Diagnostics for Evaluating Hurricane Model Forecast Errors

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Dave Zelinsky, NOAA/NHC

HFIP Physics Workshop
September 17-18, 2012

Outline

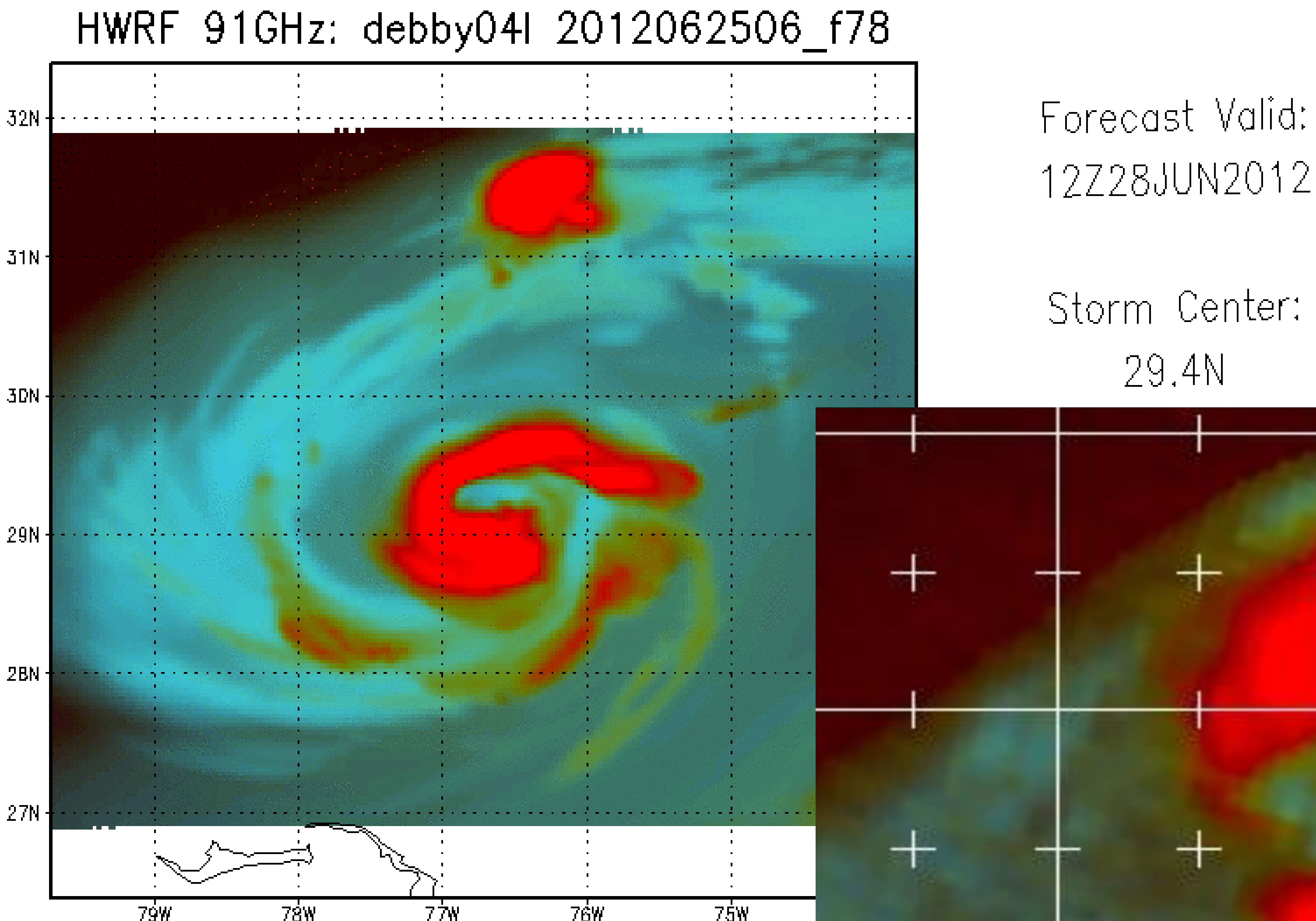
- Summary of HFIP Diagnostics Workshop Aug 2012
- Diagnostics for improving physics
  - Comparison with satellite observations
    - NHC, CIRA, JPL
  - Comparison with radar and in situ observations
    - HRD, SUNYA
  - Verification of model fields
    - DTC, NRL, CIRA
  - Evaluation in theoretical frameworks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

