



# An Objective Verification Of The North American Mesoscale Model for Kennedy Space Center and Cape Canaveral Air Force Station

William H. Bauman III

NASA Applied Meteorology Unit  
ENSCO, Inc.  
Cape Canaveral Air Force Station, Florida



# Outline



- Background/Objective
- Launch/Landing Weather Towers
- MesoNAM Grid
- Data and Methodology
- Data Formatting
- Verification Examples
- Graphical User Interface
- Summary and Conclusions





# Background/Objective



- The 12-km NAM (MesoNAM) used
  - By 45 WS Launch Weather Officers
  - At KSC and CCAFS
  - To forecast  $T$ ,  $T_d$  and winds at launch weather towers
- Model performance not measured objectively
- The 45 WS tasked the Applied Meteorology Unit (AMU) to conduct analysis of model versus tower observations
- Need to assess model performance at each tower and sensor height



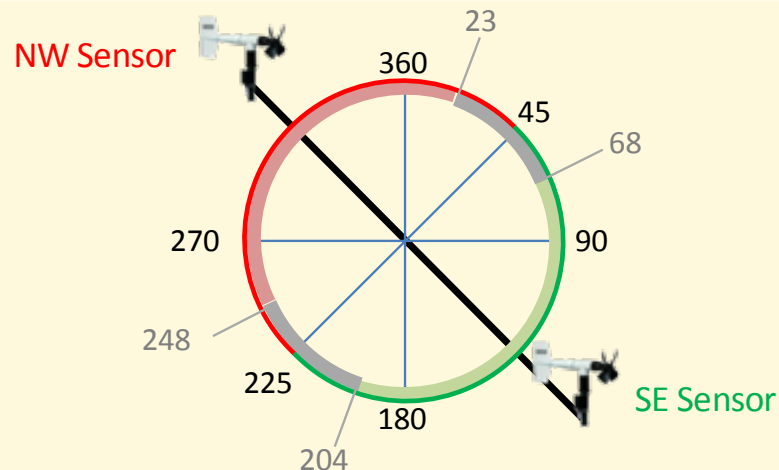




# Launch/Landing Weather Towers



Tower Number	Supported Activity and Facility	Sensor Heights
002	Delta II (LC-17)	6 ft, 54 ft, 90 ft
006/108	Delta IV (LC-37)/Falcon 9 (LC-40)	54 ft
110	Atlas V (LC-41)/Falcon 9 (LC-40)	54 ft, 162 ft, 204 ft
041	Atlas V (LC-41)	230 ft
393/394	Shuttle/Constellation (LC-39A)	60 ft
397/398	Shuttle/Constellation (LC-39B)	60 ft
511/512/513	Shuttle Landing Facility	6 ft, 30 ft





# Data and Methodology

- Used MesoNAM textual forecasts from ACTA, Inc.
  - Hourly forecasts: 0 to 84 hours
  - Model initialization times: 00, 06, 12 and 18 UTC
- Verified operational MesoNAM
  - October 2006 → April 2009
- Data sets stratified by
  - Warm season (May-Sep), Cool season (Oct-Apr), Year, Month, Onshore/offshore flow & Model initialization time
- Computed
  - Bias, standard deviation of bias and Root Mean Square Error

