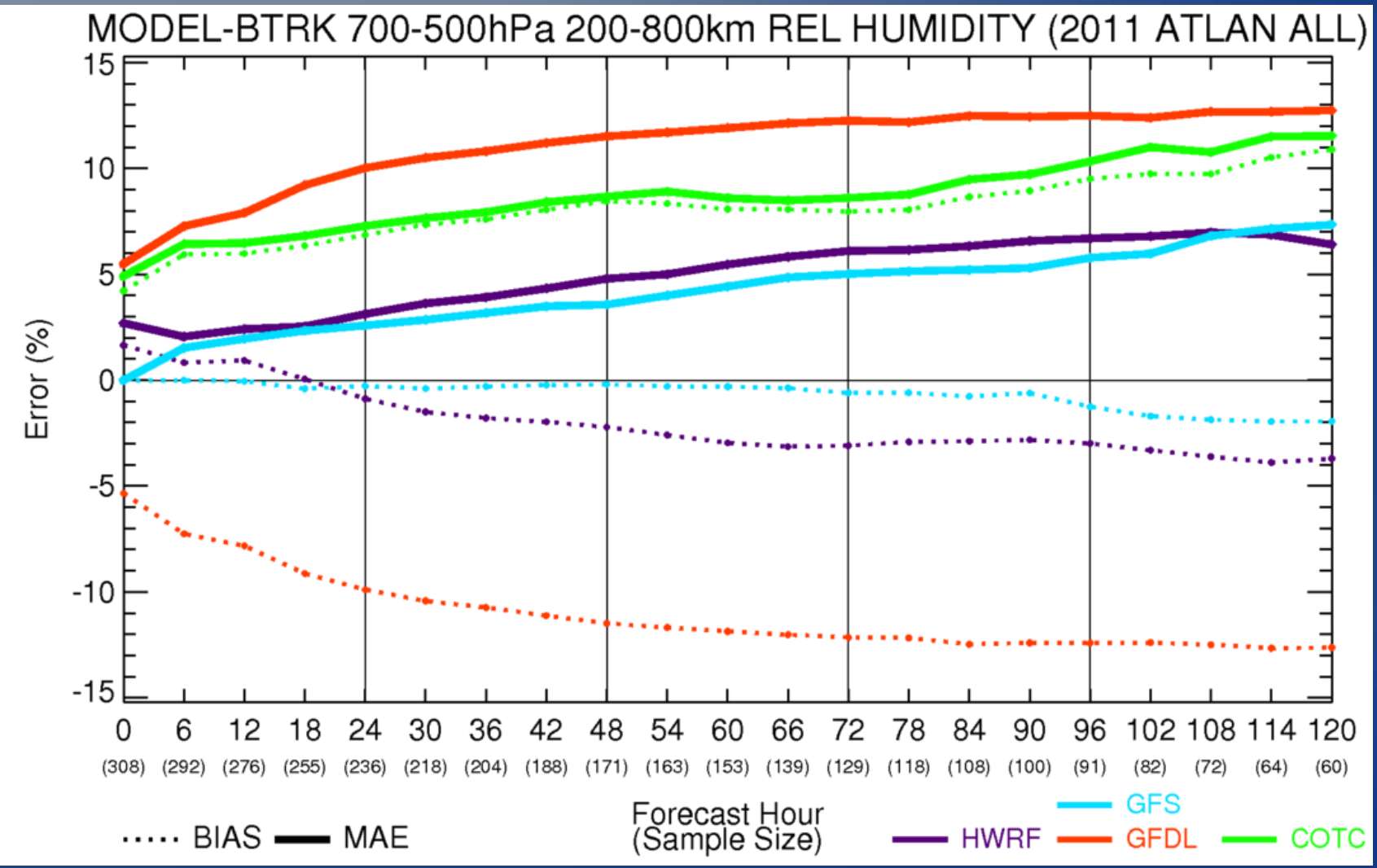
850-700mb RH

- Fairly persistent and constant low-level RH errors
- GFDL too dry (3-7%)