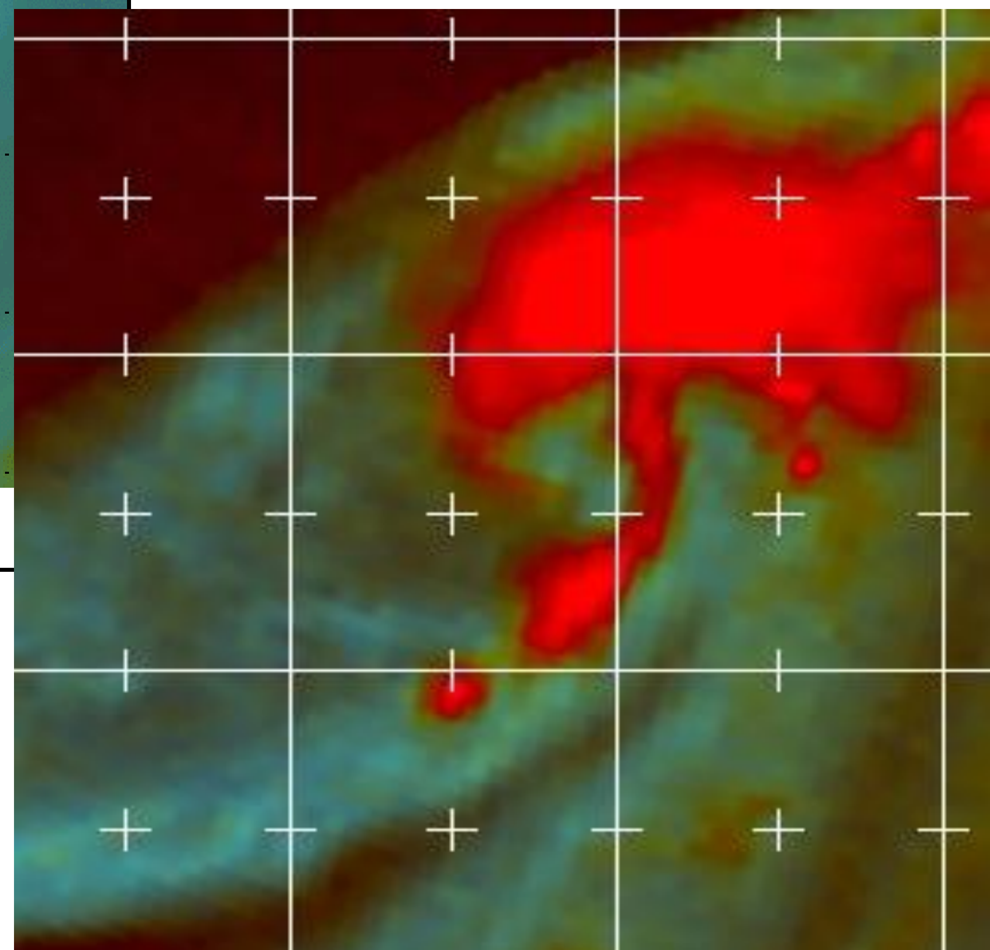
HFIP Diagnostics Workshop

- 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



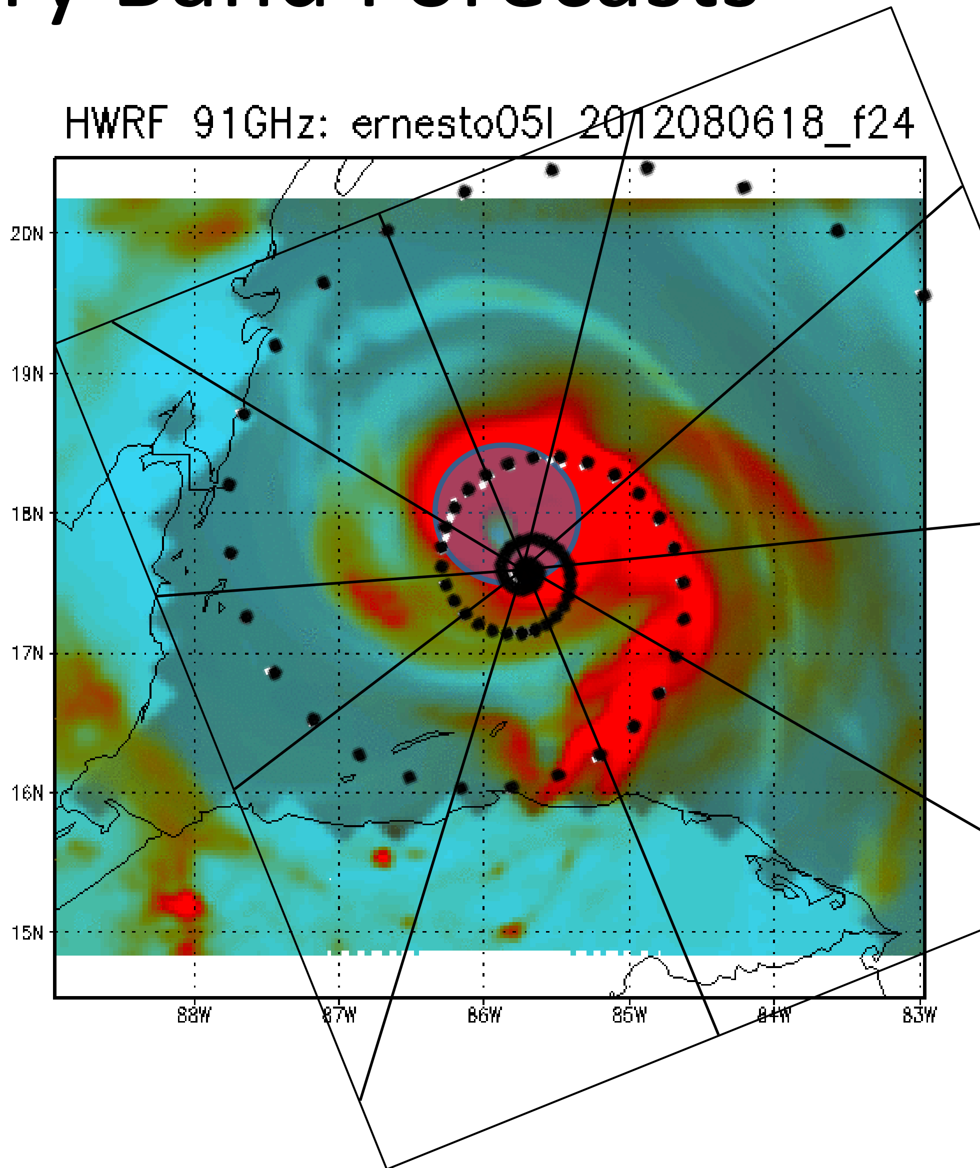


Sample Forecast: Debby HWRF forecast (above) and observed microwave images (right)

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

Forecast	Observed: Yes	Observed: No
Yes	10	2
No	11	53

Stats

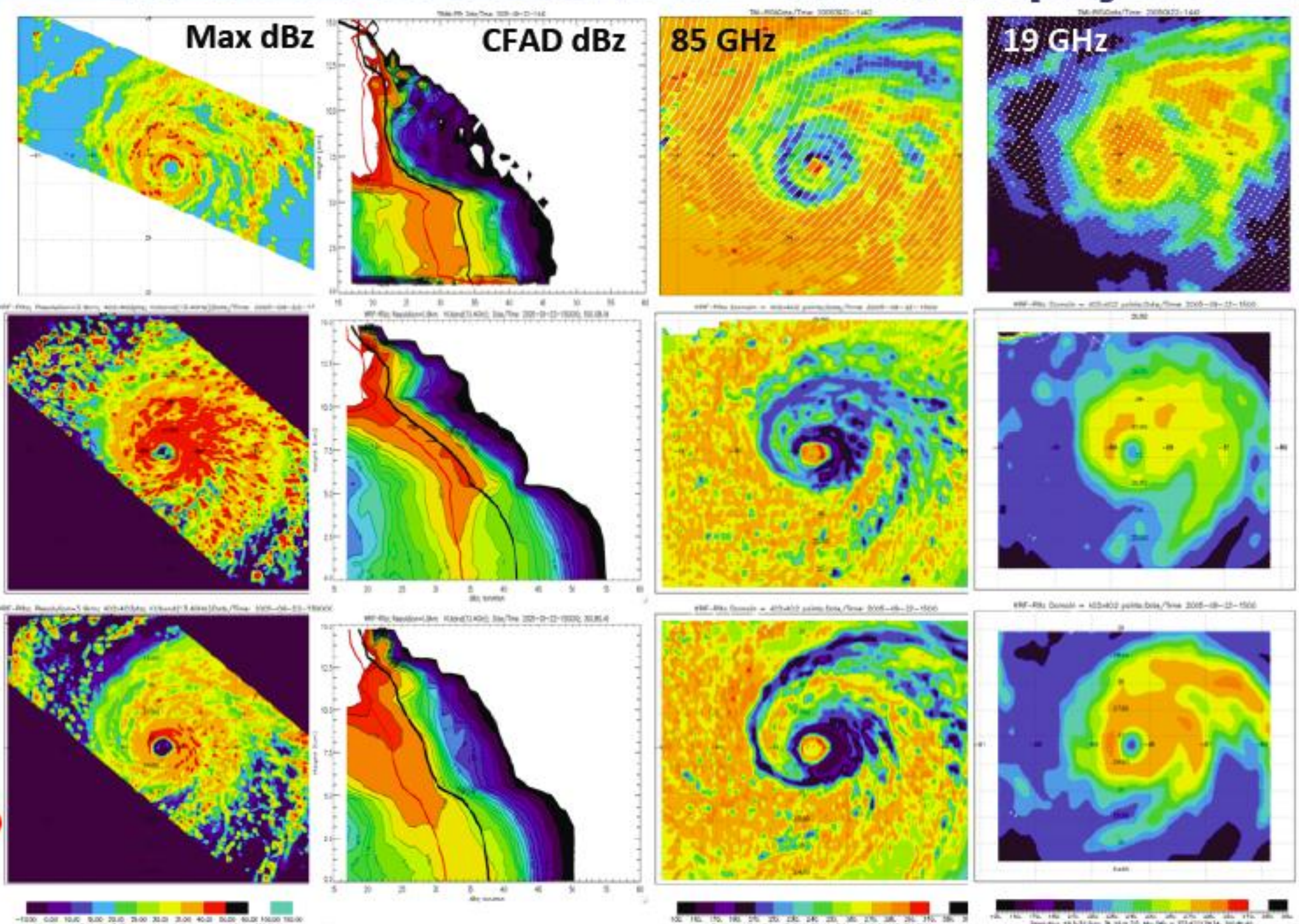
- Total Cases: **76**
- Contingency Accuracy: **82.89%**
- Probability of Detection: **47.62%**
- False Alarm Rate: **03.64%**
- Success Ratio: **83.33%**
- ETS: **0.34**

