**Proudman
Oceanographic
Laboratory**

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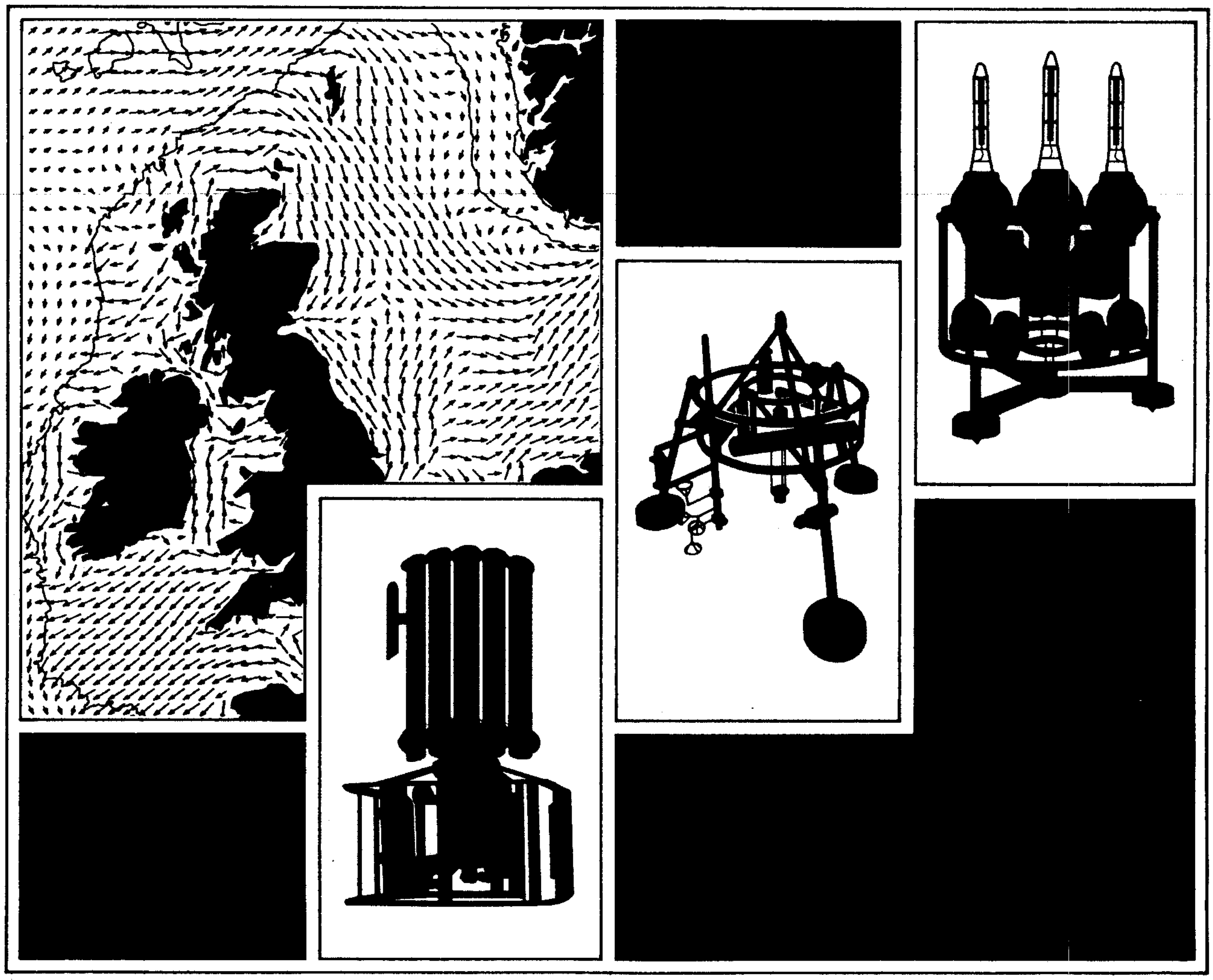
Report No. 47 1997



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PROUDMAN OCEANOGRAPHIC LABORATORY
REPORT NUMBER 47

MAST III PROGRAMME: MAS3 CT 9500025
PROMISE
(PRe-Operational Modelling In the Seas of Europe)

WAM MODEL INTERCOMPARISONS
NORTH SEA

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1997

DOCUMENT DATA SHEET

AUTHOR J. Monbaliu, M.Y. Zhang, K. de Backer, J. Hargreaves, W. Luo, R. Flather, J.C. Caretero, M. Gomez Lahoz, I. Lozano, M. Stawarz, H. Günther, W. Rosenthal and J. Ozer	*PUBLICATION* *DATE* 1997

TITLE

WAM Model Intercomparisons - North Sea

REFERENCE Proudman Oceanographic Laboratory, Report No. 47, 30pp & figures & appendices

ABSTRACT

The object of this research was to test the sensitivity of results obtained from the WAM Cycle 4 spectral wave model to different implementations. Different institutions ran the same code but used different grids, boundary conditions, bathymetry and meteorological input. The runs were all made over the North Sea for the same two week period in February 1993 for which there exist data from several spectral wavebuoys and satellite data from ERS1 and TOPEX/ POSEIDON.

All the results and data were compared and a resulting common implementation has been proposed. The specific coding necessary for the common implementation has been carefully documented and is attached to the report. It is concluded that the common implementation is both practical and produces sufficiently accurate results for use on the North Sea scale.

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KEYWORDS
WAVES
WAVE SPECTRA
WAVE BUOYS
SATELLITE ALTIMETRY
MATHEMATICAL MODELS
SHALLOW WATER
WAM
NORTH SEA

CONTRACT

PROJECT MHT-75-5

PRICE £21

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1. INTRODUCTION

The main goal of the first year activities for wave modelling in the MAS3-CT-9500025 PROMISE project was to align the wave modelling activities in the different groups and to come to a common implementation of the third-generation spectral wave model WAM Cycle 4 for application in the North Sea which is suitable for dissemination. This model implementation is considered a good base to reach the PROMISE goals of the second and third year, i.e. high spatial resolution application in shallow water and dynamic coupling to a hydrodynamic model to provide reliable input to sediment transport modelling.

The report contains in section 2 a brief description of the WAM-model as such. In section 3 a description of existing implementations at the different institutes is given. Section 4 describes briefly the wind fields used to drive the different model implementations. Section 5 is devoted to a description of the measurements used to validate and compare the model results. Section 6 reports on the intercomparison of the different implementations, on the comparison to measurements at a limited number of buoy locations, and on the comparison with ERS-1 and TOPEX/POSEIDON satellite altimeter data. The intercomparison and comparison with buoy and satellite are for a limited period in February 1993. In section 7, the sensitivity of model wave results to implementation differences is addressed. Section 8 describes the changes necessary to the official WAM Cycle 4 code to run a North Sea application according to the common implementation. The code modifications have been carefully documented and are available for dissemination. Finally, section 9 contains the conclusions.

2. DESCRIPTION OF THE WAM MODEL

WAM Cycle 4 has been chosen as a suitable third-generation wave model for the PROMISE objectives due to its characteristics of public domain, familiarity by most of the partners (large experience in some groups). The WAM Cycle 4 model is state of the art, at least up to intermediate water depth. It is definitely suitable for North Sea scale applications.

At the moment, limitations exist for the WAM-model to go into shallow water and some other models such as the SWAN-model (public domain since about April 1997) have introduced adaptations to be more suitable for fine grid shallow water applications. More on the theoretical background, and in particular the numerics of SWAN can be found in Holthuijsen et al. (1993) and Ris et al. (1994). It is however believed that alterations to the WAM-model can greatly improve its performance and make it a competitive solution to shallow water wave modelling. It is also believed that the coding structure of WAM is suitable for high performance computing (vector and parallel processing), which makes it attractive for operational real time modelling.

