Diagnostics for Evaluating Hurricane Model Forecast Errors

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HFIP Physics Workshop September 17-18, 2012

Outline

- Summary of HFIP Diagnostics Workshop Aug 2012
- Diagnostics for improving physics
 - Comparison with satellite observations
 - NHC, CIRA, JPL
 - Comparison with radar and in situ observations
 - HRD, SUNYA
 - Verification of model fields
 - DTC, NRL, CIRA
 - Evaluation in theoretical frameworks
 - UCLA, FSU, CIRA

HFIP Diagnostics Workshop

- Mostly Virtual from EMC, Aug 10th 2012
 - http://rammb.cira.colostate.edu/research/tropical_cyclones/hfip/workshop_2012/
- Participants
 - NOAA/NWS
 - EMC, NHC
 - NOAA Research
 - ESRL, GFDL, HRD, NESDIS
 - NCAR
 - DTC, TCMT
 - NASA
 - JPL
 - University
 - CSU, FSU, SUNYA, UCLA
- Progress review of the ADD Team milestones
- Ensure coordination with EMC and NHC priorities

Model Evaluations using Microwave Imagery (D. Zelinsky, NHC)

- Similar to CIRA study with GOES data
- Use radiative transfer model to create synthetic microwave imagery (~89 GHz)
- Compare with imagery from real storm
- Initial study concentrates on eyewall features



Sample Forecast: Debby HWRF forecast (above) and observed microwave images (right)

Methodology: Evaluating Primary Band Forecasts

- 3) Is deep convection present within clearly defined (unbroken) bands that spiral around the center?
- If no, band = 0.
- If yes, fit the Dvorak log-10 spiral to the middle of the band and count the number of tenths.
- Note: If the band continues unbroken into an eyewall, the eyewall can count as part of the band, as long as at least 3/10 of that band exists completely independently of the eyewall itself.



Preliminary Results: 48 hour Eyewall Forecasts

Contingency Table



Stats

- Total Cases: 76
- Contingency Accuracy: 82.89%
- Probability of Detection: **47.62%**
- False Alarm Rate: **03.64%**
- Success Ratio: **83.33%**
- ETS: 0.34



Comparison of Synthetic and Real GOES Data for Hurricane Maria 2011 (CIRA)



Synthetic GOES WV Image 24 hr HWRF Forecast valid at 00 UTC on 13 Sept 2011 Real GOES WV Image at 00 UTC on 13 Sept 2011

GOES Water Vapor T_B Histograms for 48 h Maria Forecasts



(Dashed= Model, Solid=Observed)

HRD Model Evaluations

- Comparison with in situ and radar data
 - Airborne Doppler, SFMR, GPS soundings, flight level data
- Composite vorticity structures, boundary parameters
- Low wavenumber wind fields

Height of Vtmax



Black dashed line represents the height of maximum tangential wind speed

DTC Evaluation of Basin-Scale HWRF



400-hPa Relative Humidity

GFS





GFDL Model Sensitivity Studies with Regional Ensemble System

The GFDL ENSEMBLE PRODUCT ALSO SHOWED HUGE SPREAD IN INTENSITY. LARGEST IMPACT WAS WITH INCREASE /DECREASE OF INNER-CORE MOISTURE BY 10% (PERTURBATION MAXIMUM AT STORM CENTER)