JPL Research using the TCIS Data Archive: MODEL EVALUATION – the Microphysics

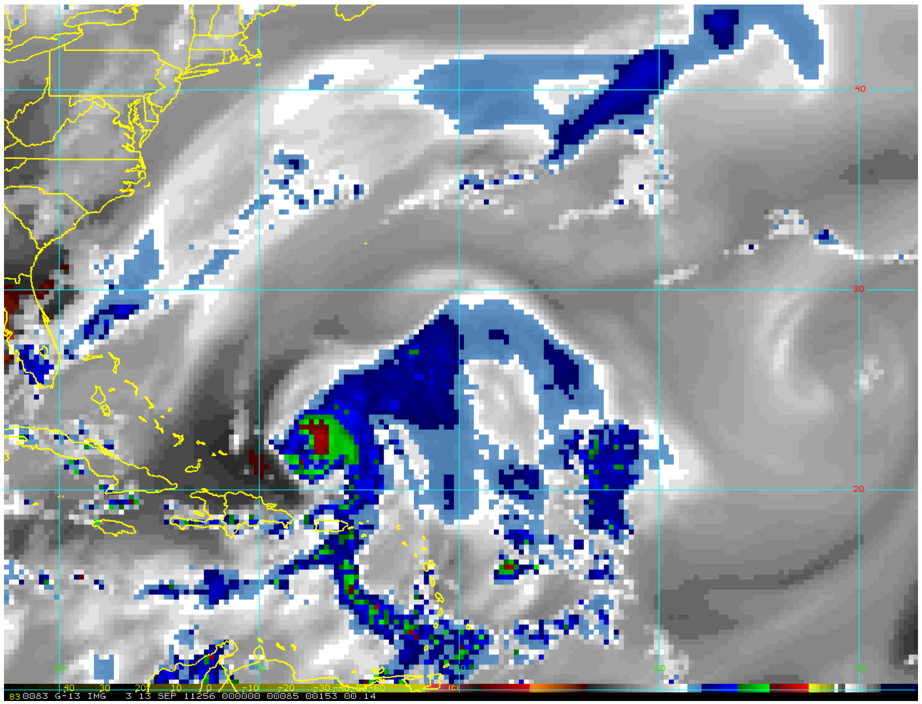
TRMM

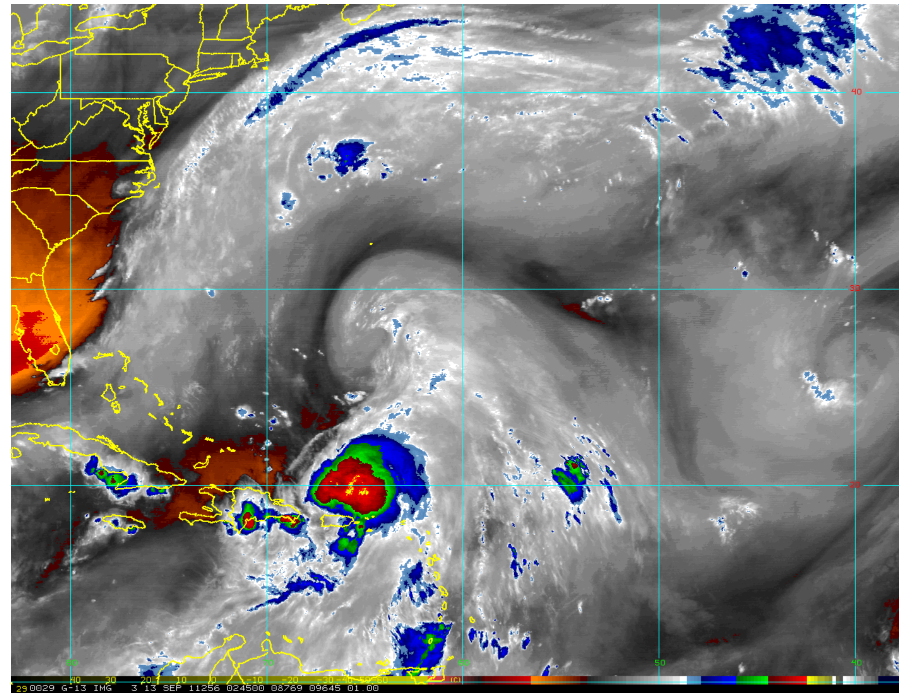
WRF WSM3

WRF WSM6 New PSD



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

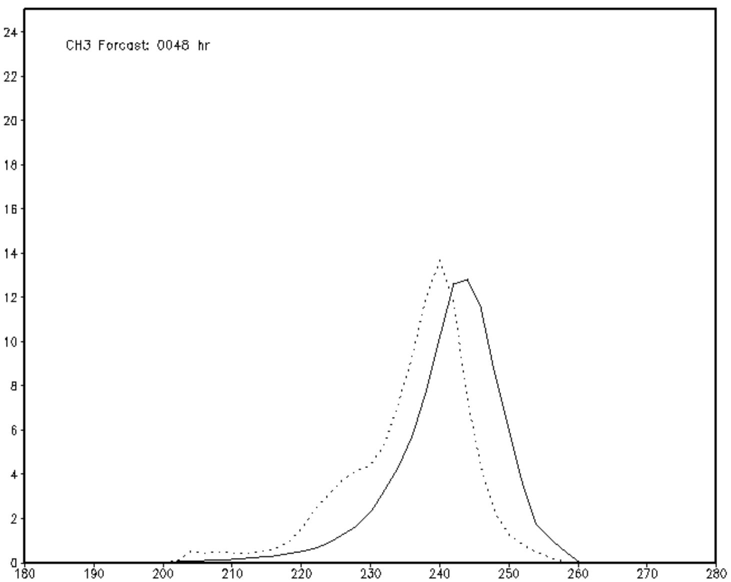




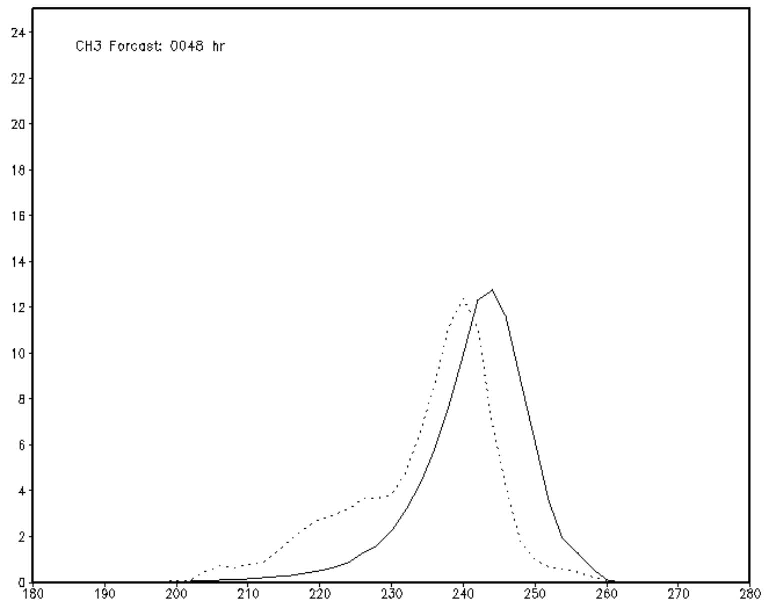
Synthetic GOES WV Image
24 hr HWRF Forecast valid
at 00 UTC on 13 Sept 2011