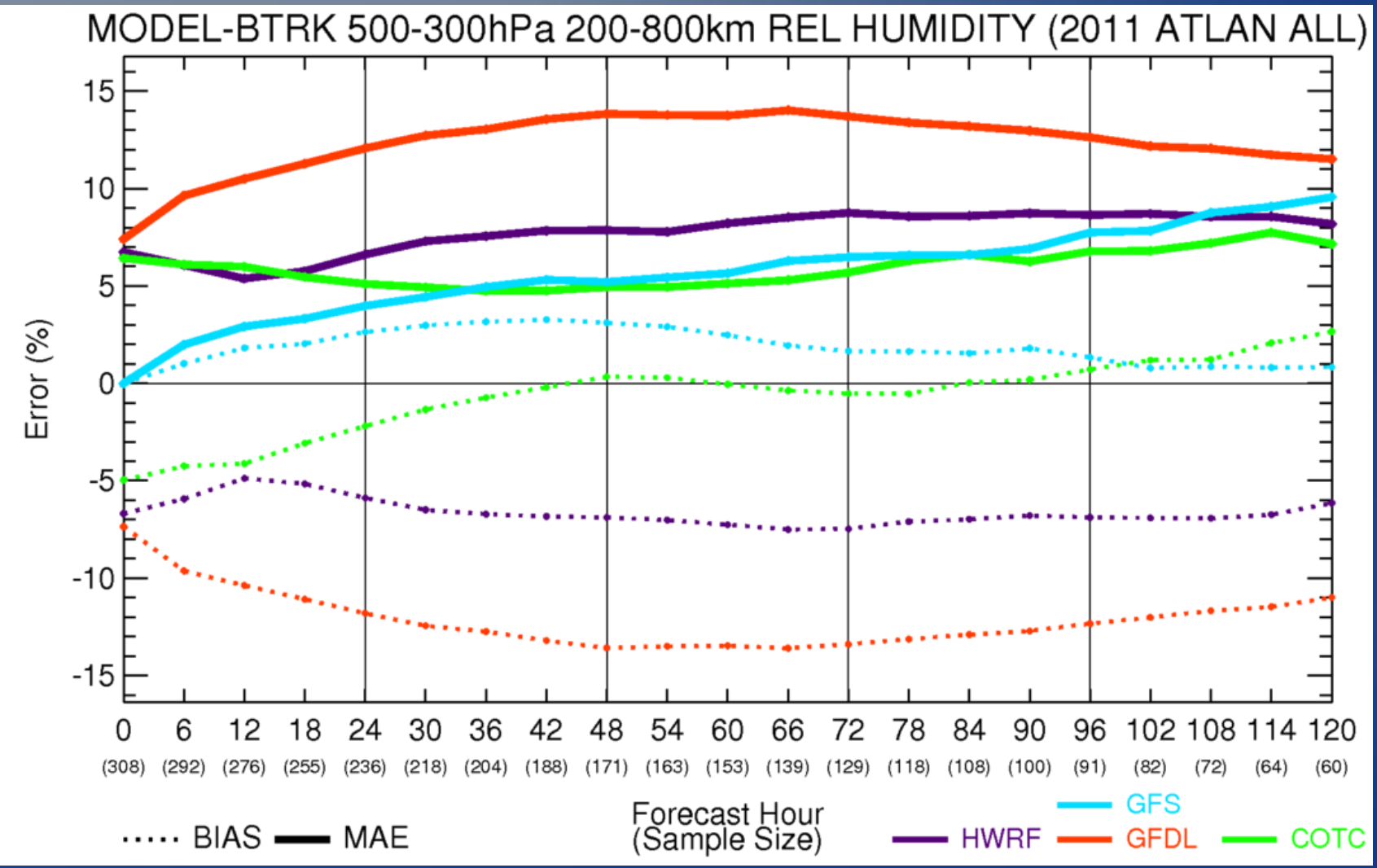
700-500mb RH

- Mid-level RH errors increase slightly with time
- GFDL drier again (5-13%)