Document - WordPad

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Station=747940

YYMMDD/HHMM	T2MS	TD2M	SKNT	DRCT	PMSL	PO1M	LCLD	MCLD	HCLD
090105/1200	17.6	14.6	0.6	180	1021.2	-9999.00	0	0	28
090105/1300	16.6	14.0	1.2	270	1019.6	0.00	0	0	0
090105/1400	19.6	14.6	1.6	330	1021.4	0.00	0	0	38
090105/1500	22.4	16.1	2.8	335	1021.7	0.00	0	0	0
090105/1600	23.5	16.3	2.1	338	1020.5	0.00	10	0	100
090105/1700	24.4	16.0	2.9	20	1021.0	0.00	10	0	0
090105/1800	24.9	15.9	3.6	49	1020.3	0.00	10	0	0
090105/1900	25.0	16.0	5.5	72	1019.0	0.00	10	0	0
090105/2000	24.6	16.7	6.8	72	1018.7	0.00	10	0	0
090105/2100	23.6	17.3	7.2	82	1018.4	0.00	0	0	0
090105/2200	22.3	17.4	7.0	82	1017.8	0.00	0	0	0
090105/2300	20.1	17.4	7.6	87	1017.8	0.00	0	0	0
090106/0000	19.2	17.3	8.4	103	1017.9	0.00	0	0	0
090106/0100	19.0	17.1	8.9	117	1017.8	0.00	0	0	0
090106/0200	19.0	17.0	9.4	130	1019.1	0.00	0	0	0
090106/0300	18.8	16.9	9.4	142	1018.4	0.00	0	0	0
090106/0400	18.7	17.0	9.8	156	1018.6	0.00	0	0	0
090106/0500	18.7	17.3	10.5	165	1018.6	0.00	0	0	0
090106/0600	18.8	17.8	11.8	166	1017.8	0.00	0	0	0
090106/0700	19.0	18.1	11.8	171	1017.5	0.00	0	0	0
090106/0800	19.0	18.1	11.3	180	1017.1	0.00	0	0	0
090106/0900	18.4	17.5	10.2	189	1016.6	0.00	0	0	0
090106/1000	17.8	16.9	9.9	192	1016.5	0.00	0	0	0
090106/1100	17.5	16.5	10.5	191	1016.3	0.00	0	0	0
090106/1200	17.3	16.3	10.5	191	1016.6	0.00	0	0	0
090106/1300	18.1	16.7	9.7	190	1017.2	0.00	0	0	0
090106/1400	21.0	17.5	9.6	189	1017.0	0.00	0	0	0
090106/1500	23.3	17.8	9.8	189	1017.4	0.00	0	0	0
090106/1600	24.9	17.6	10.5	183	1017.2	0.00	10	0	0
090106/1700	25.9	17.1	11.1	174	1016.1	0.00	10	0	0
090106/1800	26.7	16.9	11.5	164	1015.4	0.00	10	0	0
090106/1900	27.1	16.9	11.5	156	1014.3	0.00	10	0	0
090106/2000	27.1	17.4	12.1	147	1013.5	0.00	10	0	0
090106/2100	26.4	18.6	12.6	141	1013.0	0.00	10	0	0
090106/2200	25.0	19.9	13.9	141	1013.0	0.00	0	0	0
090106/2300	22.9	20.3	15.2	145	1013.3	0.00	10	0	0
090107/0000	22.5	20.1	16.4	149	1013.6	0.00	0	0	0

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# Data Formatting

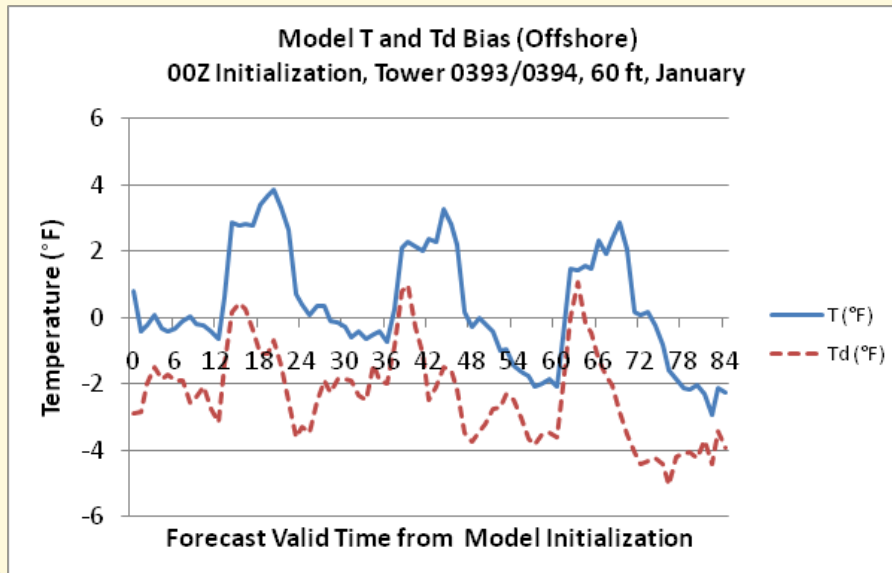
- MesoNAM files: space-delimited text files
  - Hourly forecasts
  - T and T<sub>d</sub> in degrees C
- Tower observations: tab-delimited text files
  - Five minute observations
  - T and T<sub>d</sub> in degrees F
- QC'd, Imported, Manipulated, Merged into Excel™
  - Result: 24,570 Workbooks
  - Four Worksheets per Workbook