A general description of WAM Cycle 4 is outlined here, for details one can see the User Manual by Günther et al. (1994) and the book by Komen et. al (1994).

WAM Cycle 4 is a third-generation wave model which solves the action density balance equation explicitly without any presumptions on the shape of the wave energy spectrum. It represents the physics of wave evolution in accordance with our knowledge today for the full set of degrees of freedom of a 2D wave spectrum.

The model can run for deep and shallow water conditions, can include depth and current refraction (steady depth and current field only), and can be set up for any local or global grid with a prescribed topographic dataset.

Nesting of grids is possible. The boundaries of the nested 'fine' grid have to be given. The corner points of the 'fine' grid have to coincide with nodes on the 'coarse' grid. In a coarse grid run the spectra can be outputted at the boundaries of the defined subgrid. The boundary spectra are then interpolated in space and time to the boundary points of the subgrid and are consequently used as boundary condition for a 'fine' grid run. The 'fine' grid can be a 'coarse' grid in turn, since additional nesting of an even finer grid is possible.

The propagation can be done on a spherical or on a Cartesian grid. The model outputs many wave parameters, such as the significant wave height, mean wave direction and frequency, the swell wave height and direction, wind stress fields, wave-induced stress and the drag coefficient at each grid point at chosen output times, and the 2D wave spectrum at chosen grid points and output times. The runs can be interrupted and restarted.

The source term integration and the propagation of wave energy are solved with different numerical methods and time steps. A semi-implicit scheme is used for the source term integration while a first-order upwind flux scheme is used for the propagation scheme. The wind time step can be chosen arbitrarily, but it has to be a multiple of 1 minute. The source term integration step has to be smaller than or equal to the propagation time step and also has to be a multiple of 1 minute. The ratio of $\Delta t_{prop}/\Delta t_{source}$ has to be integer and greater than or equal to 1.

The model is regularly updated to incorporate the latest results of research and it is available to the entire research and forecasting community. It is expected that results achieved with the model are made available in return to the wave modelling group. Official users of the WAM-model are automatically informed when a new cycle of the model is available. The latest update of the cycle 4 version of WAM was disseminated from the Max-Planck-Institut für Meteorologie on 27/11/1996.

3. THE IMPLEMENTATIONS

It was decided during the second workshop of PROMISE that wave hindcasting for the North Sea for February 1993 would be carried out for the intercomparison exercise of the different implementations at KULeuven/MUMM, POL and CM/GKSS. Since CM/GKSS were involved in the WASA-project (EU-Climate and Environment project EV5V-CT-94-0506) in which 40-years (1955-1994) of wave fields were hindcasted, it was agreed to use the WASA wave data set as the contribution for CM/GKSS (The WASA group, 1995). For the intercomparison exercise, data for the period of February 1993 was extracted from this dataset.
KULeuven/MUMM hindcasted a six-month period from October 1992 to March 1993 on two different grids: a Cartesian grid (using a stereographic projection, see Luo (1995)) and a spherical grid. A summary of these results is included as Appendix C.

In table 1 the grid specifications for the different implementations are summarized.

Table 1 Grid specifications

	Cartesian	Spherical	POL	CM/GKSS
northern boundary	70 °N (*)	70.00 °N	57.17 °N	77 °N
southern boundary	48 °N (*)	48.00 °N	48.50 °N	38 °N
western boundary	7 °W (*)	10 °W	3.75 °W	30 °W
eastern boundary	12 °E (*)	10 °E	9.25 °E	45 °E
resolution lat.	50 km	0.33°	0.11°	0.5°
resolution lon.	50 km	0.67°	0.17°	0.75°
grid (NX x NY)	25 x 48	31 x 67	79 x 79	101 x 79

(*) approximate position on spherical grid

Some important parameters for the different model set-ups are given in Table 2. Note that the WASA implementation has a higher directional resolution than the other implementations.

Table 2 Parameters used in the computation

Symbol	Explanation	Cartesian	Spherical	POL	CM/GKSS
NANG	Number of angle discretization	12	12	12	24
NFRE	Number of frequency	25	25	25	25
NGX	Number of longitude in grid	25	31	78	101

The source term integration time step and the propagation time step for the different implementations are given in Table 3.

Table 3 List of time steps used.

	Cartesian	Spherical	POL	CM/GKSS
Propagation	1200 s	1200 s	300 s	900 s
Source Term Integration	600 s	600 s	300 s	900 s

Remarks:

- KULeuven/MUMM is basically standard WAM.
- POL implemented two grids for the period in question, with the finer resolution (as listed in Table 1) grid taking boundary conditions from the results of their coarser grid. The wave results reported here were all output from the finer grid. The coarser grid domain is from 47.83^0 N to 63.17^0 N and from 12.25^0 W to 13.25^0 E, with resolutions 0.33^0 and 0.5^0 in the latitude and longitude direction, respectively.
- The WASA runs were adjusted for variable (monthly mean) ice cover. There is also a possibility to output various additional sea-state parameters (e.g. different wave periods).

The computational domain for different model runs is shown in Figure 1(a). Figure 1(b) shows the computational grid used for the KULeuven/MUMM Cartesian run together with the locations of the model output points.

4. THE WIND FIELDS

KULeuven/MUMM wind fields

The time series of surface wind field is one of the main inputs required by the WAM model. Wind data for the period from Oct. 1992 to March 1993 are available at MUMM. The wind fields were provided by UKMO in GRIdded Binary (GRIB) code. The GRIB code is one of the two formats which are used to provide the forecasting through the Global Telecommunication System (GTS) to the national meteorological offices. The wind fields are analyzed wind fields supplemented with forecasts, and they are provided for the entire chosen six month period, except for some short periods displayed in Table 4 (also see Luo, 1995). For those missing blocks, wind fields set to the last available wind fields are used in order to get a continuous set of data for the whole period. At MUMM, the wind forecast in GRIB code was first decoded. Thereafter, the data were bilinearly interpolated in space on the geographical and as well as on the stereographical wave model grid.

Table 4 Missing meteorological forecast: day number and time.

Oct. 92	Dec. 92	Nov. 92	Jan. 92	Feb. 93	Mar. 93
none	none	30pm 31 am&pm	01 am &pm 02 am&pm 03 am&pm 04 am&pm	none	30 am&pm 31 am&pm

POL wind fields

The wind fields used by POL also came from the UKMO, but are different from the KULeuven/MUMM wind fields. The winds are from a sigma coordinate model, and those used by POL are for a sigma level of 0.997. The conversion to 10 m winds for use in WAM is not completely straight forward, as the height of a constant sigma value will vary with weather conditions.

For the period in question POL has 10 m wind data for five sites: k13, mpn, ym6, eur and leg (Fig. 1(b)). These were compared with the UKMO 0.997 sigma winds. For each time at which there were data for both model and buoy winds, the ratio of the two values of wind speed was calculated. It was found that multiplying the UKMO winds by a factor of 0.92 made the geometric mean of all the ratios as close as possible to 1.0 (actually GM (UKMO/buoy) = 0.98). The UKMO winds were, therefore, multiplied by 0.92 and then input to WAM in the same way as standard 10 m winds.

POL also used winds supplied by Det Norske Meteorologiske Institutt (DNMI) which is Norwegian for the Norwegian Meterological Institute to investigate the sensitivity of the wave model results to the wind field used.

WASA wind fields

The WASA data set used winds provided by the Norwegian Meteorological Institute.
These winds are calculated from mean sea level air pressure fields. The data are 6-hourly and are given in a rectangular grid on a stereographic map projection with a grid distance of 75km at 60°N. The data were interpolated to the WASA fine grid. They are 10m wind speeds. More details of winds and interpolation procedures can be found in Reistad and Iden (1995).

