EVALUATION OF A NESTED CONFIGURATION OF THE WAVE MODEL WAM4.5 DURING THE DND'S FIELD EXEPERIMENT NEAR HALIFAX, NOVA SCOTIA

Roop Lalbeharry

Environment Canada, Science and Technology Branch
Meteorological Research Division
Recherche en Prévision Numérique Section
Toronto, ON, Canada M3H 5T4

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Introduction

- During the period 12-19 September 2005, the Department of National Defence (DND) conducted an exercise off Osborne Head just east of Halifax on the ship CFAV Quest
- Objective:
  - To assess the impact of the marine environment on its Shipboard Integration Sensors and Weapons Systems (SISWS) Technology Demonstration Program (TDP)
- CMC provided nearshore shallow water wave forecasts of the sea state conditions which seem to have an important effect on the operations of some of DND's weapon systems
  - Wave forecasts up to 48 hours were provided twice daily during the exercise period
- DND deployed two additional buoys during the exercise period
  - an ENDECO Wave-Track Buoy
  - a TRIAXYS Wave Buoy
    - Directional wave buoy manufactured by Axys Technologies Inc. that is able to determine wave motion with 6 degrees of freedom

WAVE MODEL

- **WAM *(WAve Model)* Cycle-4.5 (WAM4.5)**

  - **Update of WAM Cycle-4. Enhancements include:**

    - **Fully implicit source term integration. This all allows source term integration timestep to be longer than propagation timestep**
    - **Hersbach and Janssen (1999) wave growth limiter**
    - **Addition of the linear wave growth source term to the code. This term was not included in earlier versions of the WAM**
    - **Addition of the depth-induced wave breaking dissipation source term to the code**
    - **Modification to nested run procedures**
    - **Removal of some time stepping restrictions**
    - **Additional outputs of integrated wave parameters**
    - **Turning of spectral directions by half of a direction increment to avoid directions parallel to the grid axis giving better propagation performance**
    - **Fortran 90 code**
    - **MPI parallelization**

MODEL SETUP

- **Grid Configurations**
  - Coarse grid WAM4.5 with a grid resolution of 0.5^{o}
  - Fine grid WAM4.5 with grid resolution of 0.1^{o} nested inside the coarse grid
  - Extra fine grid WAM4.5 with grid resolution of 0.05^{o}, nested within the fine grid

- **Boundary conditions**
  - Coarse grid run provides the fine grid run with boundary conditions
  - Fine grid run provides the extra fine grid run with boundary conditions

- **Model runs and wind forcings**
  - Daily 00 and 12 UTC runs producing wave forecasts up to 48 hours
  - Wind forcings obtained from CMC regional GEM model on 15 km grid resolution (implemented in May 2004) interpolated onto the 3 wave model grid configurations

MODEL SETUP (Cont'd)

- **Model assumptions**
  - Shallow water with bottom friction only
  - No currents
  - No depth-induced wave breaking
  - No depth refraction in coarse grid and fine grid WAM4.5

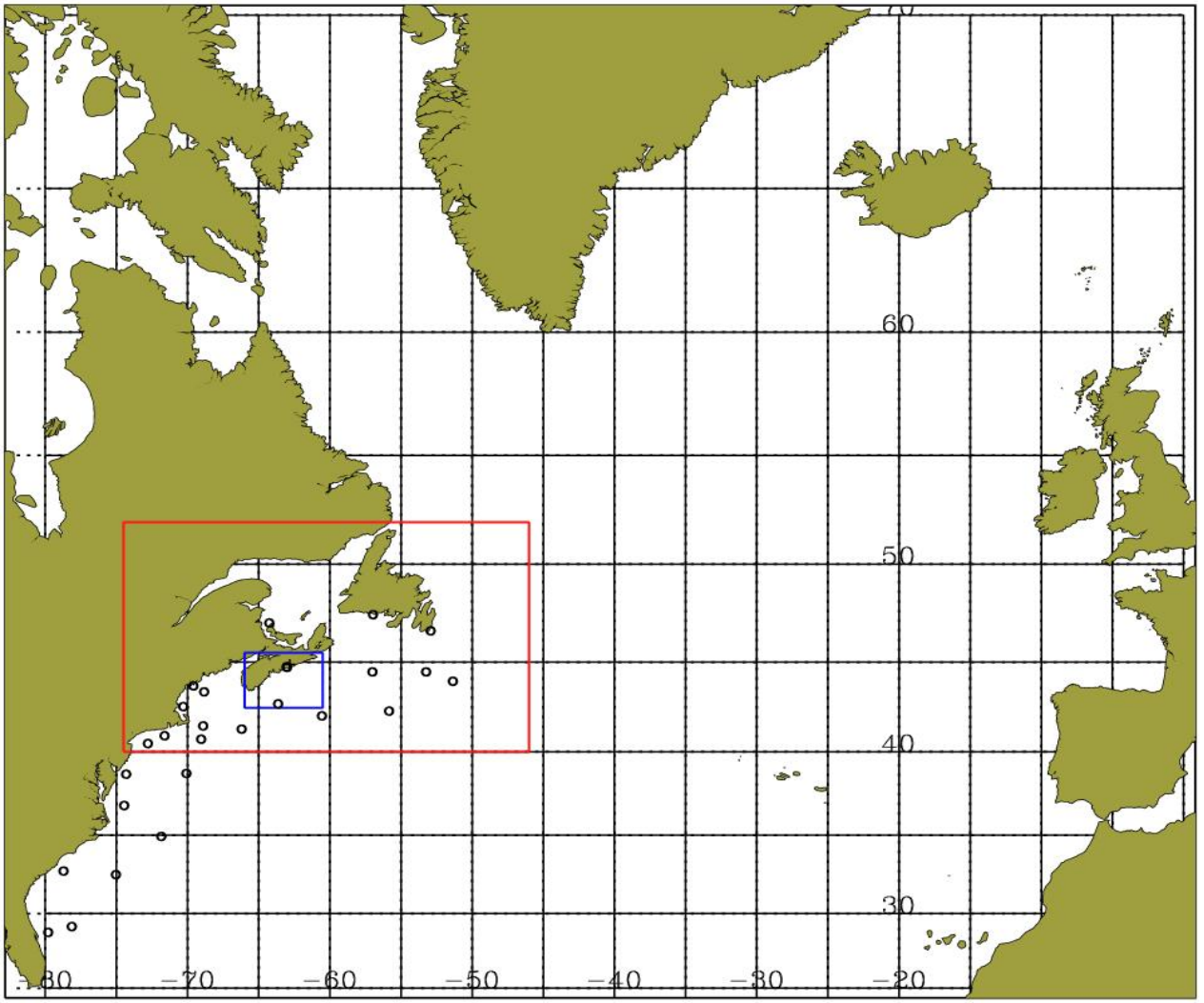
- **Frequency-direction resolutions**
  - 25 frequencies logarithmically spaced from 0.042 Hz to 0.41 Hz at intervals of $\Delta f/f = 0.1$
  - 24 directional bands at 15^{o} each with the first direction being 7.5^{o} measured clockwise with respect to true north

MODEL SETUP (Cont'd)

	WAM4.5 Coarse grid	*WAM4.5 Fine Grid*	*WAM4.5 Extra fine grid*
Grid size	**165 x 91**	**286 x 121**	**111 x 61**
No. of sea points	**11319**	**22849**	**5022**
Bottom friction, Γ (m^2s^{-3})	**0.038**	**0.038**	**0.038**
Depth refraction	**No**	**No**	**Yes**
Propagation time step	**720**	**240**	**30**
Integration time step	**720**	**720**	**180**
MPI (No. of processors)	**32**	**32**	**32**
CPU (s)	**204**	**649**	**368**