	Year	Month	Day	Hour	Mean Spd	Mean Dir	Mean T	Mean Td	YYMMDDHH	WRF Spd	WRF Dir	WRF T	WRF Td
1	2006	10	5	0	16.5	61	79.9	67.1	061005/0000	10.6	41	77.7	66.0
2	2006	10	5	1	15.6	64	79.8	67.0	061005/0100	10.9	51	78.4	64.0
3	2006	10	5	2	15.7	58	79.8	67.8	061005/0200	16.7	54	78.4	63.9
4	2006	10	5	3	16.2	51	79.8	68.6	061005/0300	18.6	53	78.4	65.5
5	2006	10	5	4	15.1	62	79.7	66.7	061005/0400	17.6	49	78.3	62.1
6	2006	10	5	5	12.8	67	79.5	66.1	061005/0500	16.1	44	77.0	63.3
7	2006	10	5	6	11.6	62	79.5	66.5	061005/0600	17.4	34	76.6	65.8
8	2006	10	5	7	11.7	54	79.6	66.9	061005/0700	19.2	42	76.8	67.1
9	2006	10	5	8	11.5	50	79.7	66.9	061005/0800	17.7	51	77.0	67.3
10	2006	10	5	9	12.9	50	79.4	67.5	061005/0900	16.6	53	77.0	69.4
11	2006	10	5	10	13.4	50	79.4	68.3	061005/1000	16.0	57	76.8	68.9
12	2006	10	5	11	15.0	43	79.5	70.0	061005/1100	14.9	48	76.5	67.5
13	2006	10	5	12	16.3	48	79.0	70.2	061005/1200	16.2	39	77.0	67.8
14	2006	10	5	13	17.2	48	79.3	69.4	061005/1300	15.1	37	79.3	67.6
15	2006	10	5	14	15.0	67	77.1	69.7	061005/1400	15.0	34	80.8	68.7
16	2006	10	5	15	14.4	53	78.6	70.9	061005/1500	15.8	34	81.7	71.3
17	2006	10	5	16	16.6	49	79.9	70.5	061005/1600	16.2	41	82.6	69.9
18	2006	10	5	17	16.6	49	80.3	69.8	061005/1700	15.9	50	82.6	71.3
19	2006	10	5	18	15.2	52	81.0	69.5	061005/1800	15.7	54	82.8	69.1
20	2006	10	5	19	13.6	59	81.3	69.1	061005/1900	15.2	54	82.5	70.0
21	2006	10	5	20	12.1	59	81.1	68.8	061005/2000	14.8	63	82.2	70.7
22	2006	10	5	21	11.1	51	80.9	68.7	061005/2100	14.6	50	81.1	71.1
23	2006	10	5	22	10.9	46	80.3	68.7	061005/2200	13.9	53	80.1	70.5
24	2006	10	5	23	10.4	46	79.9	69.1	061005/2300	12.8	62	79.0	70.9
25	2006	10	5	24	10.1	42	79.5	69.3	061006/0000	12.2	61	79.2	69.6
26	2006	10	5	25	10.1	37	79.5	68.6	061006/0100	11.1	50	78.8	66.2
27	2006	10	5	26	9.4	38	79.5	67.9	061006/0200	11.1	51	76.6	65.8
28	2006	10	5	27	9.8	45	79.4	67.4	061006/0300	11.7	51	75.9	65.7
29	2006	10	5	28	9.1	47	79.2	67.1	061006/0400	10.8	51	76.1	65.7
30	2006	10	5	29	7.6	45	78.9	67.0	061006/0500	10.3	54	76.8	65.8
31	2006	10	5	30	6.1	52	78.8	66.2	061006/0600	9.1	55	76.8	65.8
32	2006	10	5	31	6.2	44	78.7	66.2	061006/0700	8.4	56	76.6	66.0
33	2006	10	6	1	5.5	52	78.5	66.2	061006/0800	7.2	54	76.5	65.5
34	2006	10	6	2	5.4	42	78.3	66.1	061006/0900	6.5	41	74.5	65.7
35	2006	10	6	3	4.7	23	78.2	66.4	061006/1000	6.4	31	74.5	66.0
36	2006	10	6	4	3.1	357	77.0	67.0	061006/1100	6.3	22	75.4	66.2
37	2006	10	6	5	4.5	304	73.6	66.2	061006/1200	6.8	13	75.4	67.3
38	2006	10	6	6	3.8	292	74.3	66.7	061006/1300	8.0	13	78.1	66.9
39	2006	10	6	7	5.3	8	78.7	66.3	061006/1400	8.3	16	79.2	67.8
40	2006	10	6	8	6.5	23	79.7	65.3	061006/1500	8.0	23	80.4	68.5
41	2006	10	6	9	6.2	29	80.0	65.3	061006/1600	7.3	32	81.5	68.7
42	2006	10	6	10	5.9	32	80.3	65.2	061006/1700	6.9	43	82.0	68.7
43	2006	10	6	11	6.2	29	80.4	65.2	061006/1800	7.1	55	82.4	68.7
44	2006	10	6	12	6.3	23	80.5	65.7	061006/1900	7.9	62	82.2	68.5
45	2006	10	6	13	6.9	22	80.8	66.1	061006/2000	8.3	69	81.3	68.4
46	2006	10	6	14	7.7	38	80.5	66.8	061006/2100	8.2	78	80.2	68.2
47	2006	10	6	15	6.9	55	80.2	67.9	061006/2200	7.4	84	78.8	67.6
48	2006	10	6	16	5.6	61	79.6	68.6	061006/2300	6.6	97	75.4	68.0
49	2006	10	7	0	5.0	55	79.4	68.9	061007/0000	6.9	115	73.9	68.7
50	2006	10	7	1	5.8	53	79.5	68.8	061007/0100	7.2	128	73.2	69.3
51	2006	10	7	2	5.3	81	79.3	68.6	061007/0200	7.2	137	72.9	69.3
52	2006	10	7	3	3.8	129	78.7	68.3	061007/0300	7.6	151	72.7	69.3
53	2006	10	7	4	3.8	184	76.8	69.0	061007/0400	8.0	162	72.3	69.1
54	2006	10	7	5	3.5	197	75.7	69.7	061007/0500	7.5	168	71.8	68.9
55	2006	10	7	6	3.2	205	75.6	69.3	061007/0600	6.2	175	71.4	68.7
56	2006	10	7	7	4.8	237	74.4	69.8	061007/0700	3.8	195	70.9	68.5
57	2006	10	7	8	5.0	241	73.2	70.3	061007/0800	2.5	231	70.3	68.0