Real GOES WV Image
at 00 UTC on 13 Sept 2011

GOES Water Vapor T_B Histograms for 48 h Maria Forecasts



HWRF Operational



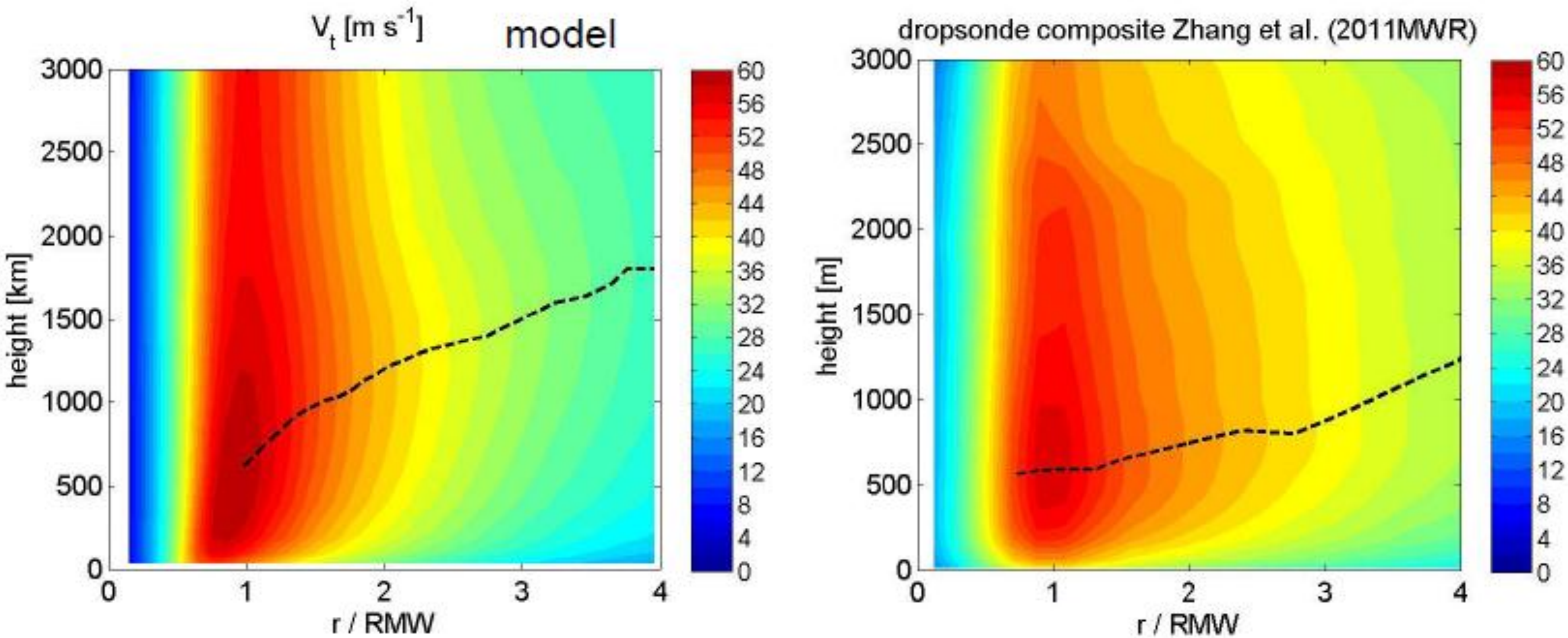
HWRF H212

(Dashed= Model, Solid=Observed)

HRD Model Evaluations

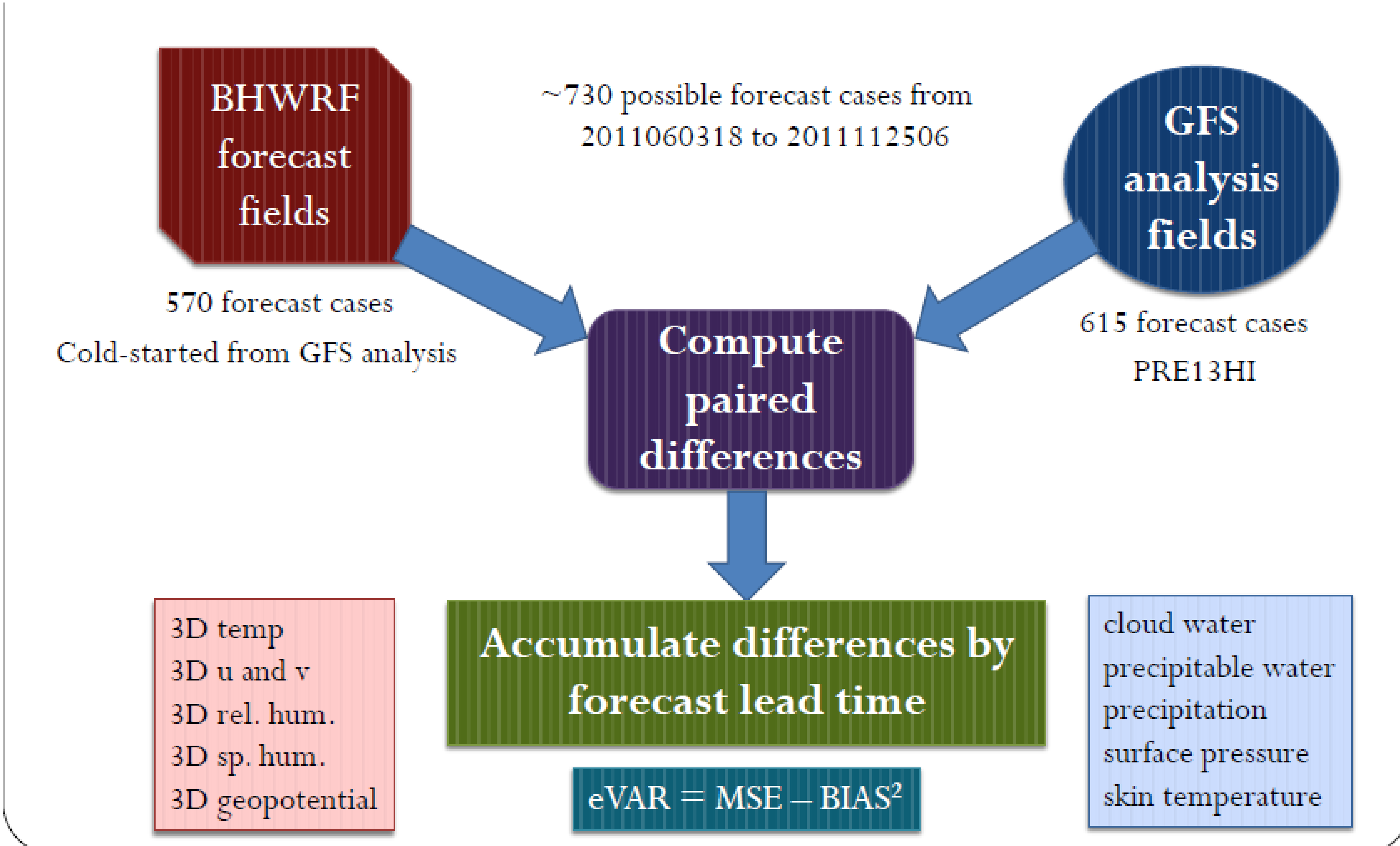
- Comparison with in situ and radar data
  - Airborne Doppler, SFMR, GPS soundings, flight level data
- Composite vorticity structures, boundary parameters
- Low wavenumber wind fields