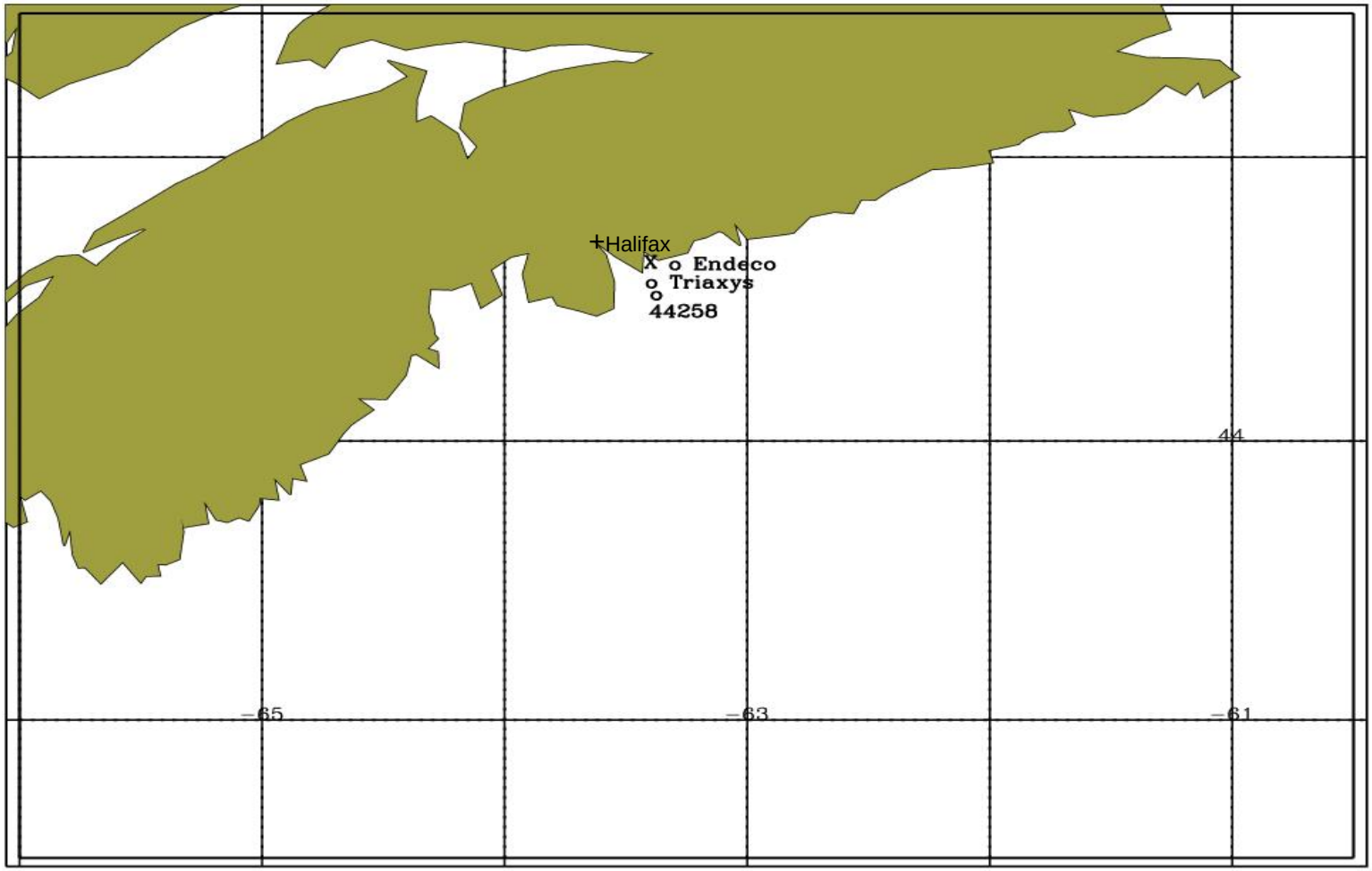
Grid Configurations

Coarse (black outline), fine (red outline) and extra fine (blue outline)



Extra Fine Grid (X = Osborne Head)

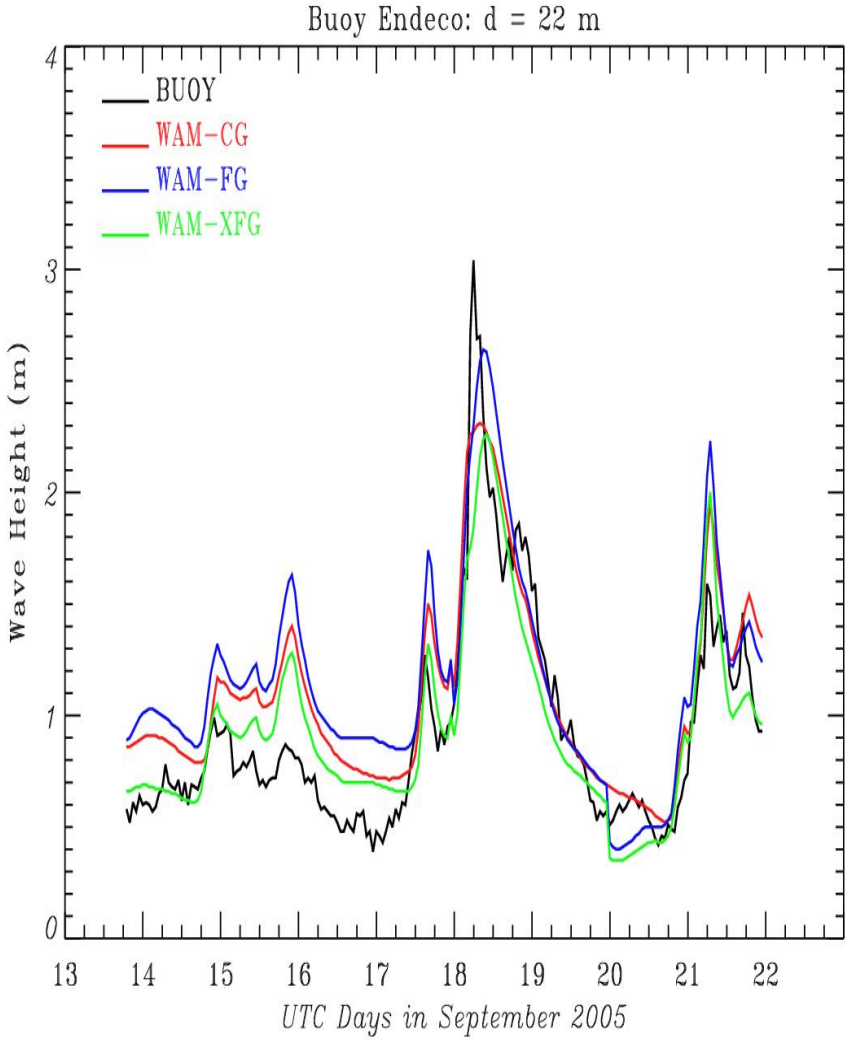
Buoy Endeco – 8 km due E
Buoy Triaxys – 8 km due S
Buoy 44258 – 12 due S

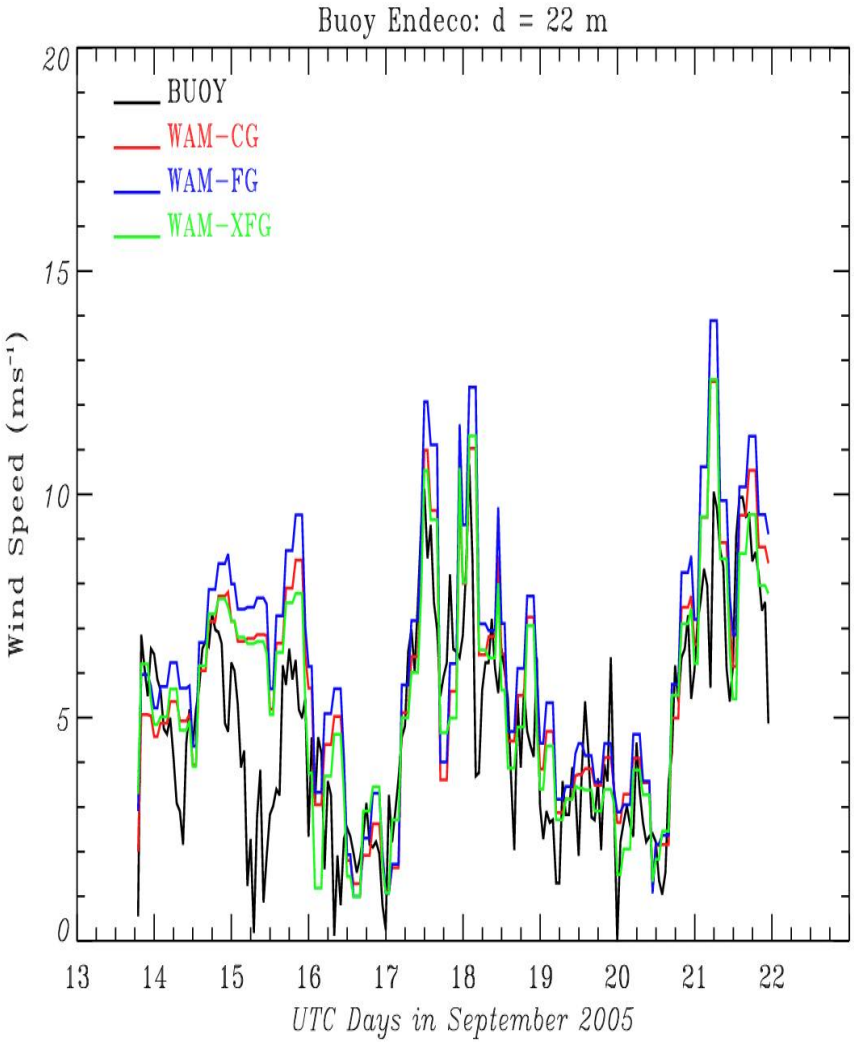


Wave model quasi-hindcast dataset

- **The quasi-hindcast dataset at hourly intervals for the period 13-22 September 2005 is created by assembling the 0, 1, 2, ……, 11-h forecast wind/wave parameters obtained, respectively, from the 0000 UTC and 1200 UTC daily wave model runs.**