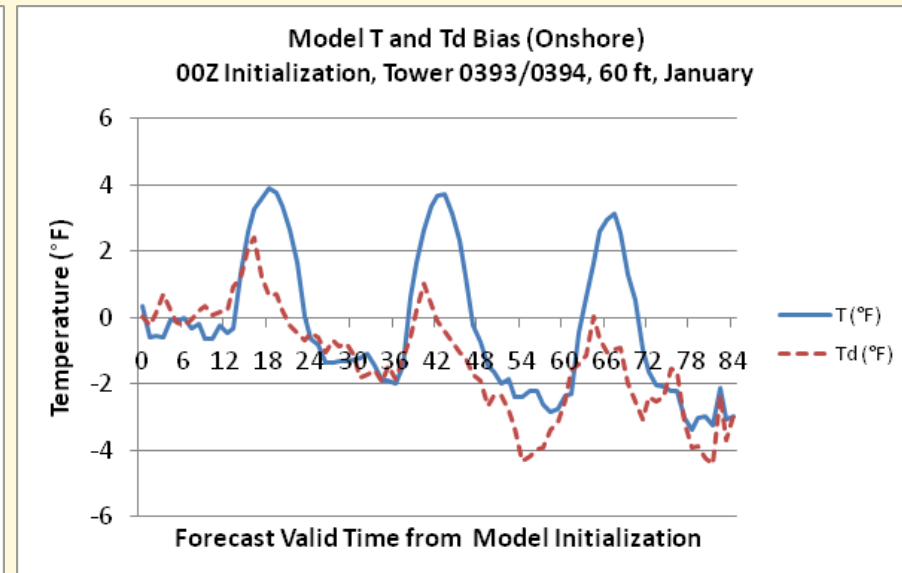


# Verification Examples

- LC 39A (Shuttle/Constellation)
  - MesoNAM T and  $T_d$  bias
  - January 2007-2009
  - Offshore and onshore
  - Cyclical model bias: largest bias local mid-afternoon