As pointed out by Ovidio et al. (1995) using statistical analysis, UKMO wind data in the North Sea region are of good quality and compare well with ERS-1 altimeter and scatterometer wind speed measurements, although those in the open sea area (i.e. north of 60°N) seem to be underestimated.

5. SITE MEASUREMENT

5.1 Buoy Data in the Southern North Sea

The locations and the approximate water depths of the buoy stations used for model comparison in this report are given in Table 5. The time series (3-hour interval) of buoy data of significant wave height and zero upcrossing period were made available by Rijksinstituut voor Kust en Zee (RIKZ, the Netherlands).

Table 5 Names and positions of observation stations.

Station	Latitude	Longitude	Water depth (m)			
			RIKZ	KUL	POL	WASA
auk	56°23'59"N	2°03'56"E	85	87	79	74
k13	53°13'01"N	3°13'12"E	30	28	27	30
mpn	52°16'26"N	4°17'46"E	18	21	16	17
ym6	52°33'00"N	4°04'00"E	21	24	22	26

Note that the water depths given in Table 5 are taken from the bathymetric data of the nearest grid point of the model implementations. The depths of KUL are the depths from the KULEUVEN/MUMM spherical implementation. The depths are somewhat different than the depths supplied by RIKZ, who supplied the buoy data.

5.2 Satellite Data for the North Sea area

The radar altimeter, the wind scatterometer data and the Synthetic Aperture Radar (SAR) data could be obtained from the first European Remote Sensing Satellite (ERS-1), which was launched by the European Space Agency (ESA) on July 17, 1991. The altimeter and scatterometer data were provided on Computer Compatible Tapes (CCT, 6250 bpi) and cover the entire globe for the period of interest: October 1992 -- March 1993. Permission was obtained from ESA to use the scatterometer data products within the PROMISE project. For this study only the altimeter data were used for verification. The product type is the so called fast delivery product copy, which means that a minimal number of calibrations and corrections of the data were performed by the ESA ground stations as the product is intended for near real-time remote sensing applications, to be disseminated via low rate links. For those reasons, data extraction routines as well as check procedures were designed by MUMM to obtain a workable and statistically coherent regional data set (Ovidio, 1995).

routines as well as check procedures were designed by MUMM to obtain a workable and statistically coherent regional data set (Ovidio, 1995).
The altimeter data were filtered and averaged over eight neighbouring points along the satellite track. The filtered output files contain the significant wave height together with the latitude and longitude. The typical accuracy of the ERS-1 radar altimeter for the significant wave height is of the order 0.5 m or 10% for wave heights between 1 and 20m, whichever is greater. The radar altimeter also provides information on wind speed with an accuracy of about 2 m/sec for moderate winds (ERS-1 Reference Manual 1993).

Besides the ERS-1 data, the altimeter measurements of the TOPEX/POSEIDON satellite can be used to verify the model results. This satellite was launched on 10 August 1992. The data that can be used for PROMISE is provided by the NRSC and covers the period from October 92 till the end of April 96 for the North Sea and from January 93 till April 96 for the Gulf of Biscay. The data include measurements of the significant wave height and wind speed together with the longitude and the latitude. Quality control has to be executed to remove outliers. Altimeter wave height accuracies are about 10% for the range 1-20m, although some investigations have reported that the altimeter underestimates wave heights of 4 m and above when compared with buoy data (Gooberlet et al., 1992; Günther et al., 1993; Komen et al., 1994).

6. INTERCOMPARISON OF MODEL RESULTS, BUOY AND SATELLITE DATA

6.1 Introduction

Visual intercomparison between the computed results of KULeuven/MUMM, POL, the WASA data set (CM/GKSS) and the observation data at a number of stations was made. Also a statistical analysis for each implementation was carried out. For this analysis the buoy data served as reference. The following statistical parameters were considered: bias, root mean square error (RMSE) and scatter index (S.I.). Appendix A gives the definitions of the statistical parameters used in this study. The statistical definitions follow Romeiser (1993), amongst others. There is a need for a common definition. Other slightly different definitions in particular for the scatter index have been used, e.g. Zambresky (1989) and Carretero and Günther (1992).

6.2 Visual Intercomparison

6.2.1 Model results versus buoy data

Comparisons among the computed results of KULeuven/MUMM (spherical run and Cartesian run, both with UKMO wind), the POL results (spherical run with UKMO wind and with DNMI wind), WASA-results (spherical run with DNMI wind) and buoy data were also carried out. Shown in Figures 2(a-b) are respectively the time series of significant wave height and mean wave periods during an extreme condition at station *auk* from 15 February to 22 February, 1993. From Figure 2(a) one can see that the significant wave heights produced by the WAM-model implementations at KULeuven/MUMM and POL agree very well with each other and also with the buoy data. The WASA data show slightly higher results than the other computed results and are higher than the buoy data as well. Figure 2(b) shows an overestimation of the mean wave period by all the WAM-model implementations, and again a little higher overestimation of WASA results can be noticed. It should be clearly mentioned here that the comparison of the mean period with the buoy results is not a true comparison, since the model mean period is calculated using the inverse of the frequency as weight, while the buoy measurements use the square of the frequency as weight (as to obtain the so called zero-upcrossing period). One should expect to see a systematic difference between the mean period from calculations and the zero-upcrossing period from the measurements (see also Figures 6-9 and comments about the WASA data zero upcrossing period in section 6.3.2). The standard WAM-model does not give the zero-upcrossing period as an output parameter.

Figures 3(a-b), 4(a-b) and 5(a-b) show the same intercomparisons at stations *k13, ym6* and *mpn,* respectively. One can see that both the significant wave height and mean wave period have the same trends as shown in Figures 2. The differences between different model implementations are smaller than the differences with the buoy data for both the wave height and mean period.

KULeuven/MUMM simulated the time series of significant wave height and mean wave period at the four stations for the six months period October 1992 until March 1993. The results are presented in Figures C-1 to C-8 in Appendix C. The trends are similar to the trends discussed above for the period of 15-22 February 1993. See Appendix C for details.

There are several possible reasons for the underestimation of the significant wave height. The first reason may be due to the underprediction of the wind speed by the UKMO wind model. The underprediction of the wind speed will certainly lead to 'not enough' wind energy input, and thus, an underestimation of significant wave height. As pointed out in Luo (1995), the altimeter wind data showed that the UKMO model tends to underpredict the wind speed, especially in the North Atlantic region.

Another reason may lie partly in the treatment of open boundary conditions used for the calculations. In the present KULeuven/MUMM computations, swells coming from the North Atlantic region were not considered. In the northern part of the North Sea inclusion of North Atlantic swell energy will be able to improve the model prediction. In the southern part of the North Sea (i.e. at the presented buoy locations), improvements are not observed (Ovidio et al.,1995). This fact is also confirmed by the test run of POL using WASA boundary conditions. There was a negligible difference in wave height at the buoy stations compared to their standard procedure. This was to be expected given that the propagation scheme in WAM is rather poor and more importantly that at the time in question there was a storm producing lots of waves locally.

Luo (1995) additionally argued that the buoy locations cannot be expected to coincide exactly with one of the grid points. Therefore, an approximation must be made, either by choosing the value on the closest grid point (as done in WAM model), or by interpolating using the values of the grid points surrounding the buoy location. Both approximations are adequate if the field is locally smooth. However, the error may be considerable if the spatial gradient is significant, especially in coastal regions. A smaller grid size may be used for these approximations, but this will increase the use of CPU time.

Besides the reasons mentioned above for the significant wave height, an additional reason may be the directional resolution. In the present WAM runs, except for the WASA runs, as in many other operational wave models, a directional resolution of 30° is used. This angular resolution is probably too coarse for shallow water regions, especially when there is a significant spatial gradient.