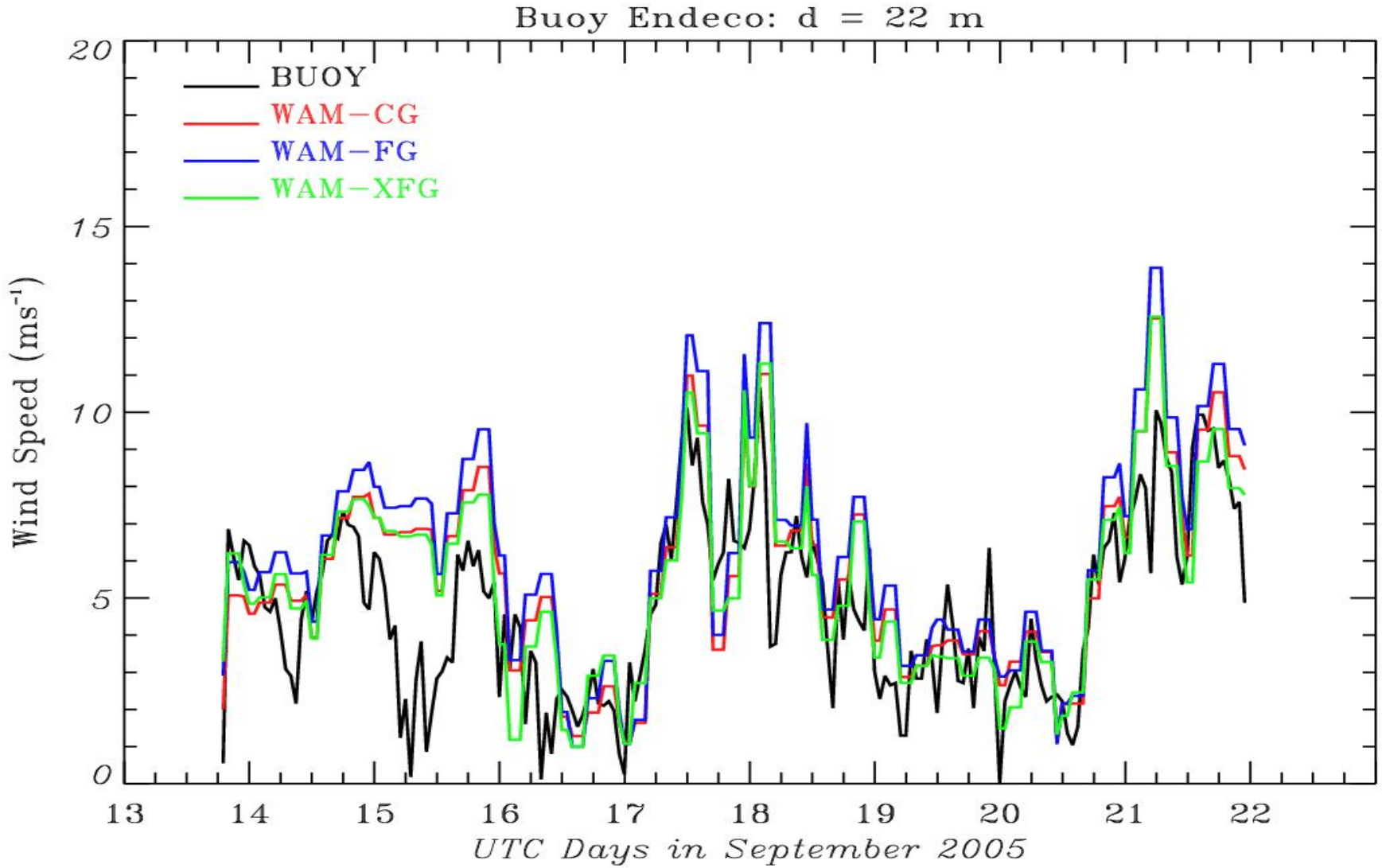
Time Series: Model vs. Buoy Endeco (d = 22 m)