Offshore



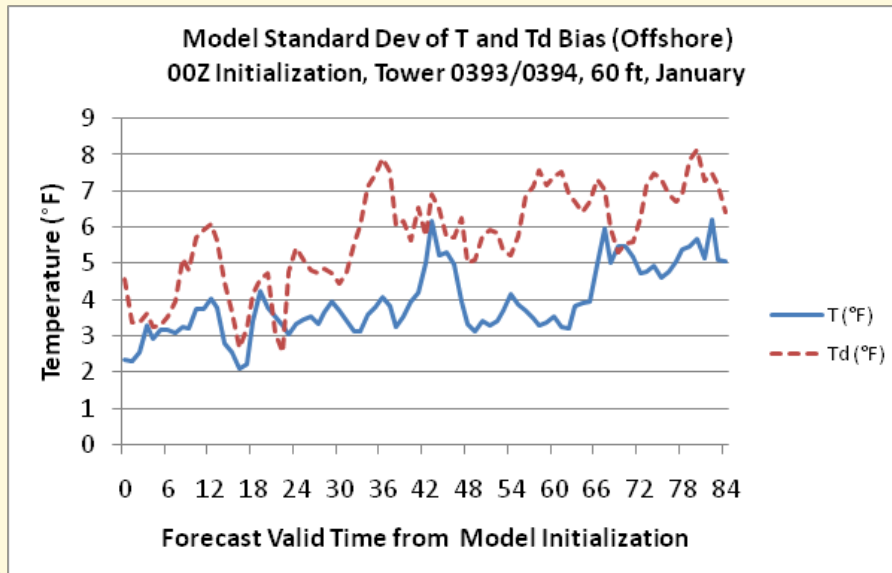
Onshore



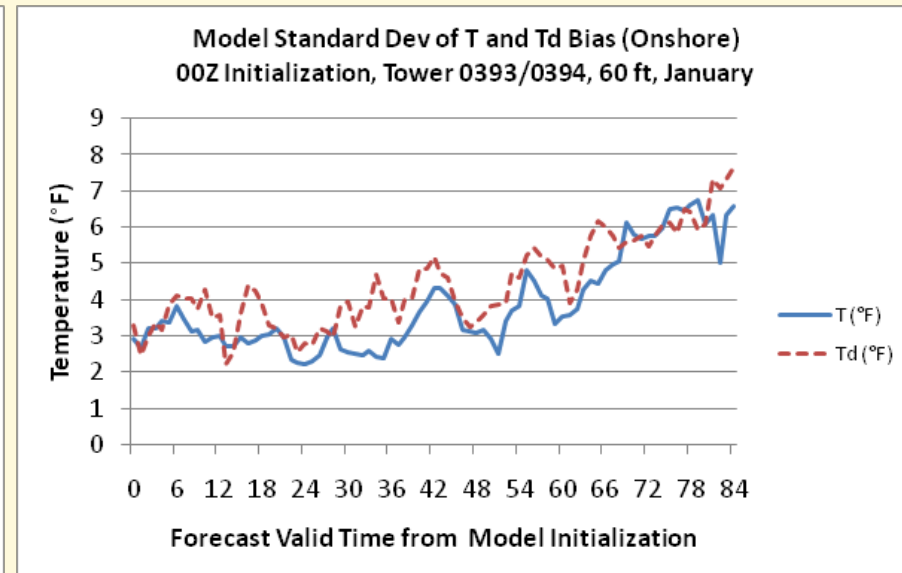


# Verification Examples

- LC 39A (Shuttle/Constellation)
  - MesoNAM standard deviation of T and  $T_d$  bias
  - January 2007-2009
  - Offshore and onshore
  - Model error increases during forecast period