Finally, it is expected that together with higher spatial and spectral resolution, the introduction of additional physics in the wave model, will improve the results in shallow water regions. Wave processes like bottom refraction, bottom friction and triads for high resolution simulation in shallow water areas are still waiting for better approximation and incorporation in wave prediction models. Moreover, wave-current interactions and current refraction should also be considered in wave models. Examining the Figures C-1 to C-4, one can see that the buoy wave height data have some small oscillations. The magnitude of these oscillations might indicate a minor effect of the tide on the wave heights, at least for the studied locations which are still not in very shallow water . The oscillations are however larger and more clear in the mean period plots (see below). The buoy data for mean wave periods clearly show a tidal oscillation corresponding to the dominant M2-tide at all the stations. The WAM results do not produce these oscillations. The interaction between waves and tidal currents might prove to be an important factor for the improvement of prediction of wave characteristics. These considerations, i.e. higher spatial resolution, the introduction of additional shallow water physics, improved numerics and dynamic coupling with a tidal model, are the main goals of the wave group contribution for the second and third year of the PROMISE project.

Although there exist some discrepancies between the model results and the buoy data, the model results obtained at KULeuven/MUMM and POL are almost the same. The negligible differences are most likely due to the different integration time steps and different grid resolutions. The more distinct differences between the WASA results and those of KULeuven/MUMM and POL may lie in the fact that the grid sizes used for the WASA computation are coarser. A coarser grid will not only mean a possibility for a larger distance (in space) between the actual buoy site and the closest computational point, it also has consequences on the treatment of islands (e.g. the

Shetland Islands). This last remark can probably explain the somewhat larger differences at station *auk* in comparison with the other output locations, inclusive the buoy data (see Figure 2).

6.2.2 Model results versus satellite data

As an addition to buoy data, satellite data can be used to verify the WAM results. The significant wave height results for February 93 of the KULeuven/MUMM spherical implementation of WAM are compared to the data of the TOPEX/POSEIDON and to data of the ERS-1 satellite. Each satellite measurement at a certain time and location is compared with the WAM output of the closest model point and model time. Figures 10 and 11 represent the scatter plot of the significant wave height measured by the satellite versus the significant wave height predicted by the WAM model. The overall agreement seems to be quite good, although the slope is not a 1/1 slope (see below for the statistical analysis).

6.3 Statistical Analysis

6.3.1 Introduction

To judge the performance of the present WAM Cycle 4, the bias, scatter index and the root mean square error were calculated. For the intercomparison purpose the emphasis was laid on the results of February 1993. A statistical analysis for the WASA simulation results and for the KULeuven/MUMM results for the whole month of February 1993, and for the WASA, KULeuven/MUMM and POL simulation results at the stations *auk, mpn, k13* and *ym6* for the period 15-22 February 1993, was made. Appendix C contains a summary of the results of the statistical analysis for each of the six months from October 1992 to March 1993 and for this whole six-month period together.

6.3.2 Buoy comparison statistics

Shown in Table 6 are the statistical results of significant wave height and mean wave period for the five different implementations (runs on Cartesian and spherical grids at KULeuven/MUMM, runs at POL with UKMO and DNMI winds and the WASA data) at the four stations for the period of 15-22 February 1993.

Significant wave height

Statistical results of the significant wave height against buoy data shown in Table 6 show that the statistical values of bias for runs at KULeuven (both Cartesian and spherical) and POL (with both the UKMO wind and the DNMI wind) agree well with each other, but are clearly different from those of WASA data for all of the four stations. The statistical values of S.I. and RMSE at all of the four stations of all the different implementations agree well with each other. Note that the discrepancy between the Cartesian run and spherical run in KULeuven/MUMM at station *mpn* is, as described above in section 6.2, mainly due to the fact that the output result in WAM is taken from the nearest neighbour grid point.

Table 6 Statistical results for different implementations at the four stations for the period of 15-22 February 1993 (positive bias means model underestimation)

15-22 Feb. 1993									
Runs	Statistics	Hs				Tm			
		auk	k13	mpn	ym6	auk	k13	mpn	ym6
KUL (Cart.)	Bias	0.38	0.05	0.56	-0.48	-0.92	-1.00	-0.75	-1.00
	S.I.	0.17	0.13	0.46	0.38	0.15	0.21	0.20	0.22
	RMSE	0.62	0.31	0.77	0.69	1.09	1.26	1.09	1.27
KUL (Sphe.)	Bias	0.40	-0.01	0.02	-0.53	-0.91	-1.04	-0.99	-0.94
	S.I.	0.17	0.14	0.14	0.40	0.15	0.21	0.22	0.21
	RMSE	0.61	0.33	0.28	0.72	1.07	1.27	1.26	1.20
POL UKMO	Bias	0.40	-0.03	0.04	-0.53	-0.95	-1.22	-1.20	-1.14
	S.I.	0.19	0.13	0.14	0.40	0.16	0.23	0.25	0.23
	RMSE	0.69	0.33	0.28	0.72	1.15	1.40	1.42	1.32
POL DNMI	Bias	0.33	-0.03	0.02	-0.48	-0.89	-1.21	-1.08	-1.14
	S.I.	0.19	0.17	0.78	0.41	0.17	0.23	0.37	0.23
	RMSE	0.63	0.40	1.47	0.70	1.21	1.42	2.16	1.33
WASA	Bias	-0.44	-0.21	0.06	-0.75	-2.30	-1.57	-1.56	-1.48
	S.I.	0.18	0.19	0.32	0.50	0.30	0.27	0.30	0.27
	RMSE	0.70	0.48	0.63	0.94	2.34	1.71	1.79	1.61

Mean wave period

As mentioned before, the mean wave period of the buoy data is actually the zero-upcrossing period, while that of the WAM output is of the mean absolute period. The statistical values for the bias of the mean wave period are of the order of -1 s and even larger for the WASA data. Plots with the zero-upcrossing period of WASA data show that the zero upcrossing period of the WASA data agrees very well with that of the buoy data. Statistical values of S.I. and RMSE of the different implementations for all four stations show a good consistency.

Table 7 Statistical results for WASA data and KUL/MUMM spherical run results for the whole month of February 1993.

Unit	Station	Hs			Tm		
		Bias	S.I.	RMSE	Bias	S.I.	RMSE
WASA	auk	-0.52	0.29	0.77	-2.75	0.41	2.98
	mpn	-0.03	0.38	0.42	-1.76	0.39	2.05
	k13	-0.11	0.25	0.40	-1.83	0.35	2.03
	ym6	-0.41	0.53	0.58	-1.88	0.39	2.10
KUL/ MUMM (Spher.)	auk	0.39	0.26	0.58	-0.49	0.15	0.96
	mpn	0.04	0.19	0.20	-0.98	0.26	1.31
	k13	0.10	0.22	0.32	-0.70	0.19	0.73
	ym6	-0.19	0.42	0.42	-0.93	0.25	1.23

Shown in Table 7 are the statistical results of WASA data and KULeuven/MUMM model results for significant wave height at all of the four listed stations and this for the whole month of February. One can see the similar trends as those discussed above for the period of 15-22 February 1993. Tables C-1 and C-2 in Appendix C present the statistical results of the KULeuven/MUMM model results against buoy data for each month separately and for the entire period of October 1992 until March 1993 as well. These results reassure the accuracy and consistency of the present WAM implementations.

Zero upcrossing period (T_{m2} period)

As mentioned above the buoy data at the four stations for the wave period are zero upcrossing period (calculated as T_{m2} period). At present we have the zero upcrossing period data of the WASA results, but not those for other implementations. The statistical results of the zero upcrossing period for WASA data versus the buoy data for February 1993 are listed in Table 8. The comparison of the WASA data versus the buoy data for the zero-upcrossing period for the same period are also displayed in Figures 6-9 for each of the four stations.