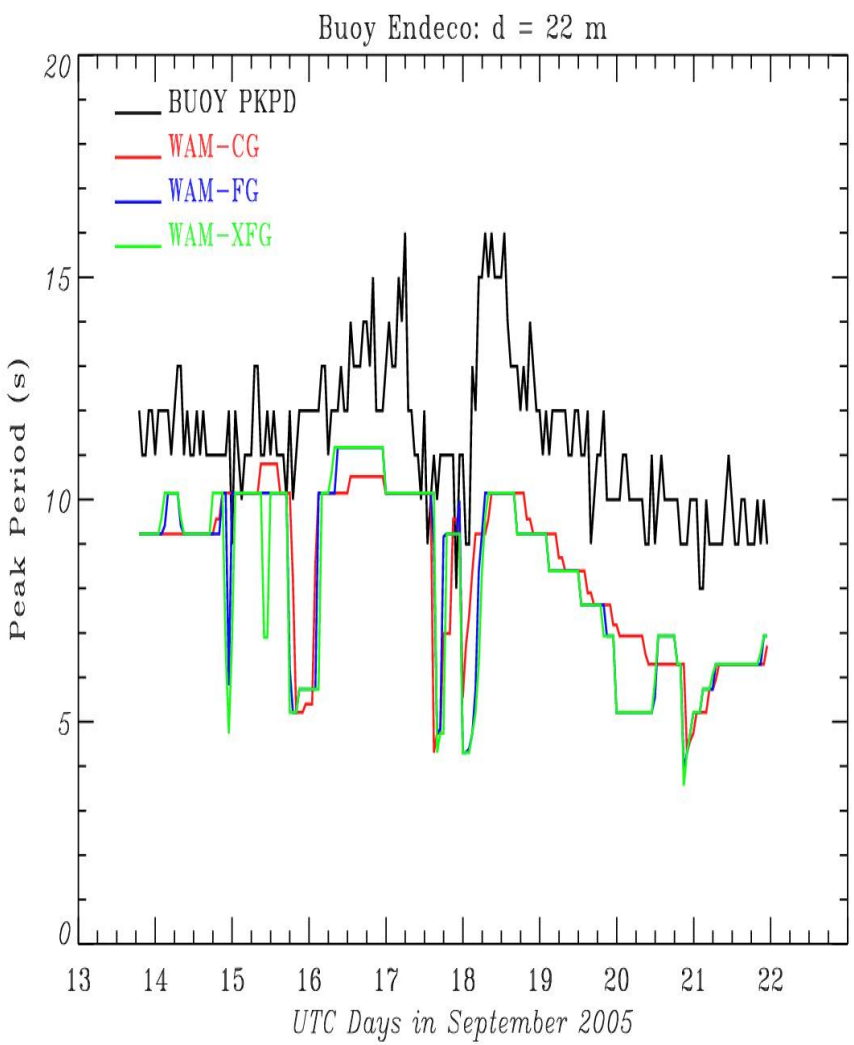


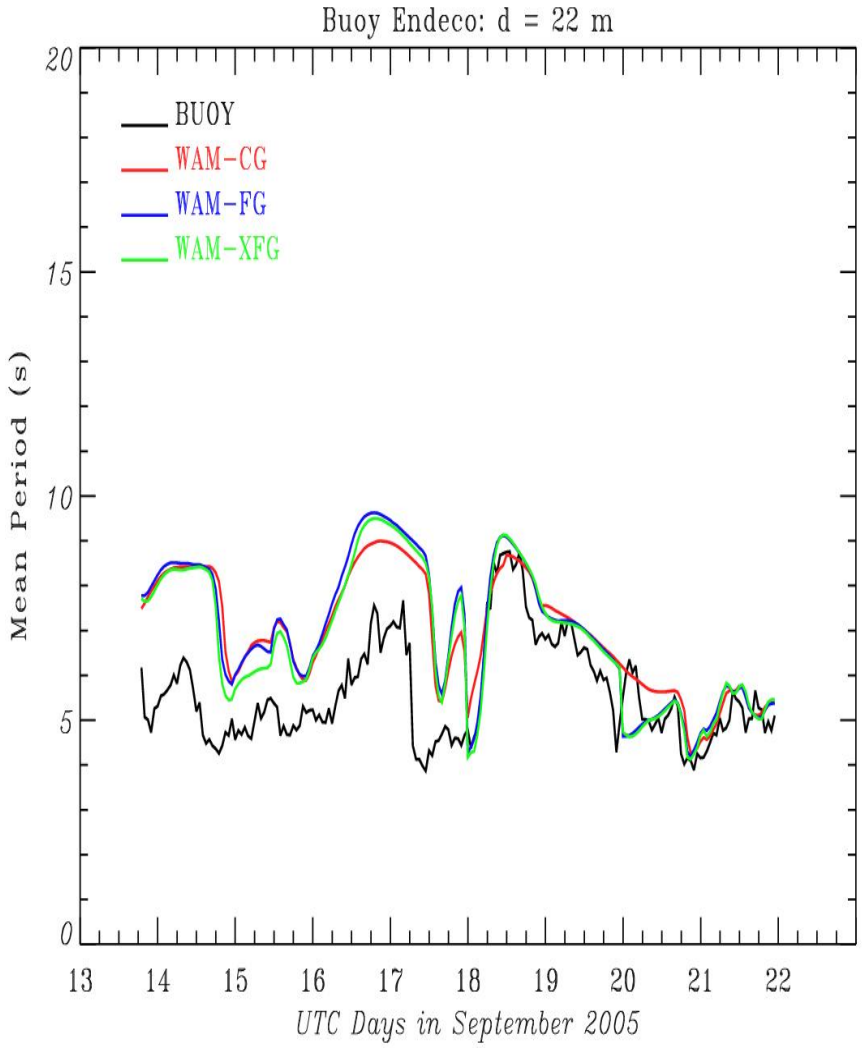
Enlarged view of buoy Endeco winds

Anemometer level = 1.5 m

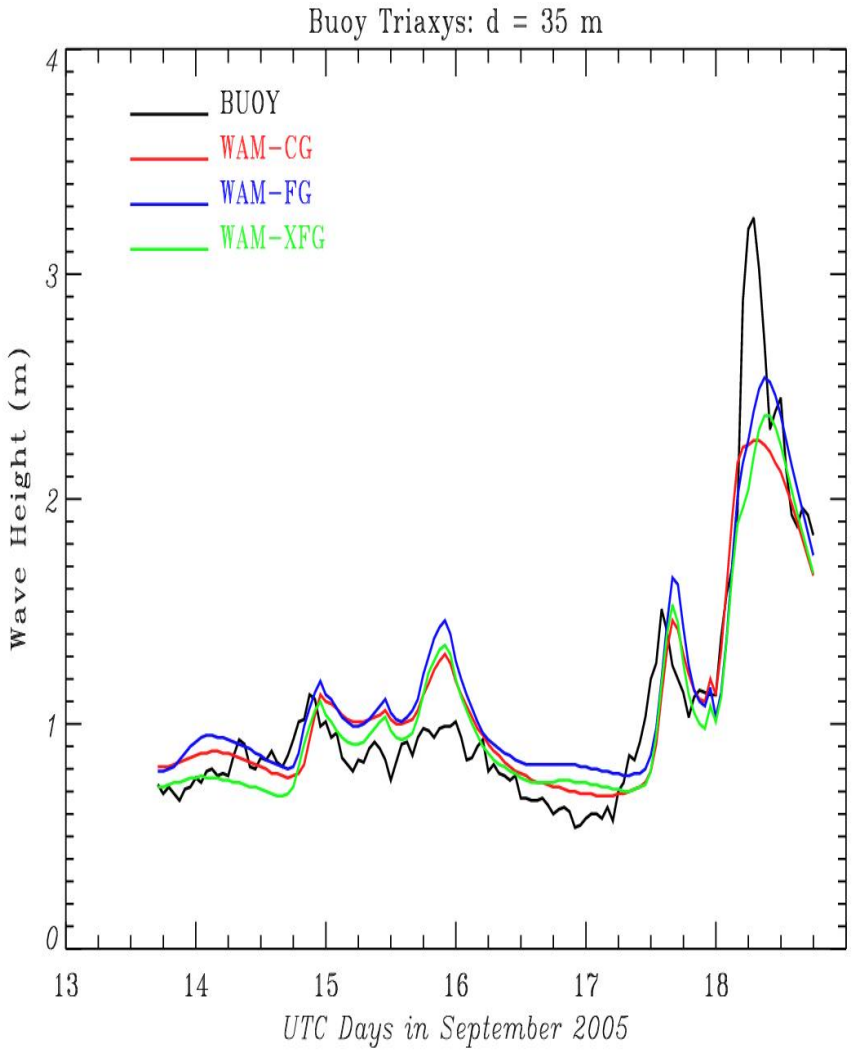


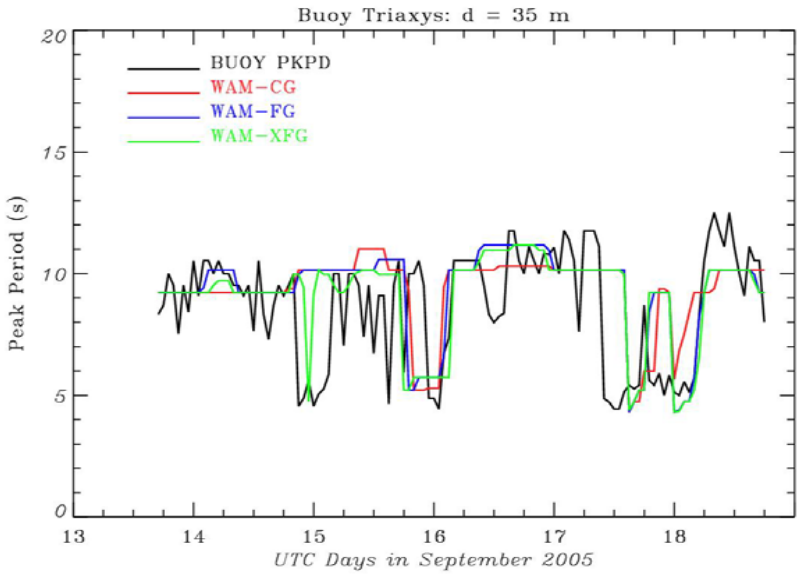
Time Series: Model vs. Buoy Endeco (cont'd)

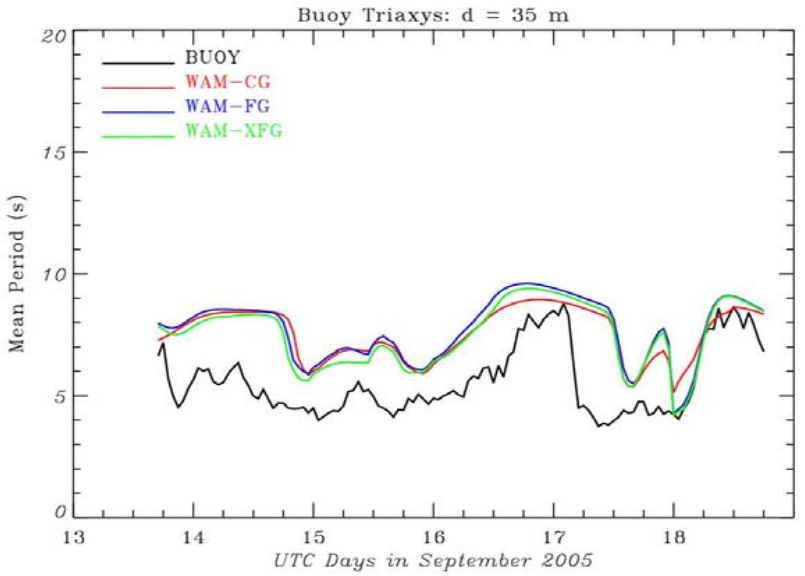




Time Series: Model vs. Buoy Triaxys (d = 35 m)