Offshore

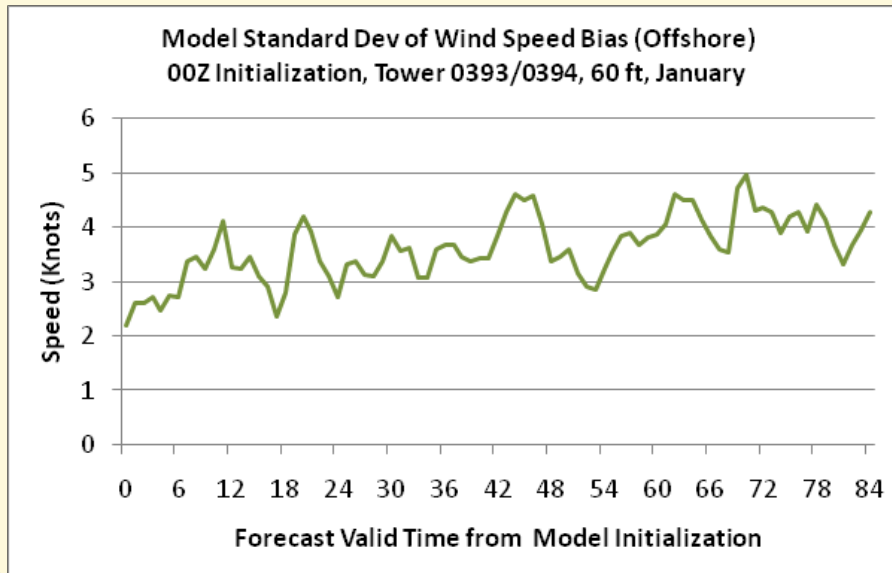


Onshore

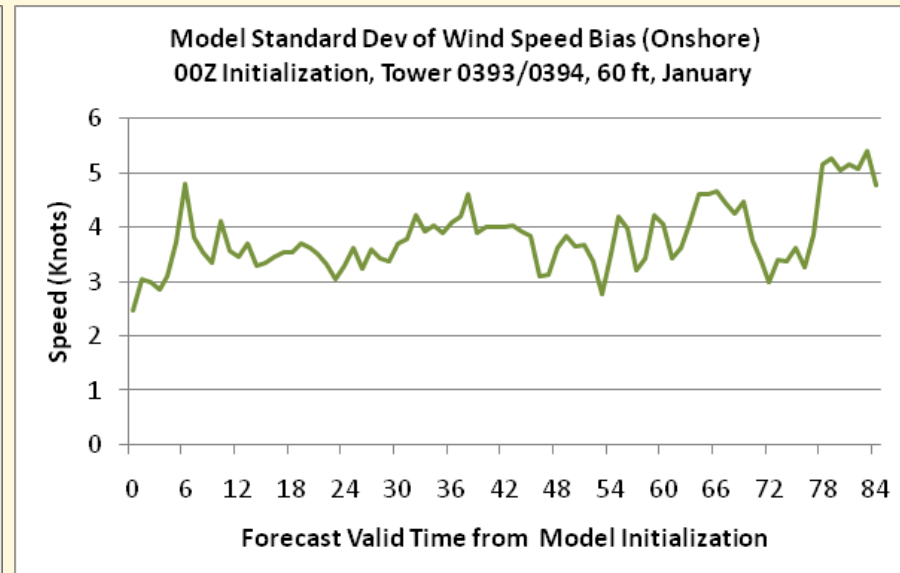


# Verification Examples

- LC 39A (Shuttle/Constellation)
  - MesoNAM standard deviation of wind speed bias
  - January 2007-2009
  - Offshore and onshore
  - Model error increases during forecast period