Table 8 Statistical results of WASA data versus buoy data
for zero upcrossing period

Station	Bias	S.I.	RMSE
auk	-0.50	0.16	0.97
k13	0.00	0.10	0.49
ym6	-0.00	0.11	0.52
mpn	0.17	0.13	0.59

We can see from both Table 8 and Figures 6-9 that the WASA data compare very well to the buoy data, especially at the stations *k13* and *ym6*. At these stations the bias value is zero. In previous literature, many comparisons of model wave period against buoy data have used the inverse frequency weighted mean wave period, and not the zero upcrossing period, although this is quite often the only 'mean' wave period supplied by buoys. For future work we advise strongly to add the zero upcrossing period as an output parameter of the WAM-model, so it can be used for comparison with buoy data.

6.3.3 Satellite data

The statistical analysis of the KULeuven/MUMM WAM-implementation results versus TOPEX/POSEIDON data and versus ERS-1data, is given in Table 9. The mean Hs of the WAM model is the mean predicted significant wave height along the satellite tracks during February 93.

Table 9 Statistical analysis satellite versus WAM, February 93

	WAM vs. TOPEX/POSEDION	WAM vs. ERS-1
Mean Hs WAM model	1.63	2.01
Mean Hs satellite	2.04	2.65
RMSE	0.61	0.88
SI	0.34	0.38
BIAS	0.40	0.64
Slope trend line (least square fit)	0.84	0.89
Intercept trend line	-0.08	-0.35

6.3.4 Wave model statistics in literature

Table 10 shows some wave model statistics found in literature. Examining this table, one can find that the third generation operational model produces results with a bias in the order of 1.04 m, a scatter index of about 0.29, and the root mean square error of 1.35 m for the significant wave height. The wave model with analyzed wind force yields results with a bias in the order of 0.27 m, a scatter index of 0.21 and a root mean square error of 0.7 m. It is evident that results obtained with analyzed wind fields, which can be assumed to be of better quality than the forecasted wind fields, are much better than the results of the operational runs.

The present significant wave height results (Tables 6, 7, C-1 and C-2) are satisfactory when compared with those found in literature (Table 9) in terms of the bias and the root mean square error. The scatter index in the order of 0.50 (station *mpn*) is rather large compared to the ones found in literature (in the order of 24%). The station *mpn* lies in a quite shallow area, where differences in location between the buoy and the calculation point can greatly affect the results.

When compared to the results found in literature (Zambresky, 1986b, bias: -0.71s/-0.01s; S.I.: 0.18/0.21; RMSE: 1.44s/1.99s), the mean wave period results obtained in the present computations are satisfactory in terms of the bias, the scatter index and the root mean square error (Table 6). Note again that the S.I. in literature is not always defined in the same way. Also, as pointed out in section 6.3.2, the buoy data period is not the mean wave period, but the zero upcrossing period. Due to differences in definition of statitistical parameters and differences between model output and buoy measurement, hard conclusions cannot be made.

Table 10 Wave model statistics found in literature

Significant wave height					
Model	Bias	S.I.(%)	RMSE (m)	References	Remarks
Operational WAMS	0.82/1.48	20/38	0.96/1.63	Zam., 1986a	Storm
Operational WAMS	0.36/1.37	23/24	1.13/1.69	Zam., 1986b	Storm
Analyzed WAMS	0.08/0.40	15/21	0.61/0.96	Zam., 1986a	Storm
Analyzed WAMS	0.26	19	0.96	Zam., 1986b	Storm
Analyzed WAMS	-0.4/-0.22	22/37	0.47/0.82	Zam., 1989	Storm
Analyzed NEDWAM	-0.18/0.13	10/21	0.23/0.88	Rie., 1989	
Analyzed	-0.61/-0.13	16/20	0.32/0.74	Mas., 1993	911215-
Data Assimilation	-0.08/0.54	16/21	0.33/0.7	Mas., 1993	911215-
Data Assimilation	0.01/0.36	16/19	0.31/0.69	Mas., 1993	911215-
ECMWF WAM	-0.53/-0.19	14/24		Janssen, 96	9501-12
Mean period					
Model	Bias (s)	S.I. (%)	RMSE(s)	Ref.	Remarks
WAM	-0.71/-0.01	18/21	1.44/1.99	Zam.(?)	Storm

7. SENSITIVITY

7.1 Role of Windfield

POL set up their implementation for the month of February 1993 using DNMI wind. No significant differences are found between the wave model results obtained by using UKMO winds or obtained by using DNMI winds. Both wind fields seem to be of similar (high) quality. No attempts have been made to use wind fields form other meteorological institutes, but one can expect that some but no major tuning of the winds will be necessary. This conclusion might however not be valid for wind fields at other periods. One should for the period of comparison check if no important changes were made to the software used by met-offices to produce wind fields.

Some differences in wind fields are to be expected when land and sea atmopsheric boundary layers are treated differently in the numerical meteo model or not. These effects will be most visible close to the coast for offshore winds and/or local wind seas.

In their SWADE study on optimal wind fields, Cardone et al. (1995) showed that excellent agreement between WAM-Cycle 4 model results and buoy data in deep and intermediate water depth could be obtained (0.2 m for bias and 14% for S.I.) when wind fields were obtained through manual analysis. These results were considerably better than results obtained with an objective analysis procedure. It illustrates the need for very good wind fields.

7.2 Role of Bathymetry

When waves propagate in shallow water area, bathymetry will play a significant role, due to effects such as refraction, wave breaking, wave-bottom interaction and triads. This will require a high resolution model for the prediction of wave characteristics in these areas.

For the North Sea implementation, the bathymetry does not seem to be a crucial factor. Moreover, the grid resolution used, is still too coarse to reflect the bathymetric details. It is expected that for the shallow water applications the role of the bathymetry will become important. The effect will then have to be studied in detail.

7.3 Sensitivity to Implementation and Overall Performance

Although an intercomparison exercise of wave model results for a short period only, cannot be considered as a very solid and comprehensive test, it gives together with previous experience confidence in the applicability, robustness and dissemination qualities of the WAM-model for North Sea scale applications. The different implementations were done totally independently and the obtained results are quite comparable and of reasonable to good quality.

The different resolutions used in the spherical implementations by POL and by KULeuven/MUMM, did not yield significant differences in model results. One could conclude that for North Sea scale applications, a resolution of 2/3 of a degree in longitude and 1/3 of a degree in latitude is adequate.

8. COMMON IMPLEMENTATION

8.1 Choice

The present intercomparison exercises with different implementations of WAM Cycle 4 for the hindcasting of wind waves in North Sea shows that the WAM Cycle 4 produces good results compared with buoy data.

As a good choice for the common North Sea implementation and for dissemination, the following choice was suggested:

- Model domain
  10^0W ------ 10^0E, $\Delta\lambda=(2/3)^0$,
  48^0N ------ 70^0N, $\Delta\phi=(1/3)^0$,
- Model integration parameters
  $\Delta t_{prop} = 1200$ s, $\Delta t_{source} = 600$ s

8.2 Dissemination Code Change Documentation

The modifications from the original WAM Cycle 4 are attached in Appendix D as five diff-files: *preprowk.f_diff*, *presetwk.f_diff*, *wamodwk.f_diff*, *pspecwk.f_diff* and *pgridwk.f_diff*, in which changes with respect to the original WAM Cycle 4 code have been clearly documented . For easy reference, names of subroutines in which changes have been made are given in the diff-files.

The PROMISE Web-page (WWW http://www.nbi.ac.uk/promise) should contain all the information needed to download these documentation files. This web-site also contains the bathymetric data needed to set-up the North-Sea model application. An example wind file is given as well, together with output results as to check correct implementation. Only code modification is available from the PROMISE web-site. New users have to be aware that they have to become official users of the WAM-model to get the original code (see web-site on how to become an official user). Also real wind fields will have to be obtained from a meteorological office.