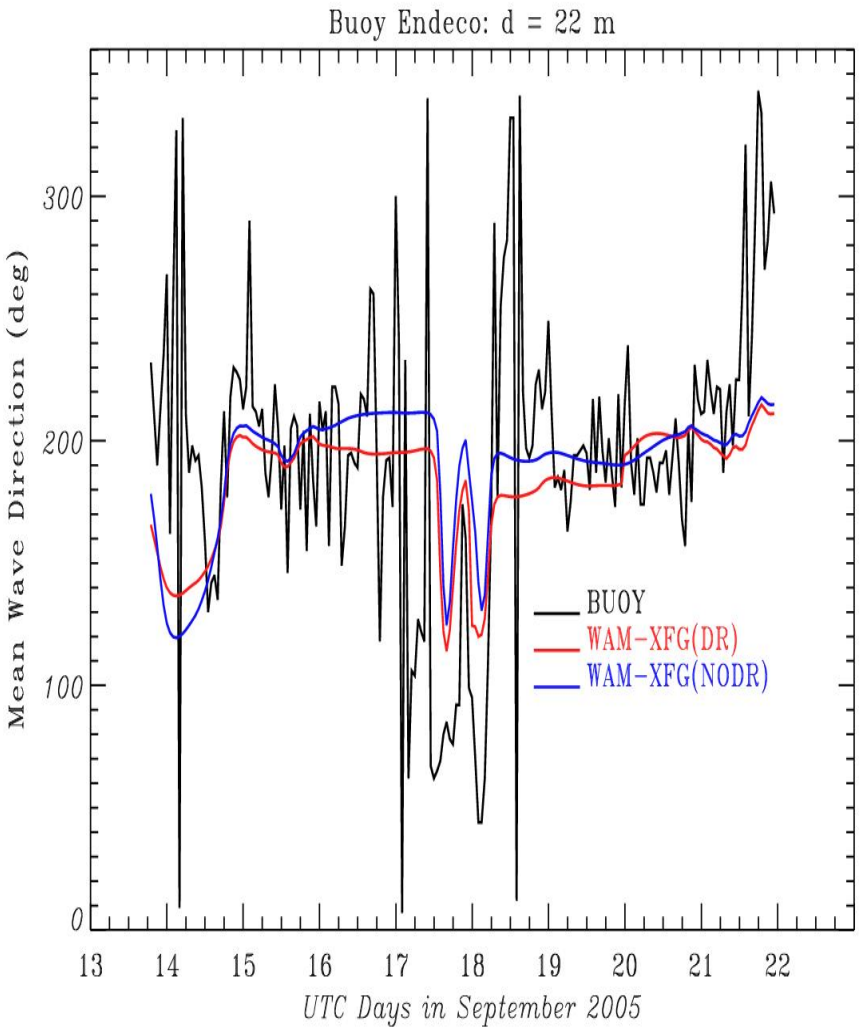


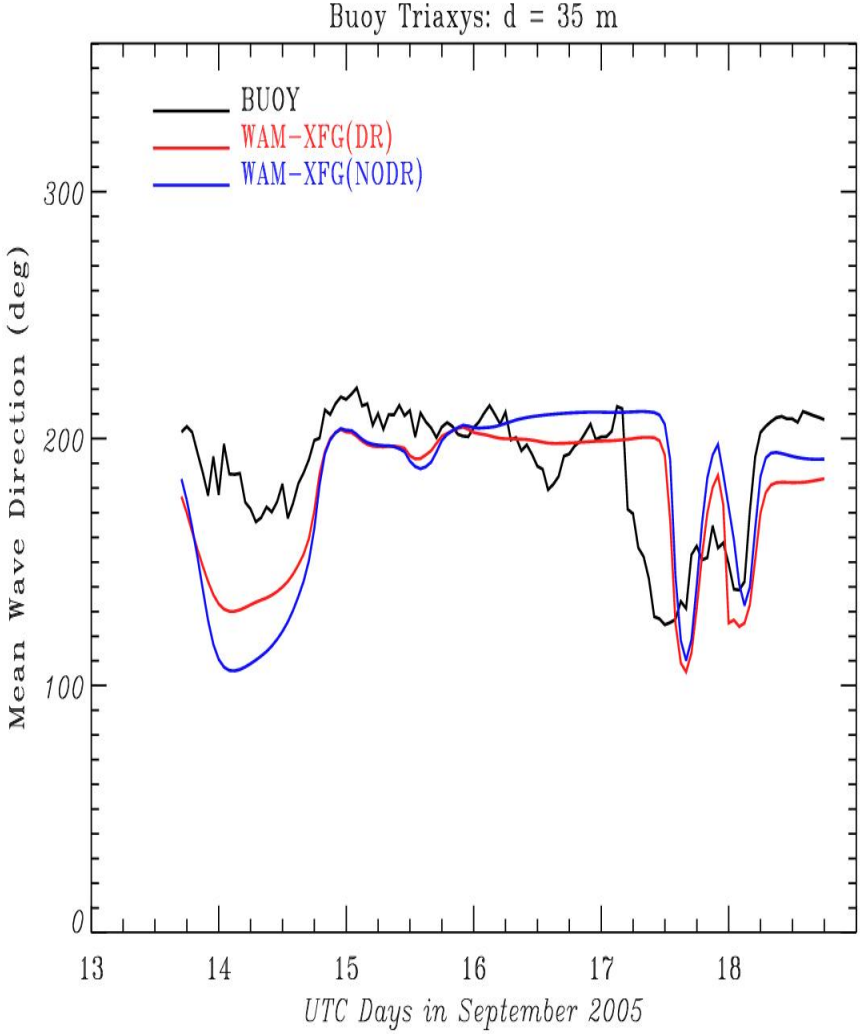




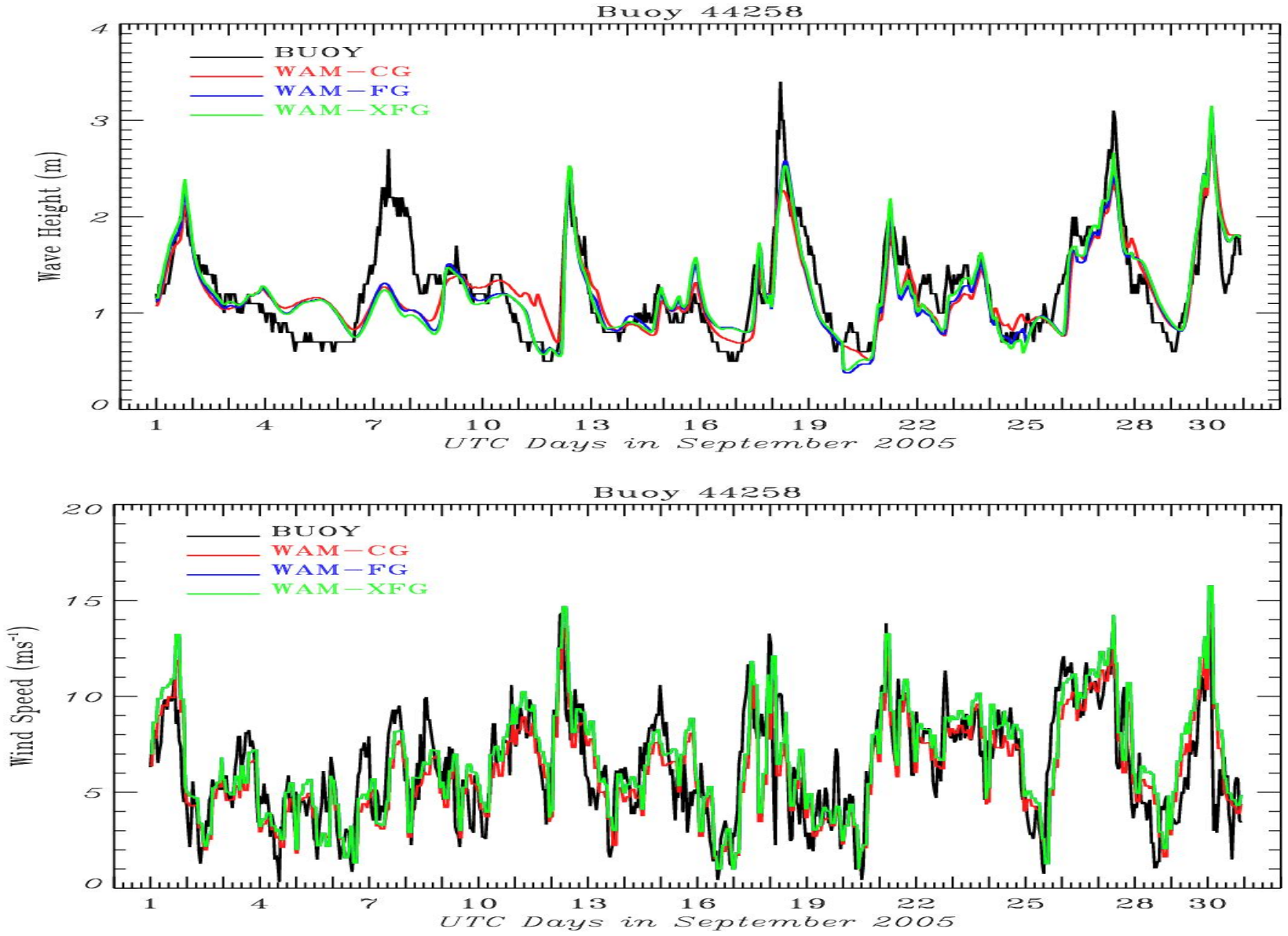
Time Series: Mean Wave Directions

Model (with and without depth refraction) vs. Buoy