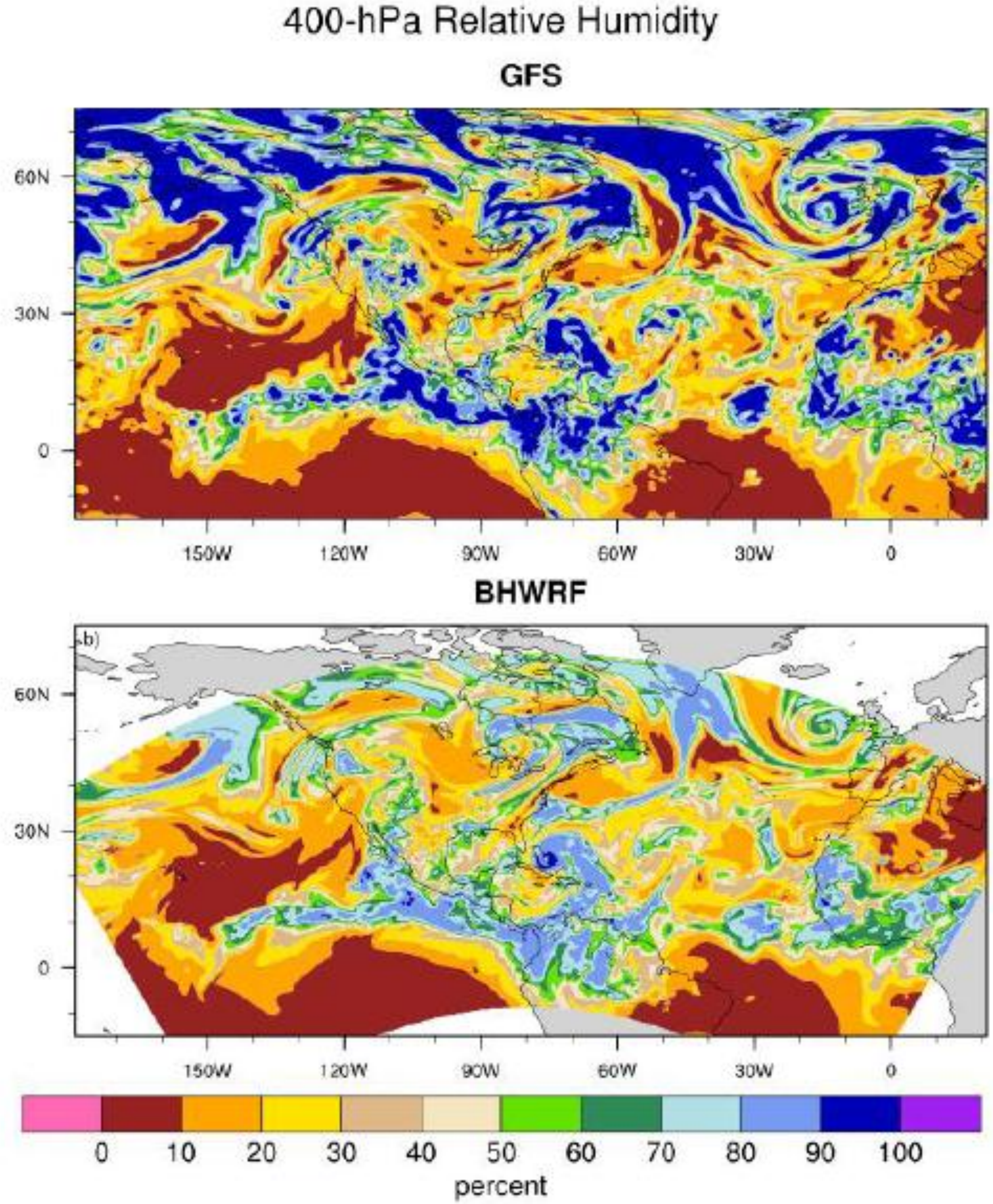
Height of Vtmax



Black dashed line represents the height of maximum tangential wind speed

DTC Evaluation of Basin-Scale HWRF

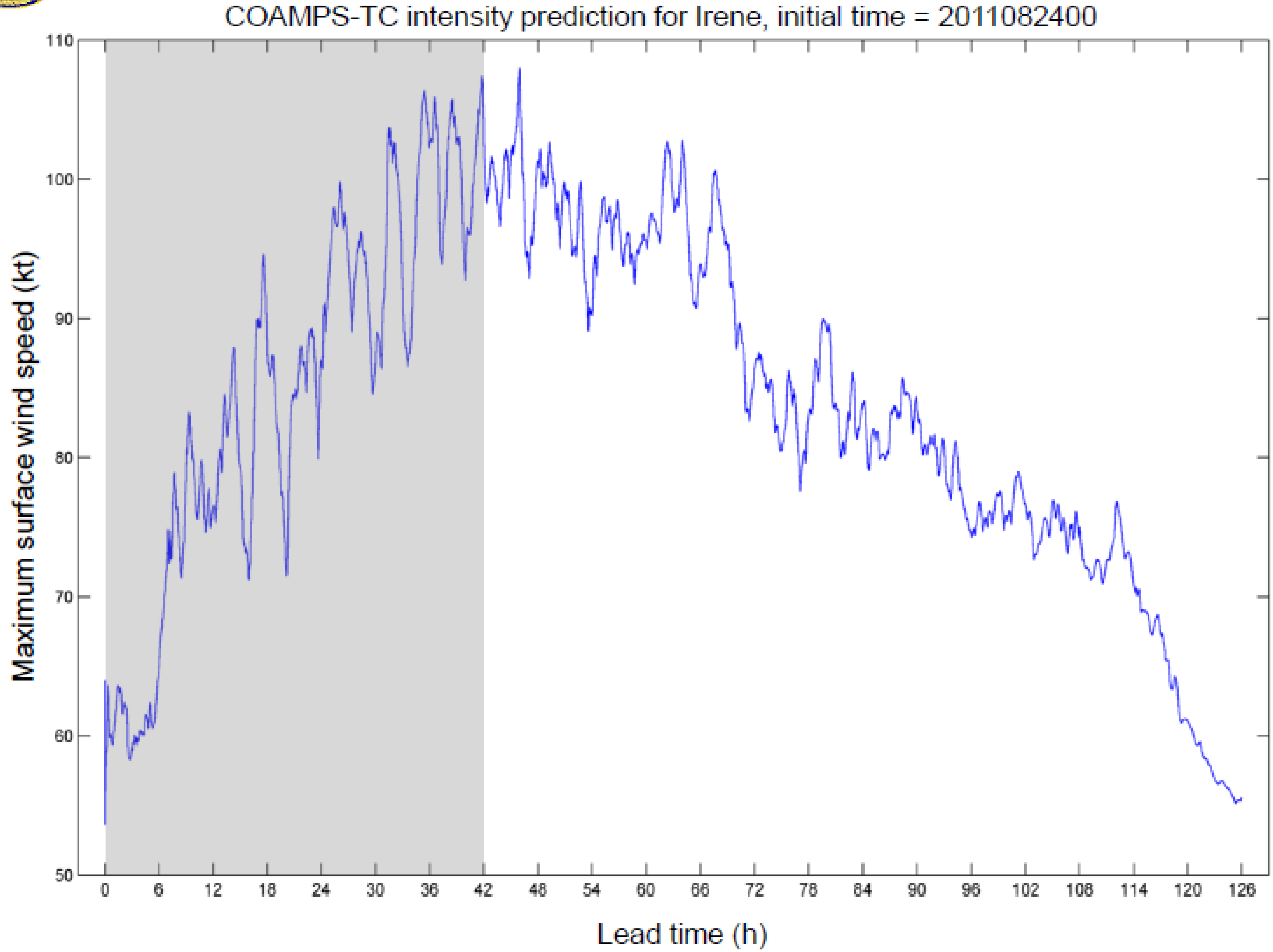




400-hPa Relative Humidity
GFS
60N
30N
0
150W
120W
90W
60W
30W
0
BHWRF
b)
60N
30N
0
150W
120W
90W
60W
30W
0
0
10
20
30
40
50
60
70
80
90
100
percent

COAMPS-TC

High-frequency TC model output (HTCF)