9. CONCLUSIONS

WAM Cycle 4 has been successfully applied to hindcast wind waves in the North Sea. The intercomparison exercise did not reveal any significant differences in model results between the POL and the KULeuven/MUMM implementations, although boundary conditions and grid resolution were quite different.

The WASA results showed systematic differences with the other implementations. However, the trends of significant wave height and mean wave period are similar.

The wind fields used, i.e. UKMO winds and DNMI winds, seem to be of comparable and of good quality, at least for the period considered.

Comparison over a short period of buoy or satellite data and model results showed good agreement. Statistical analysis of buoy or satellite data and model results indicated that the current North Sea implementation is of comparable quality as other implementations cited in literature.

The WAM Cycle 4 KULeuven/MUMM and POL implementations tend to underpredict wave height, while the WASA results tend to overestimate the wave height.

The WASA results showed excellent agreement with the buoy data for the zero upcrossing mean period. Since the zero upcrossing mean period is not a standard WAM output parameter, the other implementations did not provide this comparison. It is therefore recommended to add this to the WAM-model through dissemination of this additional feature. It will be a useful addition for the shallow water applications since quite often mean wave periods obtained from operational buoys have been processed as upcrossing periods.

For shallow water applications detailed sensitivity tests are needed. It is expected that many of these tests will be carried out and reported in detail during the coming two years of the PROMISE project.

Acknowledgements

We thank RIKZ for providing the buoy data. ESA is greatfully acknowledged for supplying the ERS-1 satellite data. The original WAM-Cycle4 code originated from the Max-Planck-Institut für Meteorologie. The work of many contributors to this computer code is greatly appreciated.

This study was carried out with financial support from the EC-MAST III PROGRAMME, contract MAS3 CT 9500025.

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CAPTIONS TO THE FIGURES

Figure 1

(a) Computational domain of different model runs;
(b) KULeuven/MUMM Cartesian grid as an example.

Figure 2

Comparison of WASA-POL-Spherical (KUL)-Cartesian (KUL) results with buoy data at station auk for February 1993. (a) Significant wave height Hs (m); (b) Mean wave period.

Figure 3

Same as Figure 2 but at station k13.

Figure 4

Same as Figure 2 but at station ym6.

Figure 5

Same as Figure 2 but at station mpn.

Figure 6

Zero upcrossing period comparison of WASA data against buoy at station auk for February 1993.

Figure 7

Same as Figure 6 but at station k13.

Figure 8

Same as Figure 6 but at station ym6.

Figure 9

Same as Figure 6 but at station mpn.

Figure 10

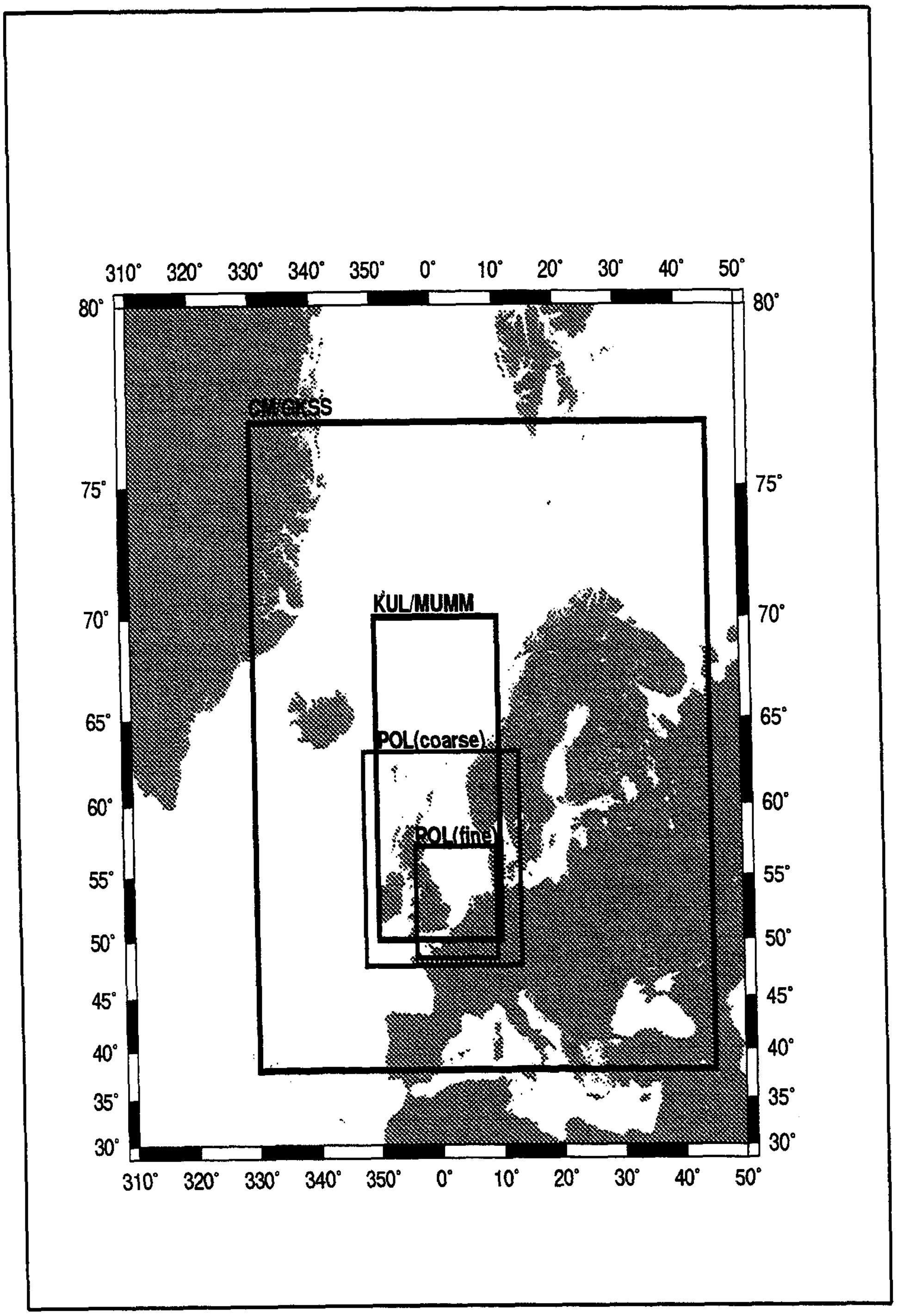
Scatterplot of Significant wave height Hs hindcasted by the KUL spherical run against TOPEX/POSEIDON data.

Figure 11

Scatterplot of Significant wave height Hs hindcasted by the KUL spherical run against ERS-1 satellite data.