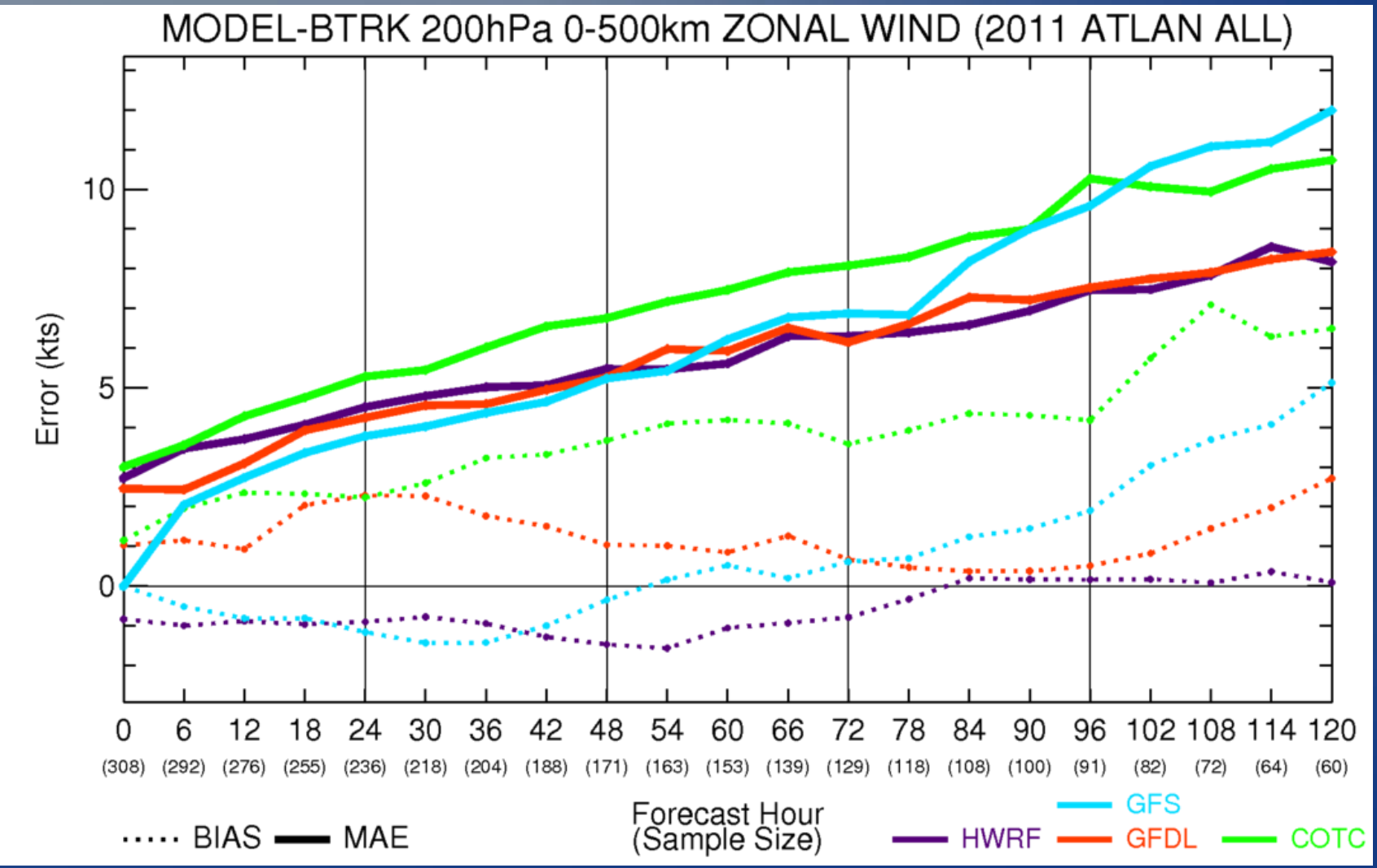
500-300mb RH

- Persistent dry bias in HWRF & GFDL upper-level RH
- GFDL 7-14% too dry



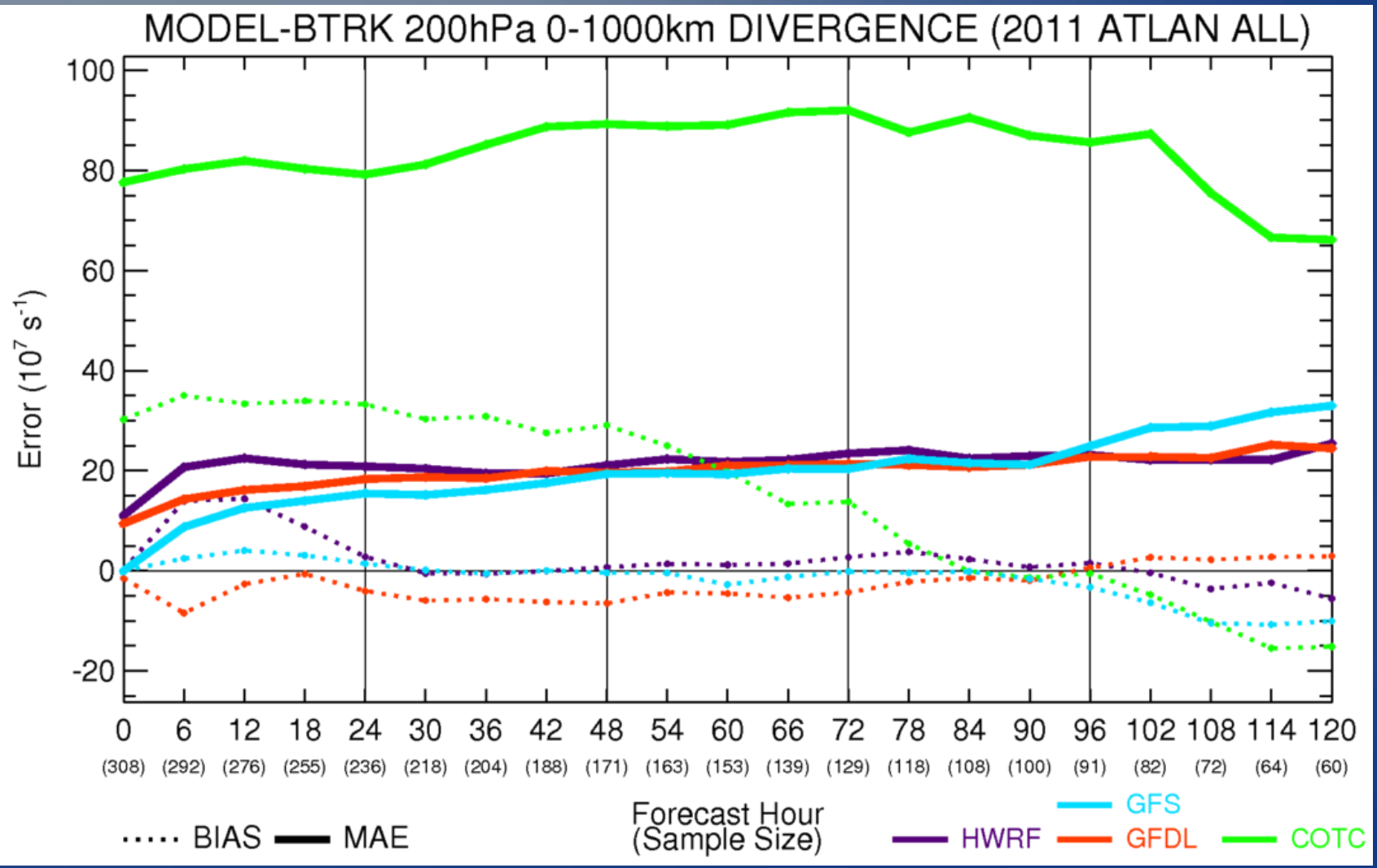