IMPACT OF MOISTURE MORE IMPORTANT_THEN +1 degree C SST INCREASE

GFDL Ensemble Forecast for ERNEST005L: Maximum Wind Initial time: 00Z04AUG2012



CIRA Diagnostic File from HWRF Used for Large-Scale Parameter Verification

*	HWRF	2011082200	*	
*	AL09	IRENE	*	

											ST	ORM DA	ITA										
NTIME O	22 DELT	200 TA																					
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)	18.0	18.3	18.6	19.1	19.5	19.6	19.9	20,2	20.4	20.8	21.3	21,9	22.7	23.4	24.4	25.4	26.3	27.3	28.2	29,1	30.1	30.9
LON	(DEG)	295.1	293.7	292.4	291.5	290.6	289.6	289.1	288.5	287.9	287.3	286.6	285.9	285.2	284.3	283.7	282.9	282.4	281.7	281.2	280.7	280.3	279.9
IMHXWIND IDMU	(KT) (PM)	50 157	57	64	69 00	107	107	75	76	74	84	89	93	103	108	110	112	110	114	120	113	114	109
MIN SEP	(ND) (MB)	997	991	986	981	975	970	971	967	336	959	73 955	945	942	937	936	931	930	925	925	925	928	926
ISHR MAG	(KT)	7	7	1	4	8	6	5	9	8	12	12	11	9	9	8	10	12	11	9	7	11	12
SHR_DIR	(DEG)	233	190	125	283	281	322	300	272	275	295	295	299	280	281	281	250	245	245	258	245	246	249
STM_SPD	(KT)	_14	13	_10	. 9	. 9	6	6	6	7	8	. 9	10	_11	_11	_12	_10	_12	_10	10	_11	9	9999
ISTM_HDG	(DEG)	283	284	300	295	276	303	298	290	305	307	313	321	310	331	324	333	328	334	334	341	337	9999
1551 10HC	(100) (KI/CM2)	291	9999	289	286	267	9999	9999	287	289	287	285	287	287	289	290	292	9999	285	285	280	295	238 9999
TPW	(MM)	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	9999	99999	9999	9999	9999	9999
LAND	(KM)	91	-22	44	37	22	-16	12	44	70	100	154	162	206	252	316	314	255	181	166	143	152	127
850TANG	(10M/S)	110	130	146	156	170	174	179	184	189	193	200	209	215	218	226	231	246	253	262	266	270	275
850VORT	(/S)	54	54	68	61	60	62	64	74	81	82	87	93	97	94	90	92	95	96	85	88	88	79
1200DAKP	(75)	75	95	80	67	55	58	52	55	47	54	50	57	40	57	63	65	50	71	48	30	55	57
1																							
											SC	UNDING	DATA										
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NLEV 02 TIME T_SURF R_SURF	0 SURF 10 (HR) (10C) (%)	00 0950 0 285 82) 0900 6 284 82	0850 (12 284 82)800 07 18 285 81	750 070 24 286 81	00 0650 30 286 81	0600 36 287 81	0550 0 42 287 81	500 04 48 287 81	50 040 54 287 80	UNDING 0 0350 60 287 80	DATA 0300 66 287 80	 0250 (72 287 80	200 01 78 288 80	50 010 84 288 79	0 90 289 79	96 289 79	102 289 80	108 289 79	114 288 79	120 287 78	126 286 77
NLEV 02 TIME T_SURF R_SURF P_SURF	0 SURF 10 (HR) (10C) (%) (MB) (10KT)	00 0950 0 285 82 1012 -137) 0900 6 284 82 1010 -111	0850 (12 284 82 1012 -97)800 07 18 285 81 1010 -90	750 070 24 286 81 1011 -79	0 0650 30 286 81 1008 -72	0600 36 287 81 1010 -82	0550 0 42 287 81 1007 -90	500 04 48 287 81 1009 -96	50 040 54 287 80 1007 99	UNDING 0 0350 60 287 80 1009 -96	DATA 0300 66 287 80 1007 -92	 0250 (72 287 80 1008 -94)200 01 78 288 80 1006 -94	50 010 84 288 79 1009 -92	0 90 289 79 1008 -97	96 289 79 1009 -69	102 289 80 1007 -62	108 289 79 1009 -57	114 288 79 1008	120 287 78 1009	126 286 77 1007
NLEV 02 TIME T_SURF R_SURF P_SURF U_SURF V_SURF	0 SURF 10 (HR) (10C) (%) (MB) (10KT) (10KT)	00 0950 0 285 82 1012 -137 -15) 0900 6 284 82 1010 -111 1	0850 (12 284 82 1012 -87 20	0800 07 18 285 81 1010 -80 38	750 070 24 286 81 1011 -78 27	00 0650 30 286 81 1008 -72 26	0600 36 287 81 1010 -82 9	0550 0 42 287 81 1007 -90 8	500 04 48 287 81 1009 -86 11	50 040 54 287 80 1007 -88 33	UNDING 60 287 80 1009 -86 28	DATA 0300 66 287 80 1007 -92 45	 0250 (72 287 80 1008 -94 40)200 01 78 288 80 1006 -94 51	50 010 84 288 79 1009 -92 53	0 90 289 79 1008 -83 50	96 289 79 1009 -69 50	102 289 80 1007 -62 63	108 289 79 1009 -57 70	114 288 79 1008 -47 82	120 287 78 1009 -42 83	126 286 77 1007 -15 105
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CIRA Study to Understand Large-Scale Controls on Model Intensity Evolution

Fit simplified LGEM model to HWRF and GFDL Output



UCLA Physics Parameterization Study

Using Motion and PV Diagnostics to Understand Differences

- Goal #1: To determine if systematic biases exist in various cumulus parameterization (CP) schemes
- Goal #2: To assess how well CP schemes work with microphysics (MP) and radiation assumptions
- Technique: construct vortex-following composite fields and analyze differences among physics-based ensemble members, including PV analysis
- Reminder: The PV equation diabatic heating (DH) term is based on gradients of diabatic heating (Q) and absolute vorticity (q), not Q or vertical velocity itself



Vortex vs. Environment



Torn and Cook (2012), MWR In Press

FSU ERROR FINDING ALGORITHM

Total tendency errors can be estimated from the following equation:

$$\varepsilon_{ijkl} = \frac{\partial Q}{\partial t} \bigg|_{ijkl}^{mod el} - \frac{\partial Q}{\partial t} \bigg|_{ijkl}^{analysis}$$

Where i, j and k denote an index for the three co-ordinates, and I the variable. The three-dimensional (multiple regression based) multiplier λ_{ijkl} is defined such that:

$$\frac{\partial Q}{\partial t} \bigg|_{ijkl}^{analysis} = \sum \lambda_{ijkl} \frac{\partial Q}{\partial t} \bigg|_{ijkl}^{mod \ el}$$

The determination of λ_{ijkl} utilizes the least squares minimization – procedure based on several multiple linear regression. λ_{ijkl} provides mean for statistically corrected estimates of the forcing for the dynamics and physics of any of the equations while minimizing (towards 0) the total tendency error. The four dimensionally distributed error at a grid location is given by (1- λ_{ijkl}) <u>Aikl</u>

Summary

• Diagnostic studies can help evaluate errors due to model physics

- Comparisons with satellite, radar and in situ data

- Physics errors contribute to large, vortex and cloud scale errors
- Verification combined with diagnostic studies can help identify the source of errors
 - PV budgets, FSU least squares method, SUNYA EOF1, GFDL ensemble system, CIRA fits of statistical models to dynamical model output