CAPTIONS TO THE TABLES

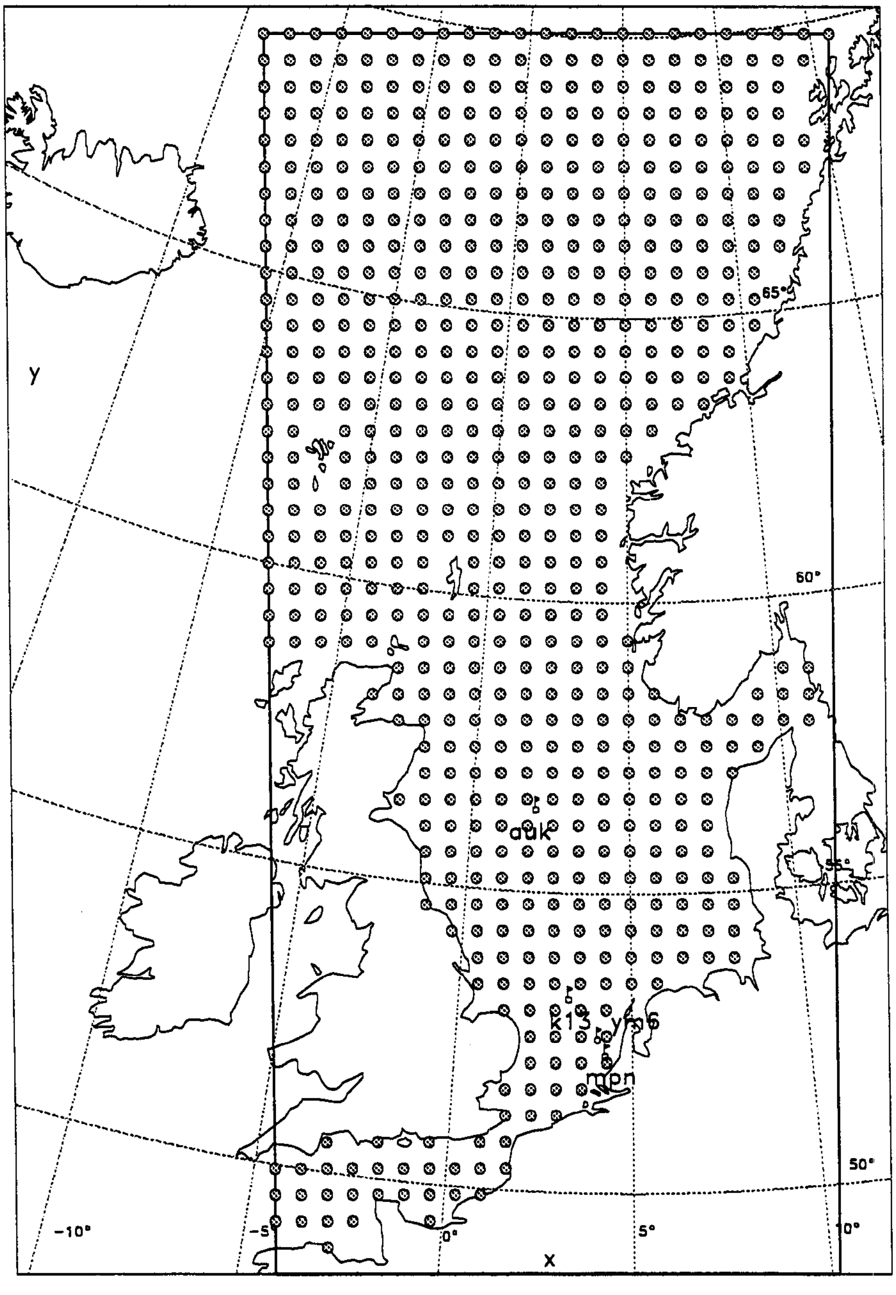
Fig. 1(a)



GMT Feb 18 15:44 PROMISE : modelled area of different wave models

Fig. 1(b)

The WAM model



KULeuven/Mumm cartesian coarse grid

Active grid points and output stations

Fri Feb 14 14:30:31 WET 1997

Fig. 2a

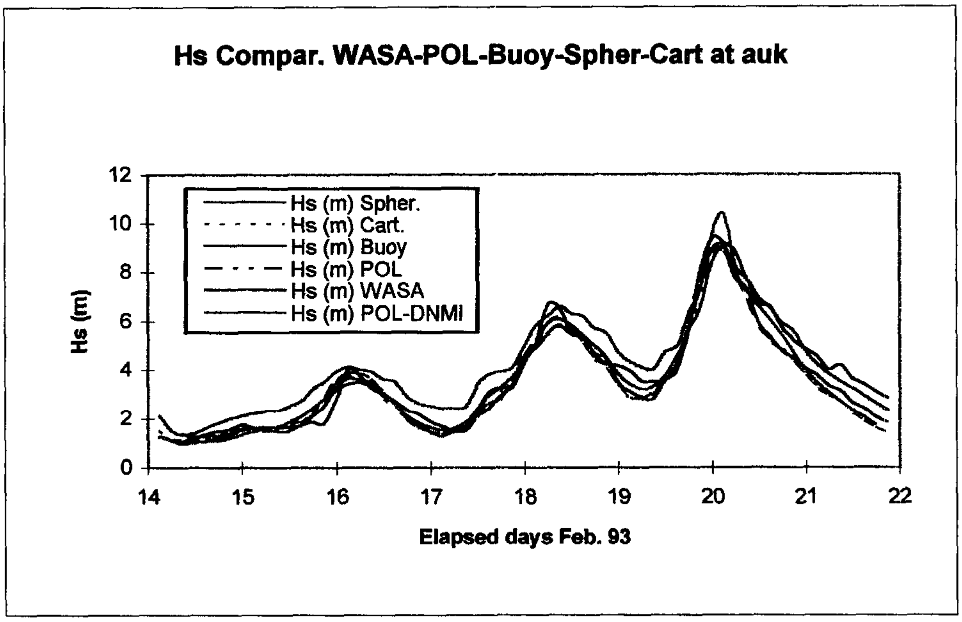

Hs Compar. WASA-POL-Buoy-Spher-Cart at auk
Hs (m)
0
2
4
6
8
10
12
14
15
16
17
18
19
20
21
22
Elapsed days Feb. 93
Hs (m) Spher.
Hs (m) Cart.
Hs (m) Buoy
Hs (m) POL
Hs (m) WASA
Hs (m) POL-DNMI

Fig. 2b

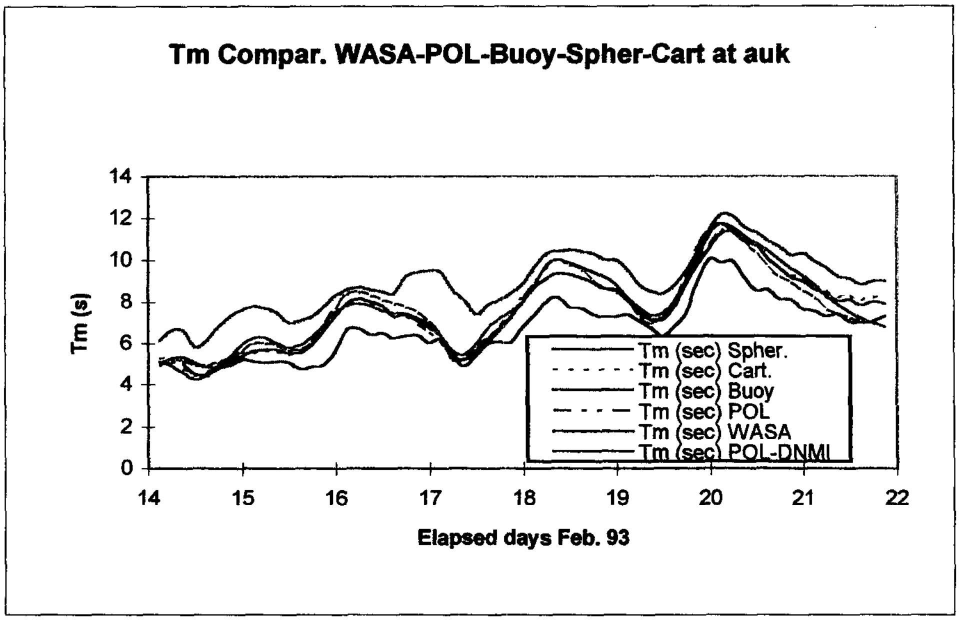

Tm Compar. WASA-POL-Buoy-Spher-Cart at auk
Tm (s)
0
2
4
6
8
10
12
14
14
15
16
17
18
19
20
21
22
Elapsed days Feb. 93
Tm (sec) Spher.
Tm (sec) Cart.
Tm (sec) Buoy
Tm (sec) POL
Tm (sec) WASA
Tm (sec) POL-DNMI