200mb Zonal Wind

- Similar errors among all models, most bias in COTC



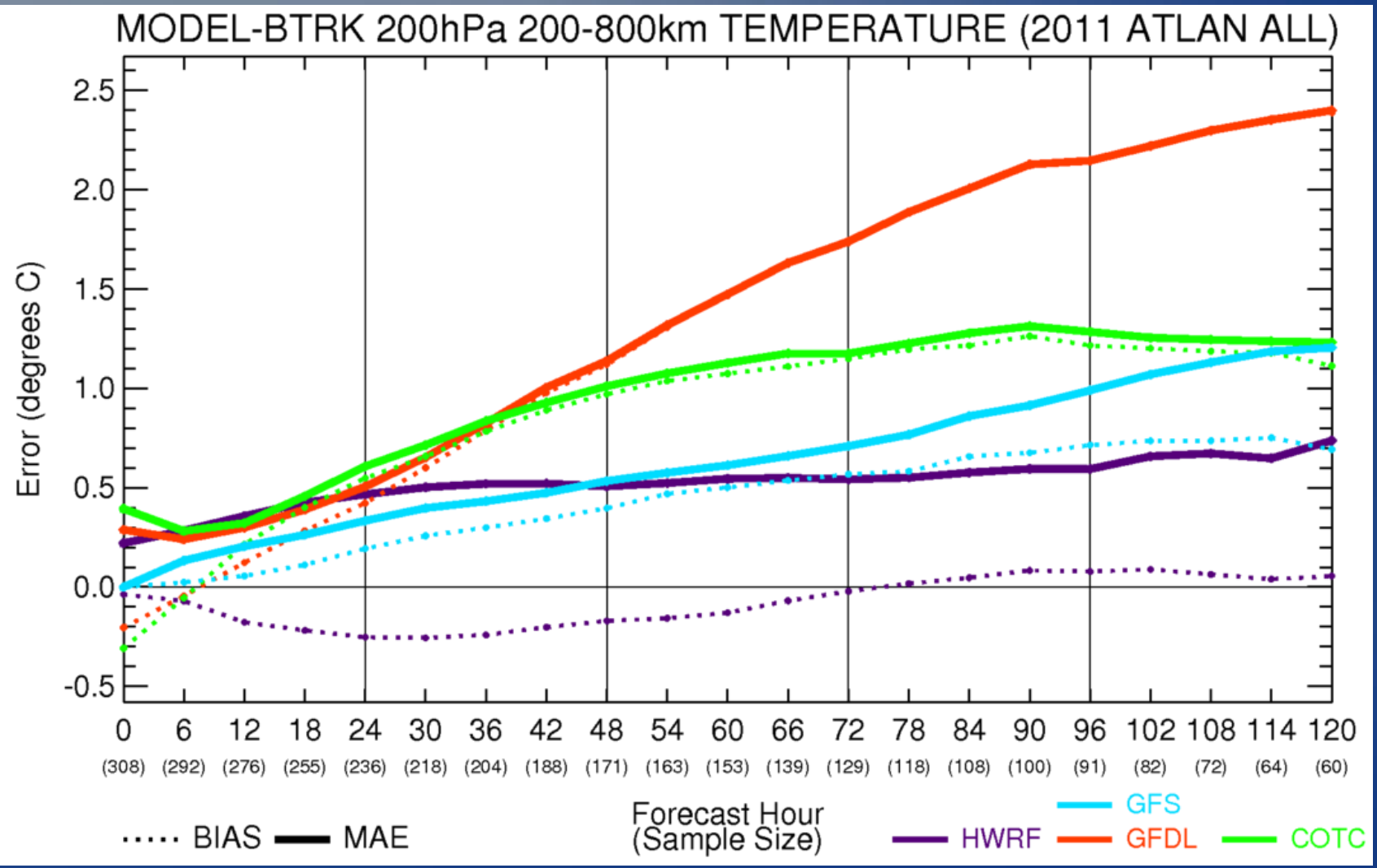
200mb Divergence

- Significant error in COTC

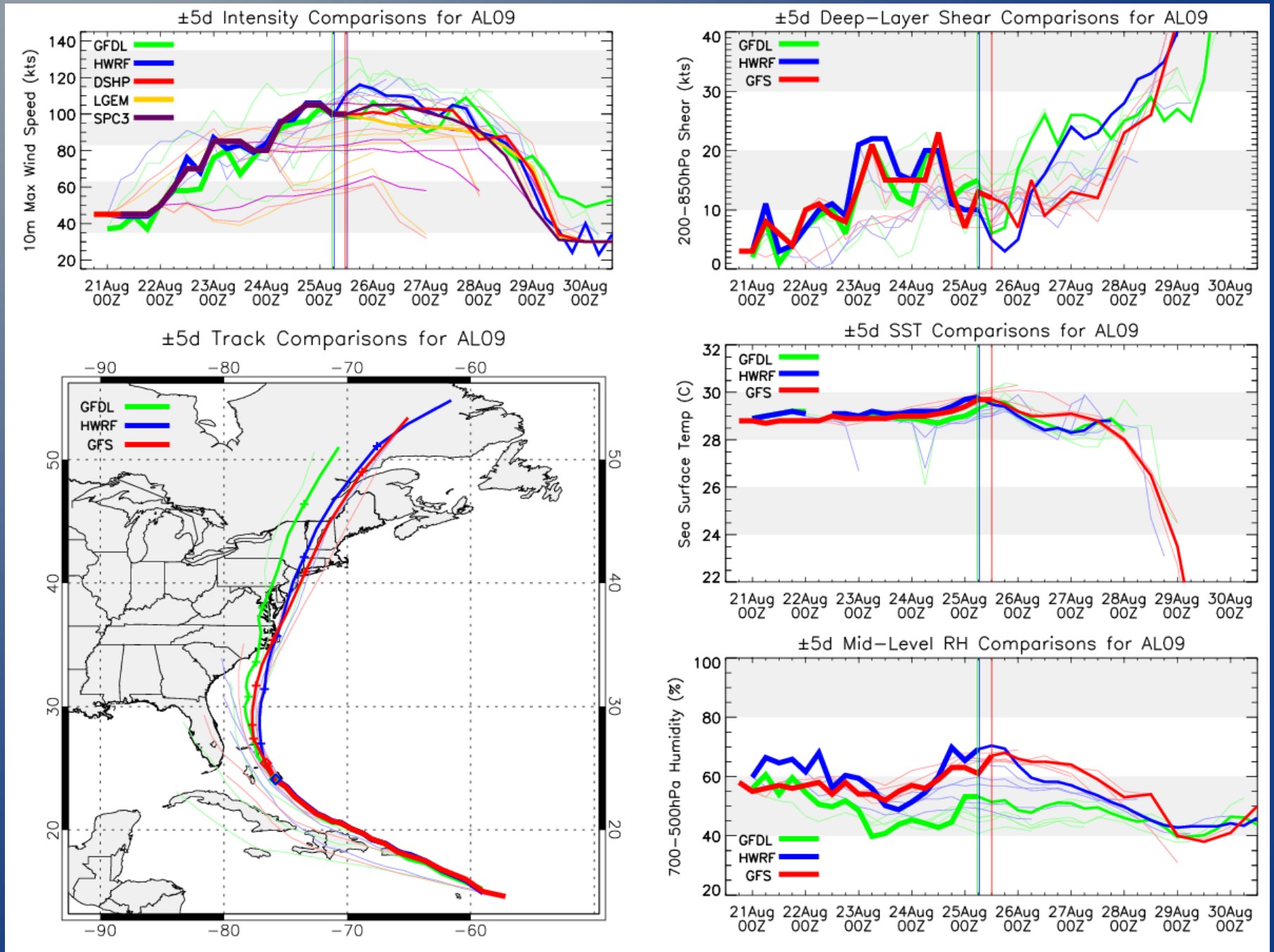