Offshore

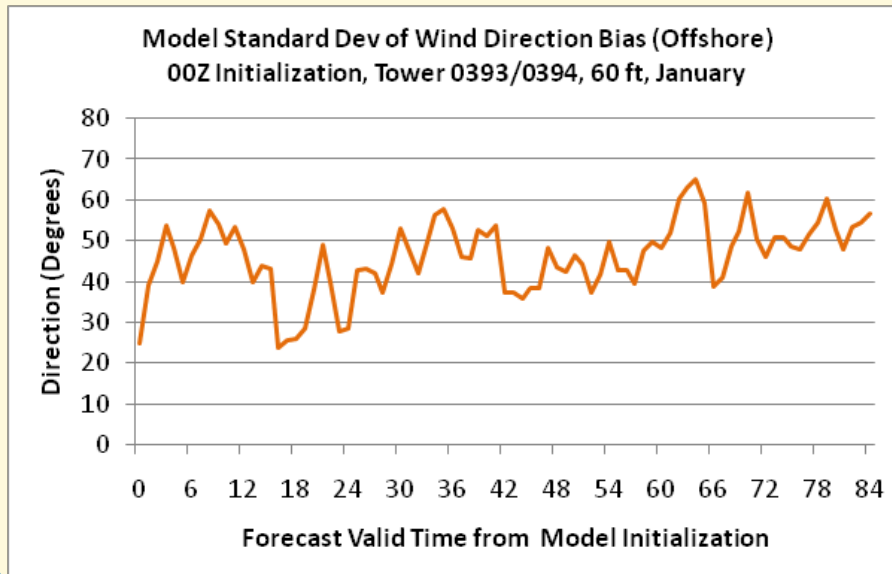


Onshore

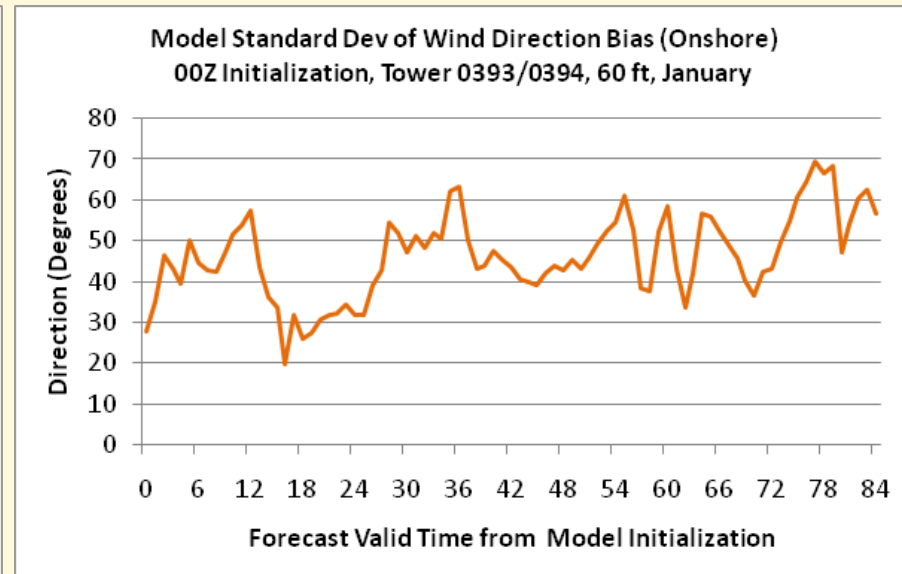


# Verification Examples

- LC 39A (Shuttle/Constellation)
  - MesoNAM standard deviation of wind direction bias
  - January 2007-2009
  - Offshore and onshore
  - Model error increases during forecast period