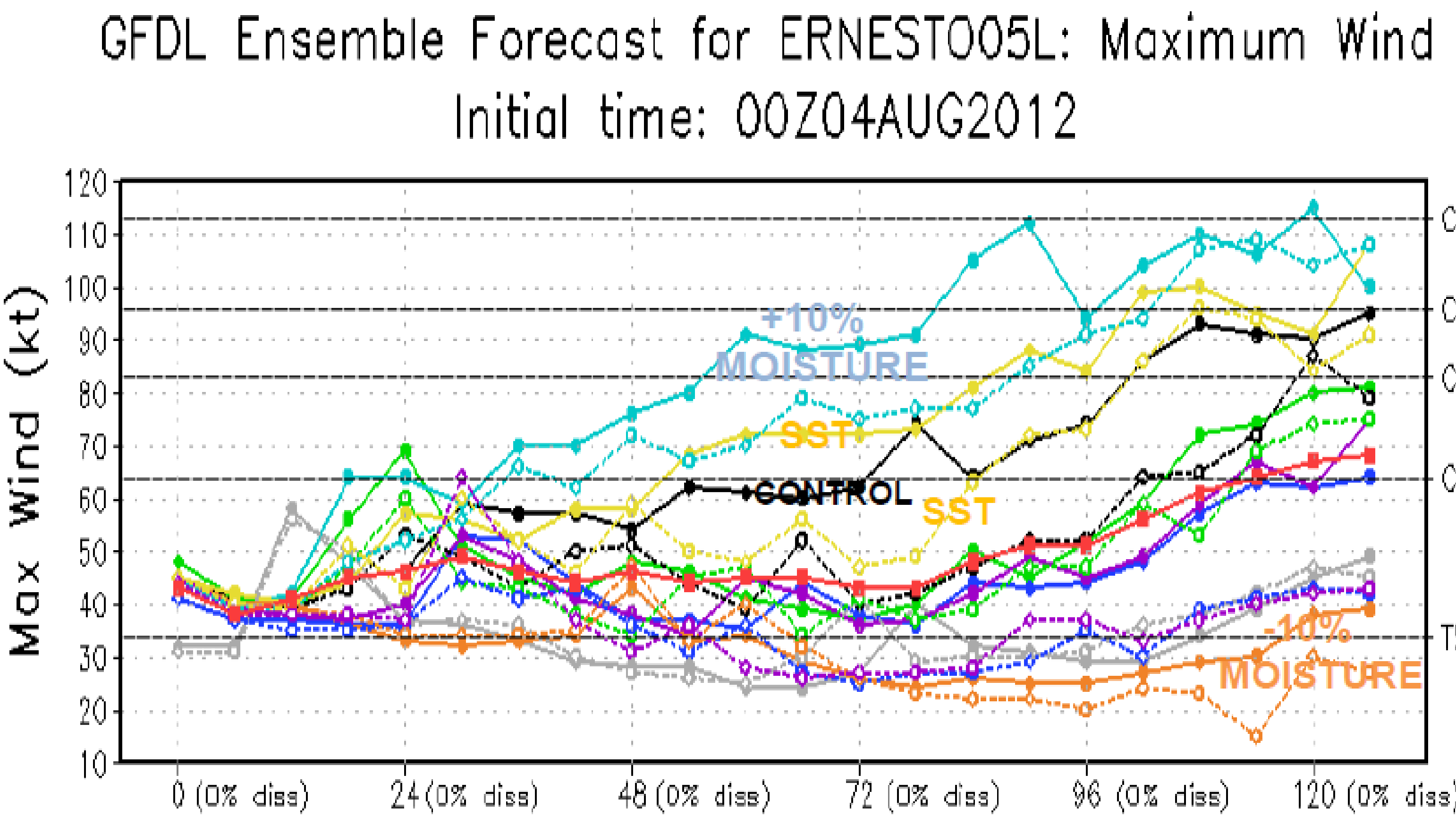


GFDL Model Sensitivity Studies with Regional Ensemble System

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



CIRA Diagnostic File from HWRF

Used for Large-Scale Parameter Verification

```
*   HWRF  2011082200   *
*   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)	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
MAXWIND	(KT)	50	57	64	69	76	71	75	76	74	84	89	93	103	108	110	112	110	114	120	113	114	109
RMW	(KM)	157	114	94	86	103	103	66	60	70	65	73	66	69	78	72	75	84	90	90	94	92	93
MIN_SLP	(MB)	993	991	986	981	975	970	971	967	966	959	955	945	942	937	936	931	930	925	925	925	928	926
SHR_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
STM_HDG	(DEG)	283	284	300	295	276	303	298	290	305	307	313	321	310	331	324	333	328	334	334	341	337	9999
SST	(10C)	291	9999	289	286	267	9999	9999	287	289	287	285	287	287	289	290	292	290	285	283	280	295	298
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)	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
200DVRG	(/S)	73	95	80	67	55	58	52	55	47	54	50	57	40	57	63	65	50	71	48	30	33	57

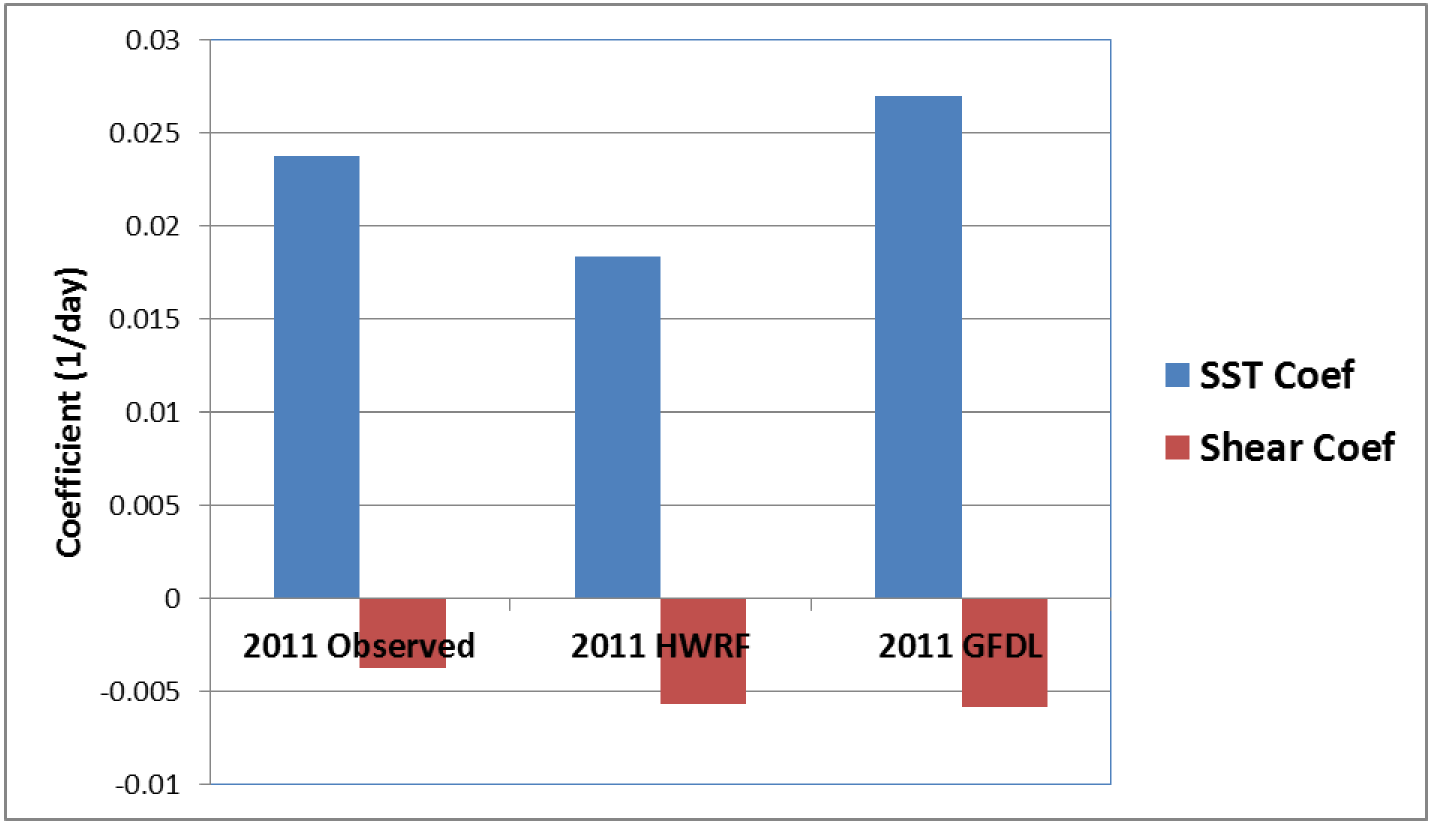
-- SOUNDING DATA --

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)	285	284	284	285	286	286	287	287	287	287	287	287	287	288	288	289	289	289	289	288	287	286