200mb Temperature

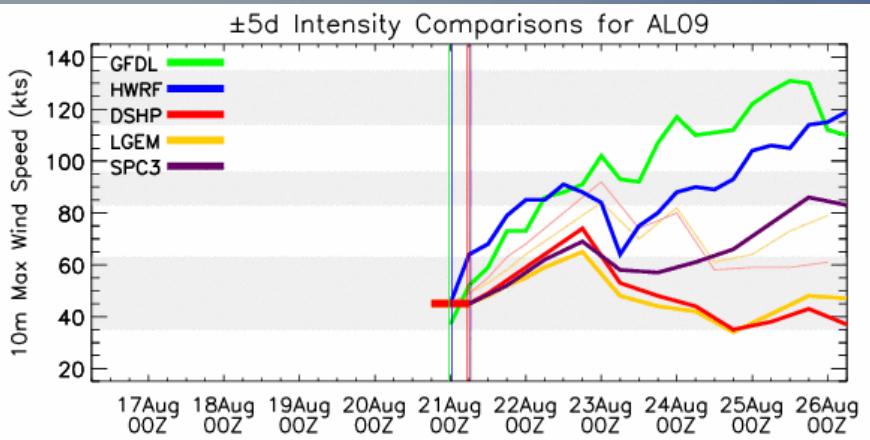
- Significant error (all positive) in GFDL's 200mb temp
  - This can have large impact on intensity