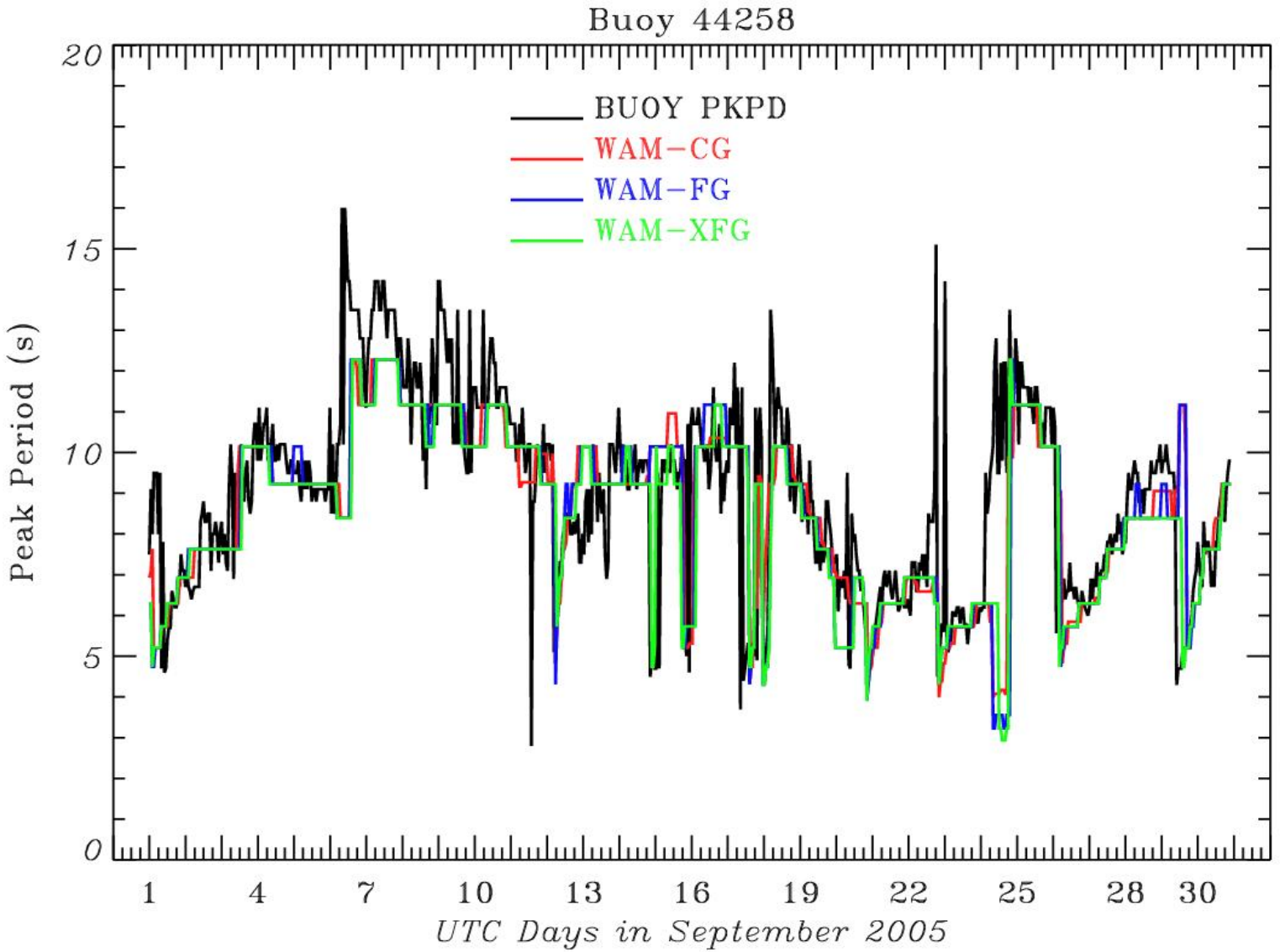




Time Series: Model vs. Buoy 44258 (d = 50 m)

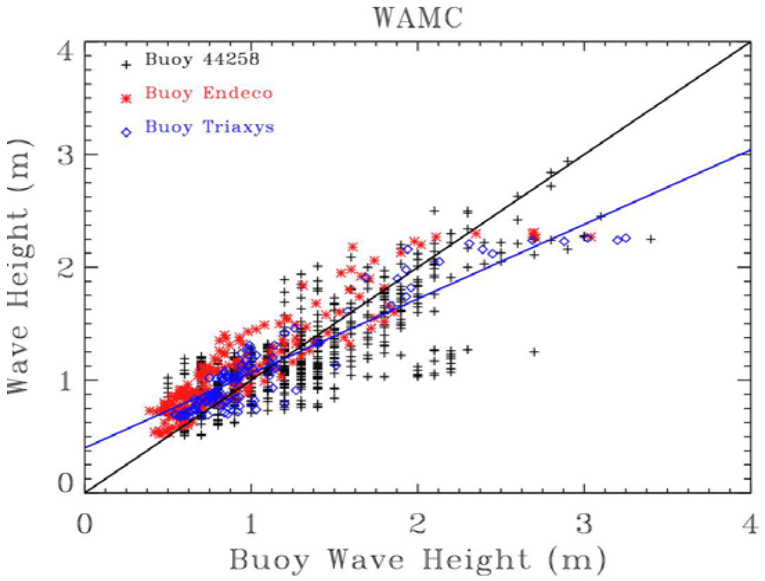


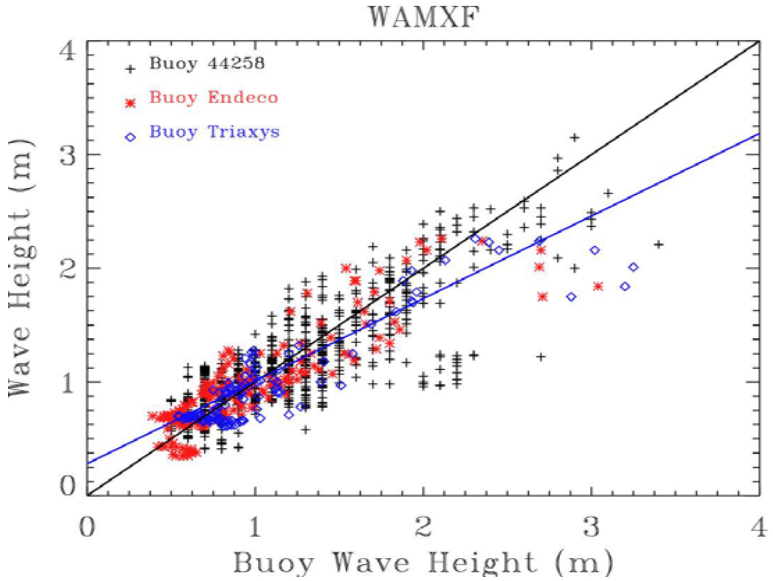
Time Series: Model vs. Buoy 44258 (cont'd)