R_SURF	(%)	82	82	82	81	81	81	81	81	81	80	80	80	80	80	79	79	79	80	79	79	78	77
P_SURF	(MB)	1012	1010	1012	1010	1011	1008	1010	1007	1009	1007	1009	1007	1008	1006	1009	1008	1009	1007	1009	1008	1009	1007
U_SURF	(10KT)	-137	-111	-87	-80	-78	-72	-82	-90	-86	-88	-86	-92	-94	-94	-92	-83	-69	-62	-57	-47	-42	-15
V_SURF	(10KT)	-15	1	20	38	27	26	9	8	11	33	28	45	40	51	53	50	50	63	70	82	83	105
T_1000	(10C)	277	278	276	278	279	278	276	278	279	278	277	279	280	278	277	279	278	274	269	272	272	266
R_1000	(%)	77	77	77	77	78	79	79	78	79	79	79	78	79	79	79	79	81	82	83	82	84	85
Z_1000	(DM)	11	9	10	9	9	7	8	6	8	6	8	6	7	6	8	7	8	6	8	7	8	6
U_1000	(10KT)	-166	-132	-104	-94	-92	-83	-95	-102	-98	-98	-98	-102	-105	-104	-105	-94	-80	-71	-65	-53	-48	-17
V_1000	(10KT)	-19	0	22	42	30	29	12	11	15	39	34	52	47	59	63	57	58	69	77	86	85	104
T_0950	(10C)	237	237	235	237	238	236	235	237	238	237	237	239	240	239	238	239	239	236	233	234	236	232
R_0950	(%)	86	88	89	89	90	90	91	90	90	90	90	90	90	90	90	90	91	91	92	92	92	93
Z_0950	(DM)	56	54	56	54	55	53	54	52	53	51	53	51	52	51	53	52	53	52	53	52	53	51
U_0950	(10KT)	-184	-155	-121	-112	-107	-100	-111	-125	-120	-119	-114	-115	-116	-116	-113	-109	-95	-92	-77	-67	-72	-46
V_0950	(10KT)	-16	-2	21	47	38	42	18	16	18	49	43	66	60	74	80	69	62	67	71	79	63	84
T_0900	(10C)	209	203	202	204	204	202	201	202	203	202	201	203	204	204	203	204	204	203	202	202	203	201