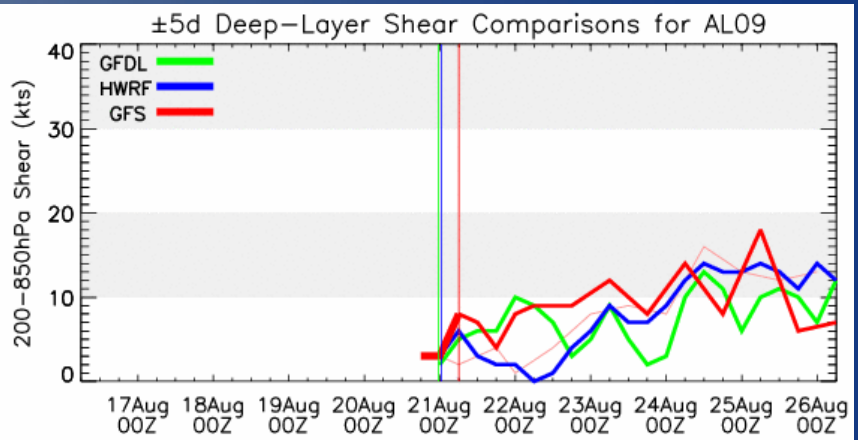


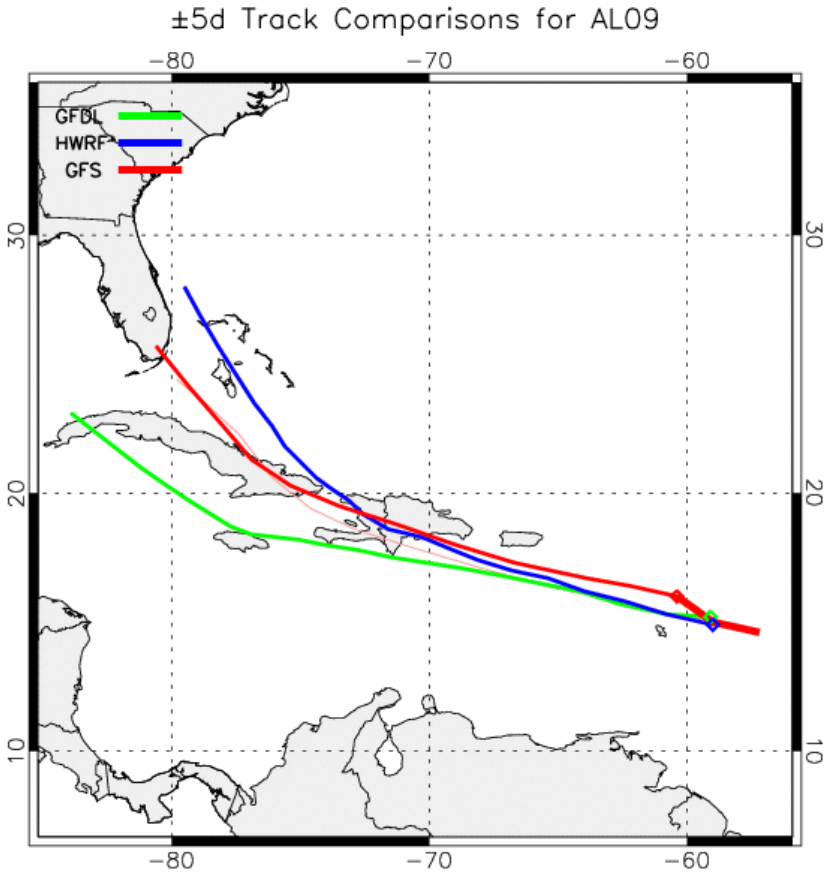
Real-time Environmental Diagnostics

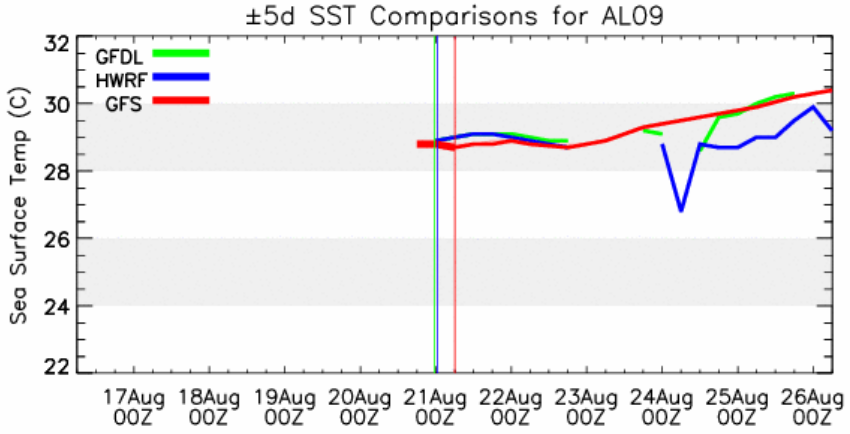


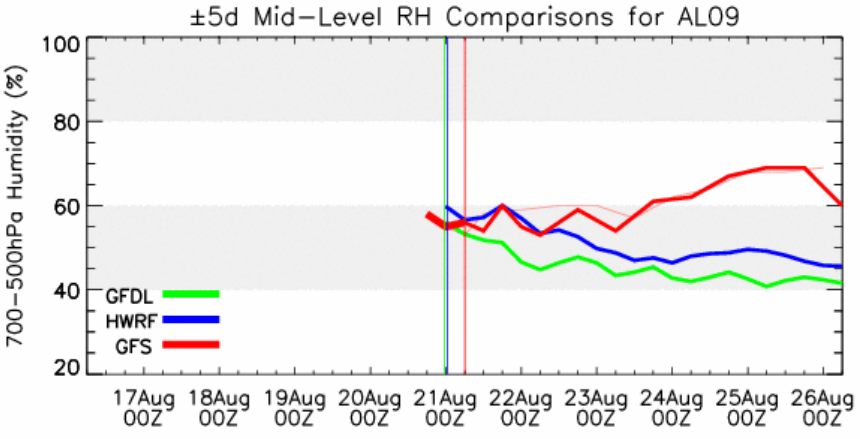
Real-time Environmental Diagnostics







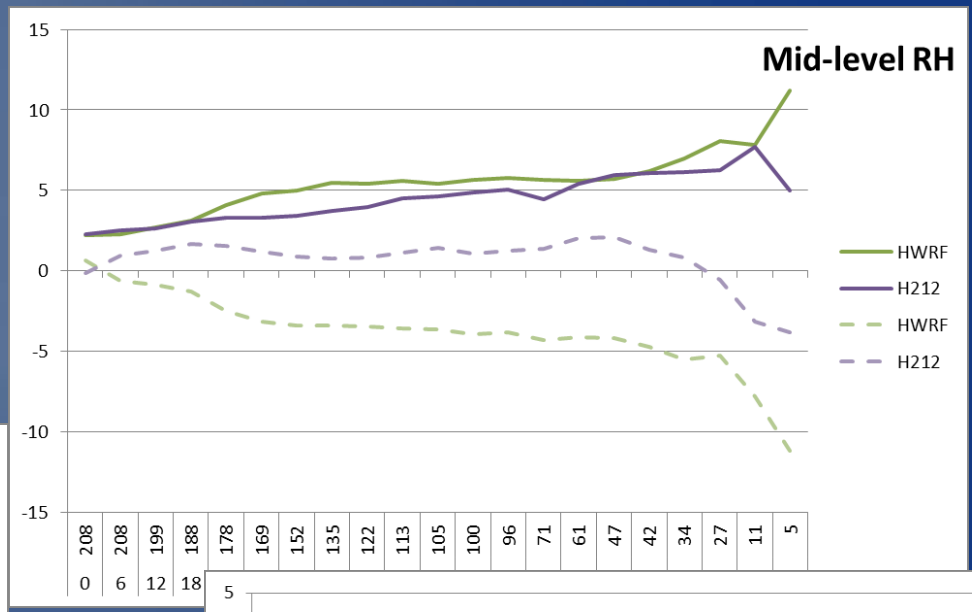


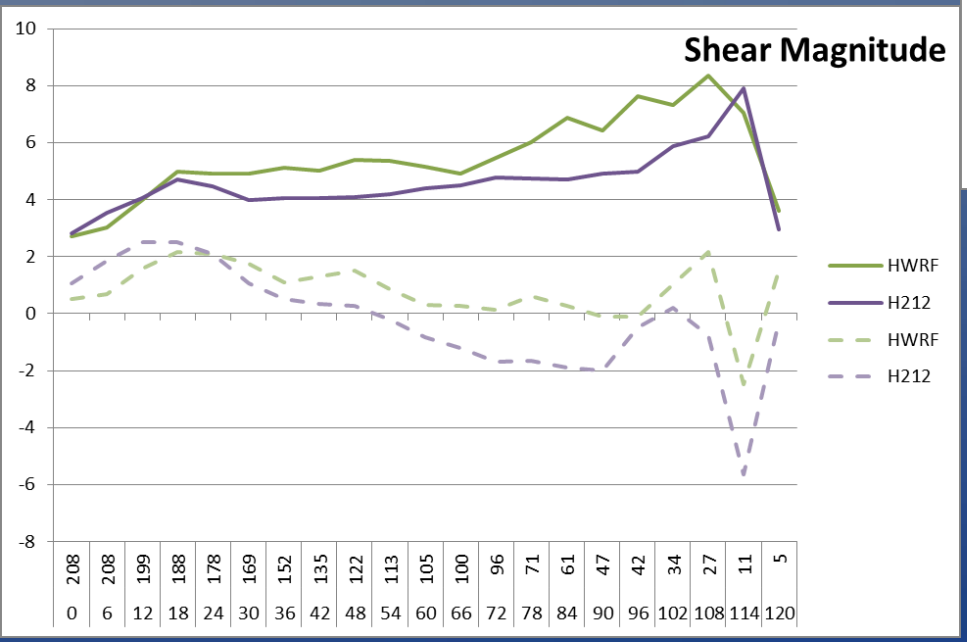


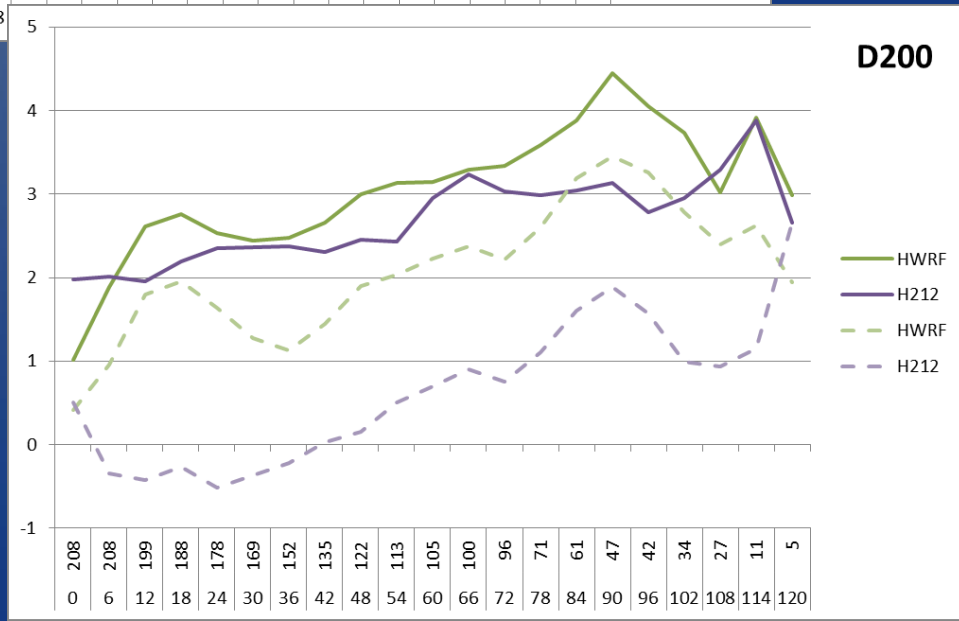
HWRF 2011 vs HWRF 2012

- Pre-implementation evaluation of model environment

Sample of results from retrospective 2010-2011 Atlantic storms







CIRA

NOAA HURRICANE FORECAST IMPROVEMENT PROJECT

Wrap-Up & Future Plans

- Create uniform summaries of model runs that contain key vortex and environmental data, including full vertical profile
  - Easy to compare different models, different versions of same model, impact of model upgrades
  - Allows for pre-implementation, real-time, and post-season evaluation of significant environmental parameters beyond intensity and track
- Improve efficiency of code, involve more modelers
- Allow for wider range of input data formats
- Centrally house files from many models/groups at DTC