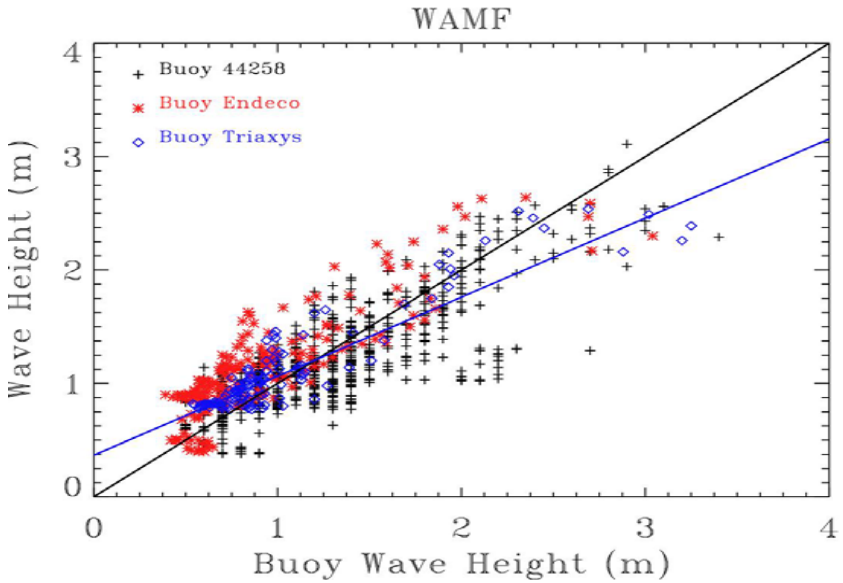


WAVE HEIGHT SCATTER PLOTS

Blue line: Linear regression line

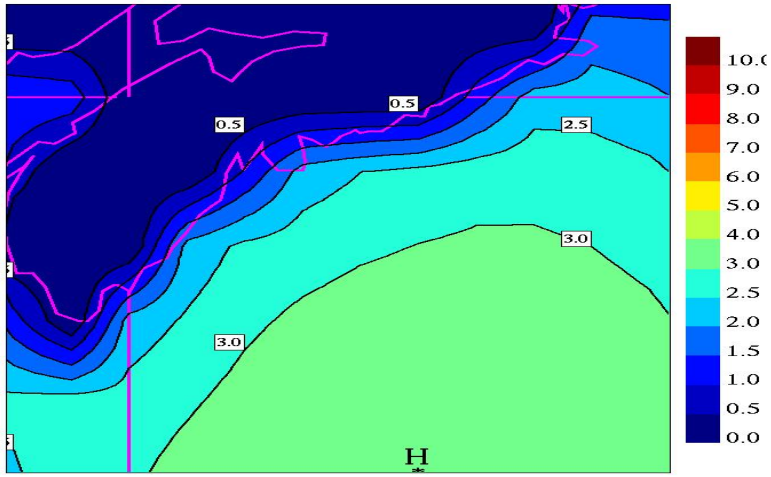




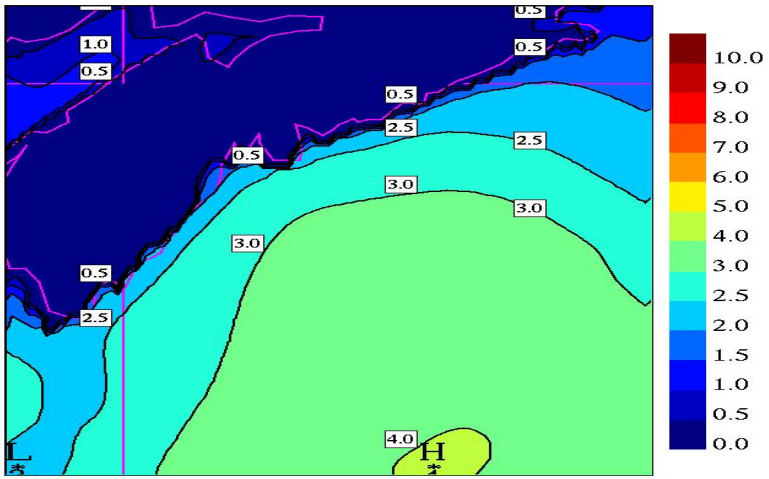


Snapshots of Forecast Wave Heights Valid 0800 UTC Based on 0000 UTC 18 September 2005 Wave Model Run

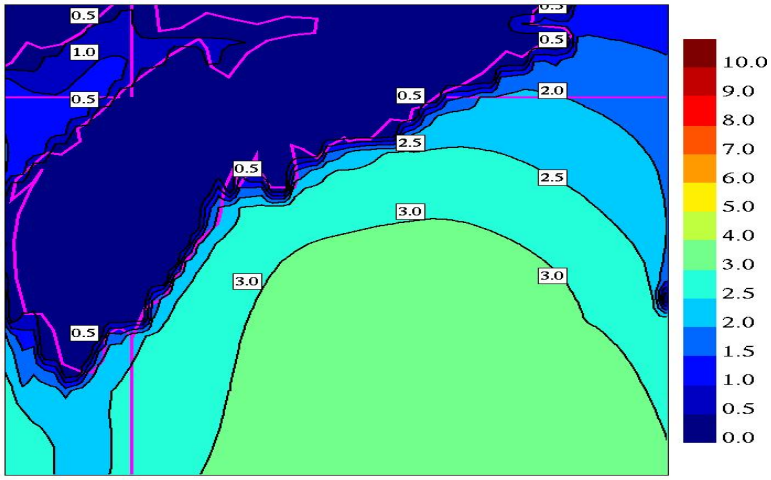
WAM_CG



WAM_XFG



WAM_FG



Description of statistical parameters

- **bias - positive denotes overprediction, negative underprediction by model**
- **rmse - root mean square error**
- **SI - Scatter Index (rmse/(buoy mean))**
- **r - linear correlation coefficient**
- **ac - anomaly correlation**
- **rv - reduction of variance**
- **a - intercept of linear regression line**
- **b - slope of linear regression line**

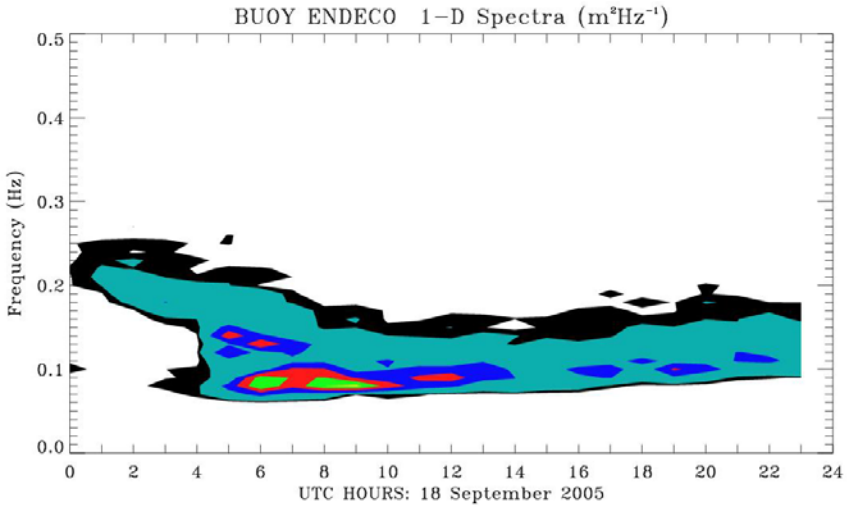
WAVE HEIGHT/PEAK PERIOD STATISTICS

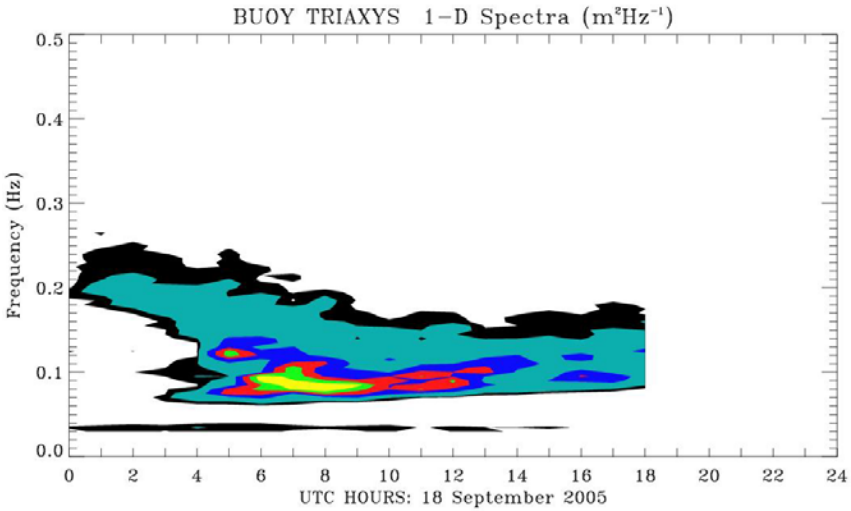
WAVE HEIGHT STATISTICS (m)	WAMC	WAMF	WAMXF
Buoy mean	1.166	1.166	1.166
Model mean	1.169	1.180	1.127
Bias	0.003	0.014	-0.039
Rmse	0.289	0.302	0.289
SI	0.248	0.259	0.248
r	0.836	0.820	0.840
ac	0.837	0.821	0.837
rv	0.697	0.671	0.699
a	0.399	0.367	0.281
b	0.661	0.697	0.726
N (no. of obs.)	1039	1039	1039