Offshore



Onshore



# Graphical User Interface

- Difficult and time consuming to search thousands of Excel files

## 45th Weather Squadron MesoNAM Verification Tool

Developed by NASA's Applied Meteorology Unit



Develop GUI  
HTML-based

You are here: Site 39A, January, 00Z Model Initialization, Onshore flow

– Easy to navigate through all stratifications

Choose a month



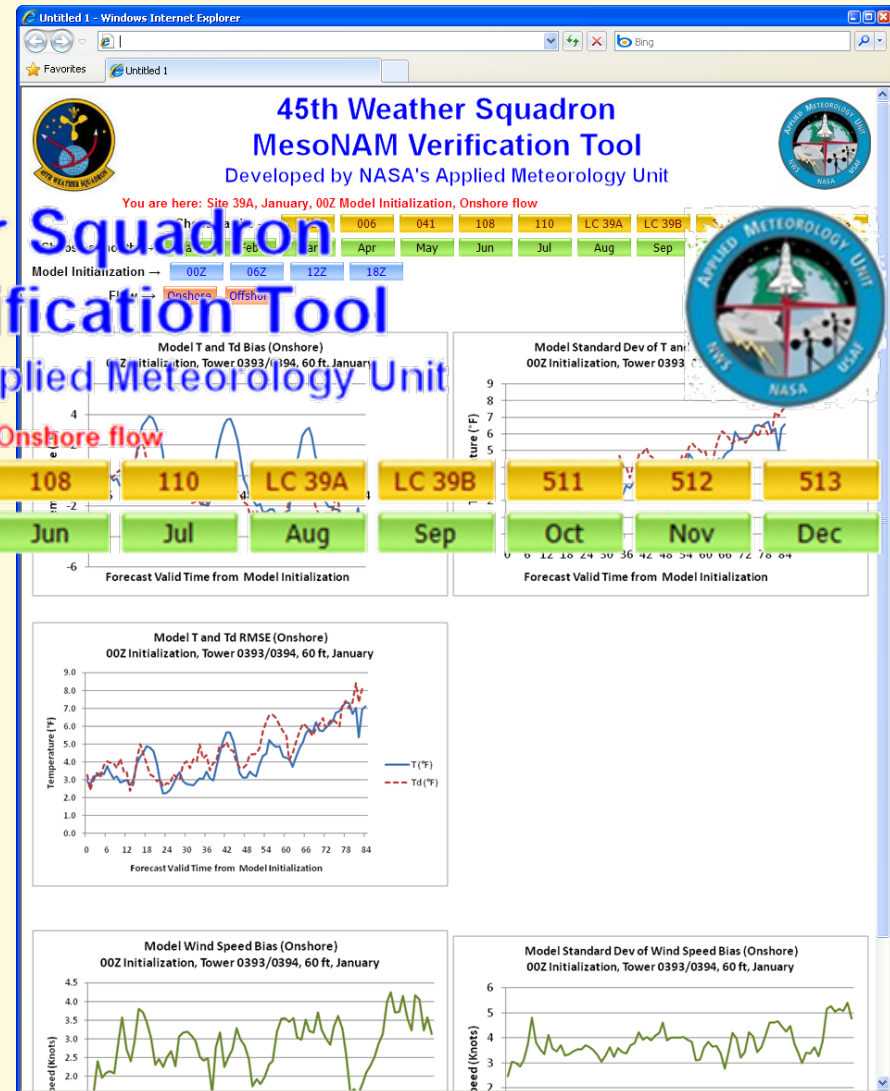
Model Initialization



Flow



– Browser and computer OS independent





# Summary and Conclusions

- LWO's use MesoNAM for launch forecasts
- MesoNAM not objectively evaluated
- 45 WS tasked AMU to conduct analysis of model versus tower observations
- Preliminary results show model performance degrades during 84-hour forecast period
- Provides tangible evidence of model performance
- Identifies model strengths and weaknesses
- Need GUI for navigation through data