R_0900	(%)	84	92	93	94	95	95	96	97	97	97	97	98	97	97	97	98	98	97	96	96	97	96

CIRA Study to Understand Large-Scale Controls on Model Intensity Evolution

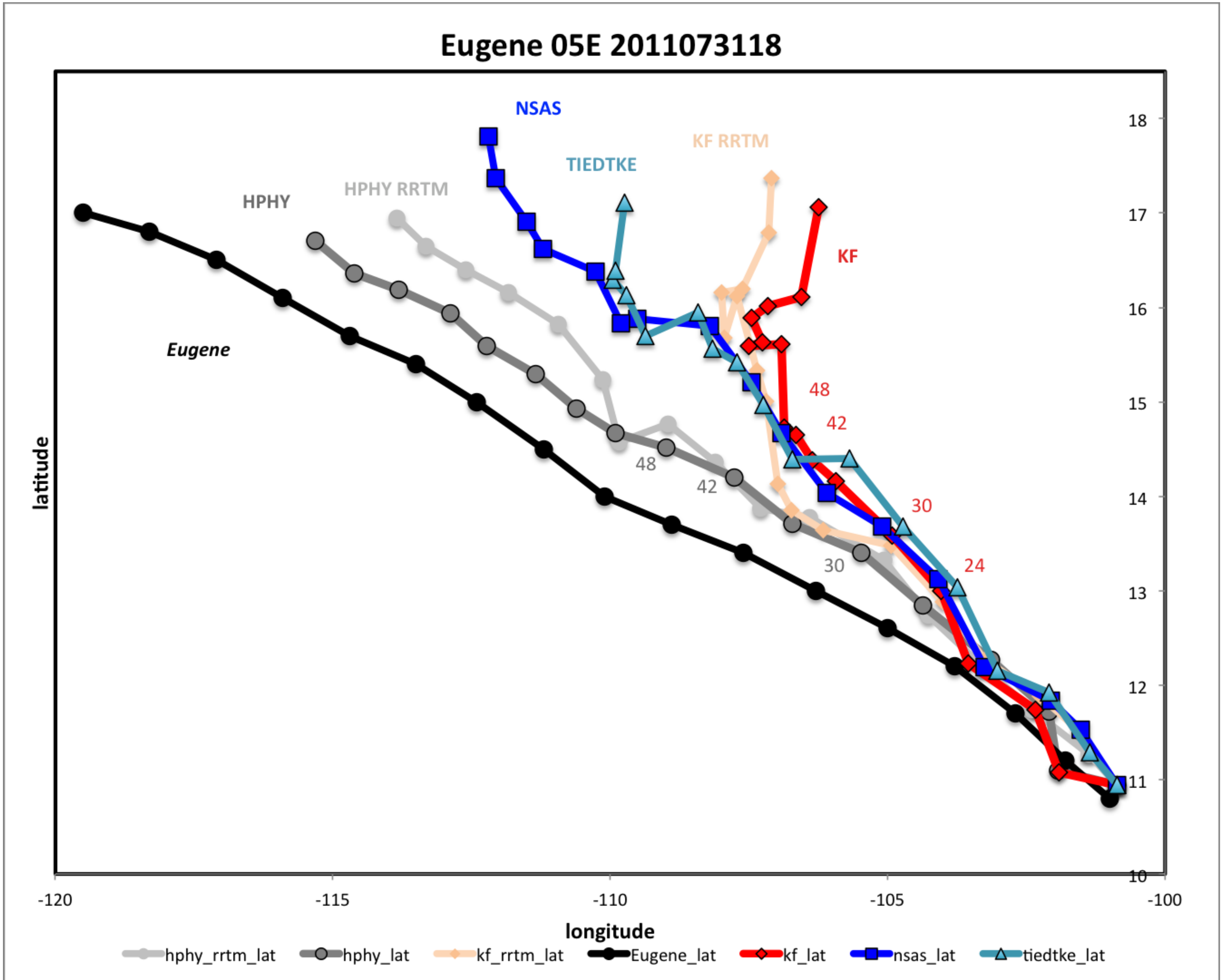
Fit simplified LGEM model to HWRF and GFDL Output



UCLA Physics Parameterization Study

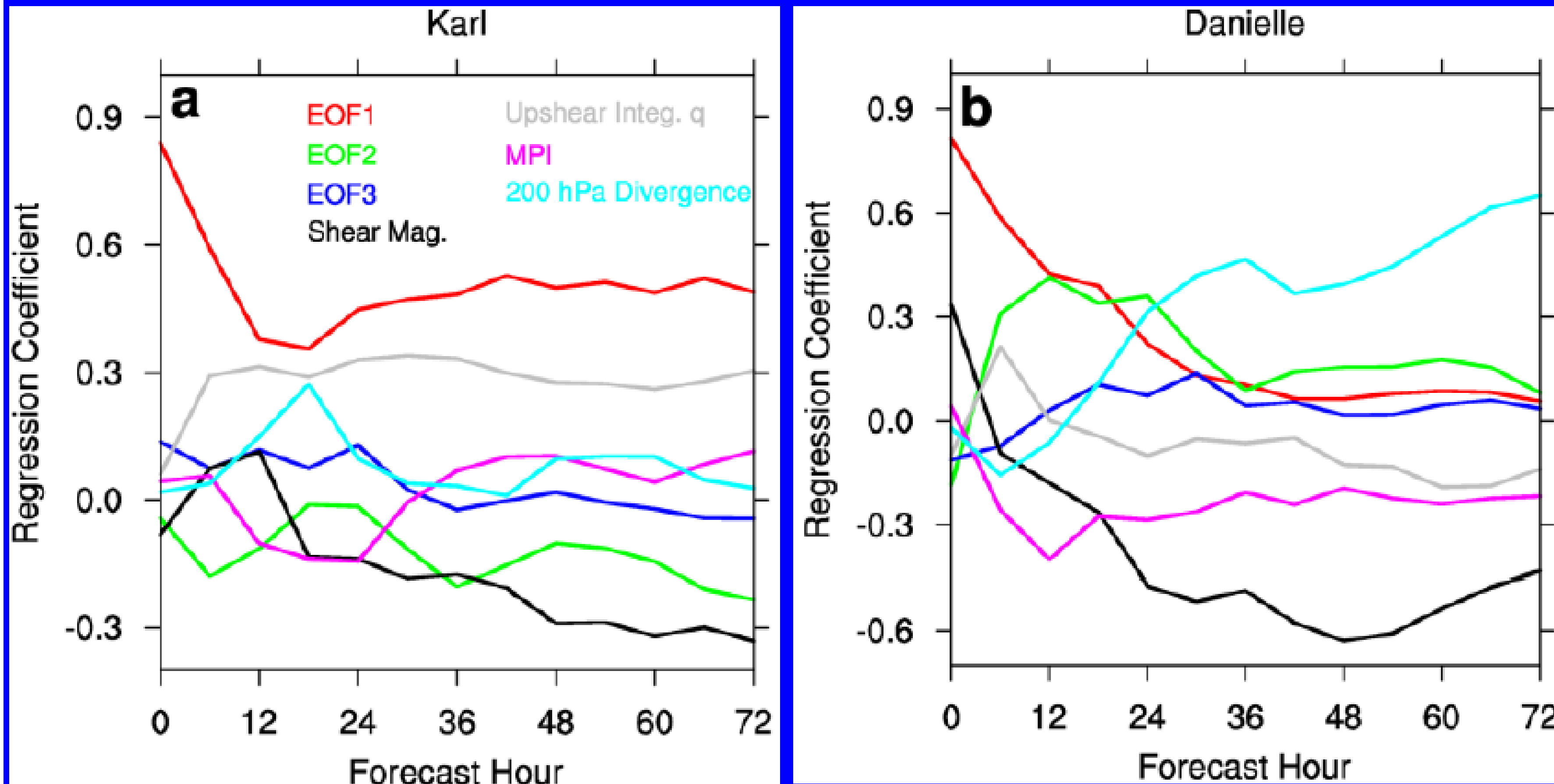
Using Motion and PV Diagnostics to Understand Differences

- *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



Eugene 05E 2011073118
NSAS
KF RRTM
TIEDTKE
HPHY RRTM
HPHY
KF
Eugene
48
42
48
42
30
30
24
latitude
longitude
18
17
16
15
14
13
12
11
10
-120
-115
-110
-105
-100
hphy_rrtm_lat
hphy_lat
kf_rrtm_lat
Eugene_lat
kf_lat
nsas_lat
tiedtke_lat

Vortex vs. Environment



Torn and Cook (2012), MWR In Press

FSU ERROR FINDING ALGORITHM

Total tendency errors can be estimated from the following equation:

$$\varepsilon_{ijkl} = \left.\frac{\partial Q}{\partial t}\right)_{ijkl}^{\text{model}} - \left.\frac{\partial Q}{\partial t}\right)_{ijkl}^{analysis}$$

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

$$\left.\frac{\partial Q}{\partial t}\right)_{ijkl}^{analysis} = \sum \lambda_{ijkl} \left.\frac{\partial Q}{\partial t}\right)_{ijkl}^{\text{model}}$$

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})A_{ijkl}

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