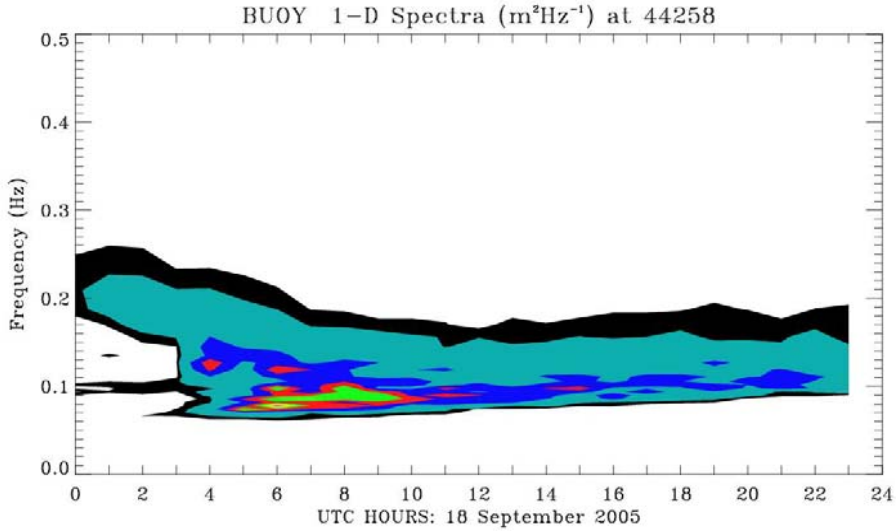
PEAK PERIOD STATISTICS (s)	WAMC	WAMF	WAMXF
Buoy mean	9.424	9.424	9.424
Model mean	8.703	8.645	8.505
Bias	-0.721	-0.779	-0.919
Rmse	2.264	2.382	2.329
SI	0.240	0.253	0.247
r	0.535	0.511	0.555
ac	0.502	0.479	0.508
rv	0.128	0.036	0.078
a	4.671	4.500	4.054
b	0.428	0.440	0.472
N (no. of obs.)	1039	1039	1039

1-D Observed Spectra (m^2Hz^{-1}) at Hourly Intervals

Colourscale: black (0.5-1), turquoise (1-4), blue (4-7), red (7-10), green (10-13), yellow (13-16)



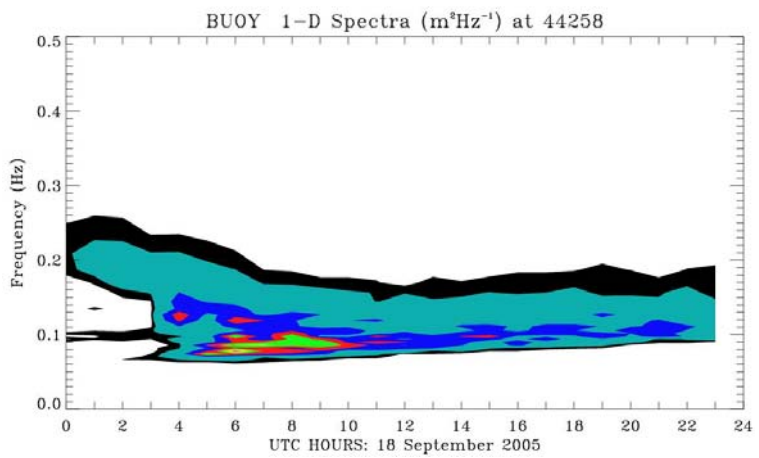


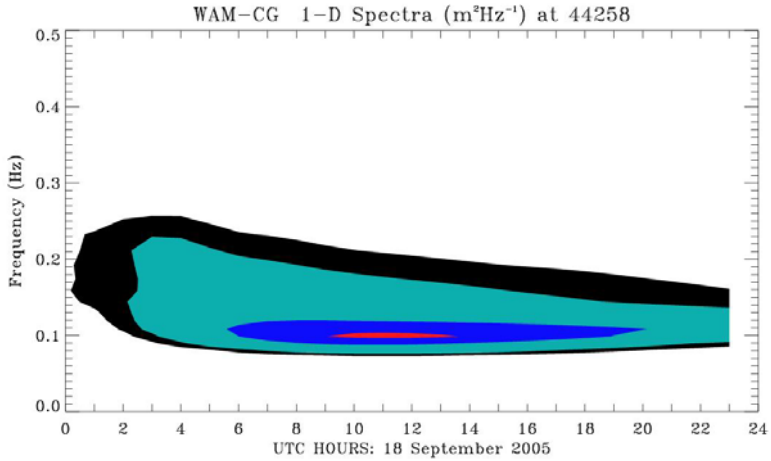


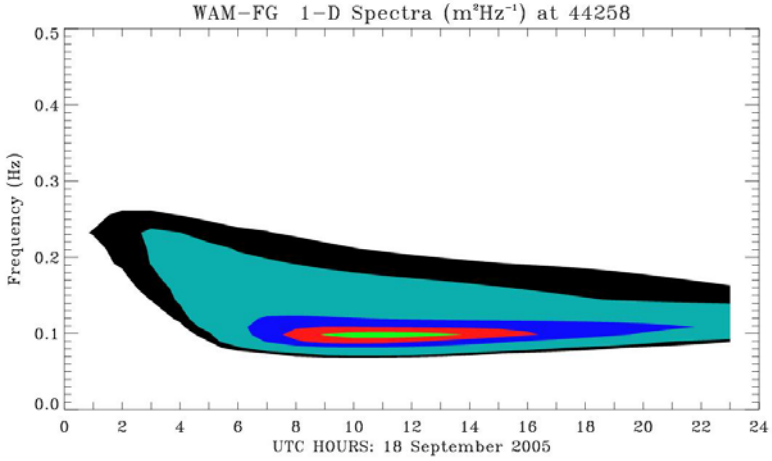
Wave Model Forecast vs. Buoy Observed 1-D Spectra (m^2Hz^{-1})

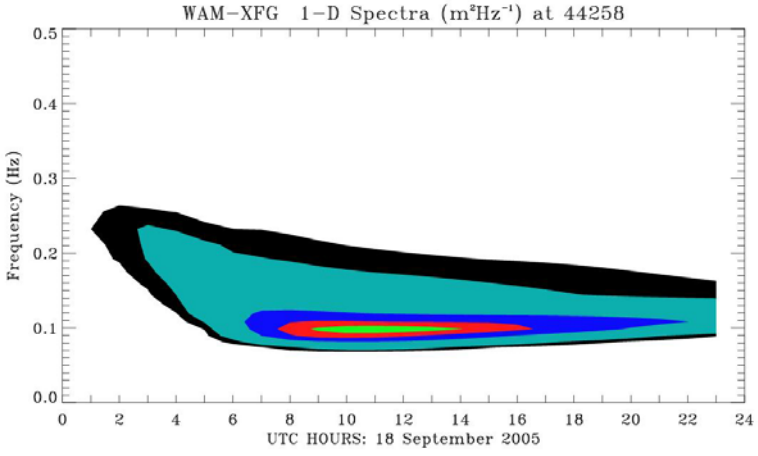
Wave Model Run: 18 September 2005

Colourscale: black (0.5-1), turquoise (1-4), blue (4-7), red (7-10), green (10-13), yellow (13-16)









CONCLUSIONS

- **The 3 versions of WAM4.5 produced results that are in close agreement with one another. However, the fine and extra fine versions give a better representation of the nearshore height contours.**

- **All 3 model runs underpredicted the major observed peak SWH of 3 m common to the 3 buoys at 0600 UTC 18 September and show that the times of occurrence of this peak vary from 1-3 hours**

- **Model winds are reasonably accurate when compared with buoy 44258 winds but not as accurate when compared with buoy Endeco winds. The correction factor applied in adjusting the latter winds from the anemometer level of 1.5 m to the 10-m level may be somewhat small.**

- **The observed peak periods show more spikiness and are not well simulated by the model. However, the model mean periods are more consistent with one another and in better agreement with the observed mean period.**

CONCLUSIONS (cont')

- WAM4.5 forecast 1-d peak spectra generally lagged the major observed peak 1-d spectra by 2-3 hours

- Activation of depth refraction does not have a significant impact on the model mean wave direction when compared with that of the buoy

- The model wave statistics for H_s and T_p show minimal differences, suggesting that for deep and intermediate water applications the WAM-CG version may be adequate to produce regional operational wave forecast and for coastal/shelf applications the nested version WAM-FG, rather than the nested version WAM-XFG, can be used with some measure of confidence.