Fig. 3a

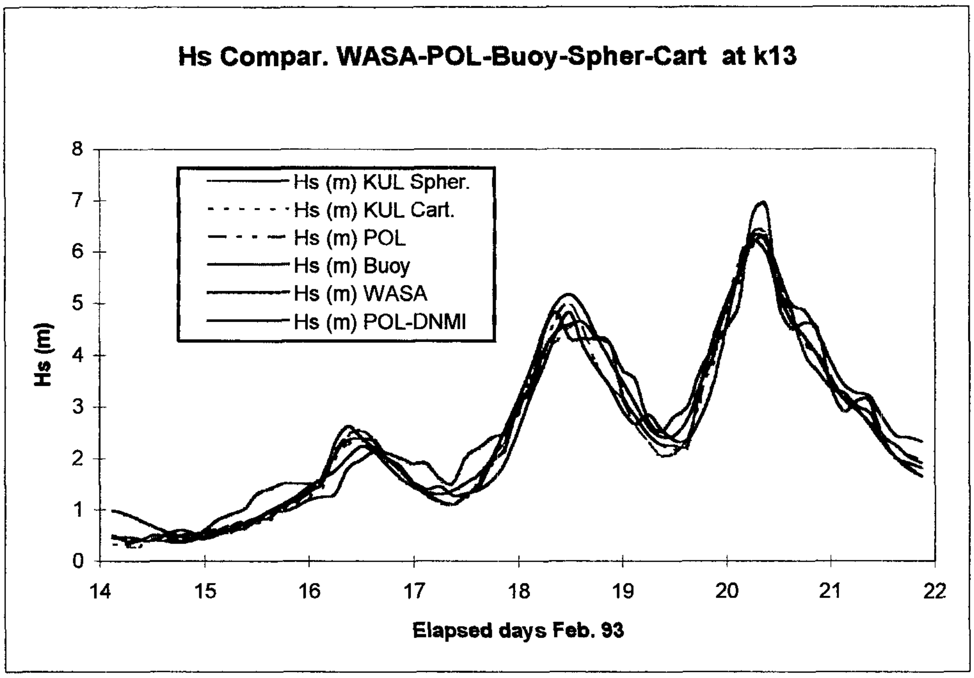

Hs Compar. WASA-POL-Buoy-Spher-Cart at k13
Hs (m) KUL Spher.
Hs (m) KUL Cart.
Hs (m) POL
Hs (m) Buoy
Hs (m) WASA
Hs (m) POL-DNMI
Hs (m)
0
1
2
3
4
5
6
7
8
14
15
16
17
18
19
20
21
22
Elapsed days Feb. 93

Fig. 3b

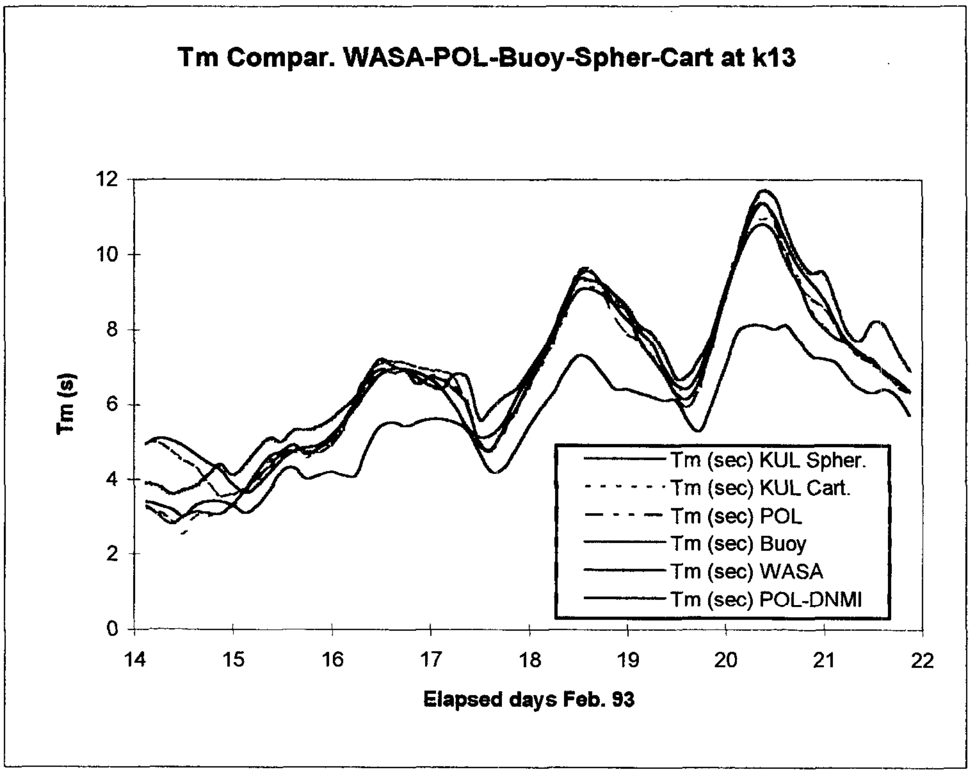
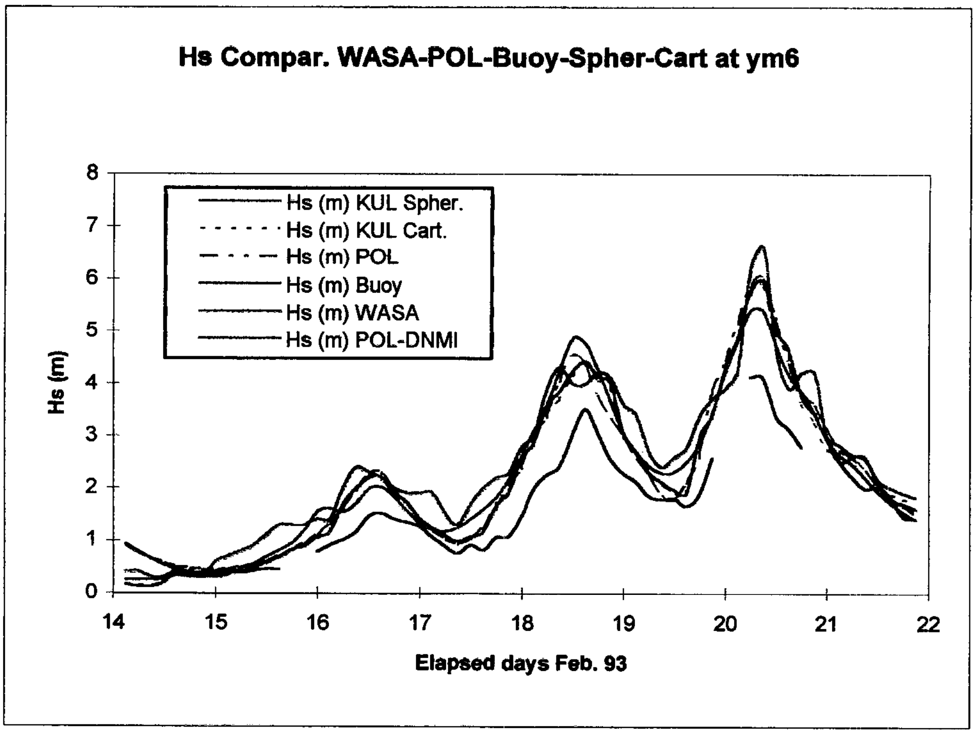

Tm Compar. WASA-POL-Buoy-Spher-Cart at k13
Tm (sec) KUL Spher.
Tm (sec) KUL Cart.
Tm (sec) POL
Tm (sec) Buoy
Tm (sec) WASA
Tm (sec) POL-DNMI
Tm (s)
0
2
4
6
8
10
12
14
15
16
17
18
19
20
21
22
Elapsed days Feb. 93

Fig. 4a


Hs Compar. WASA-POL-Buoy-Spher-Cart at ym6
Hs (m) KUL Spher.
Hs (m) KUL Cart.
Hs (m) POL
Hs (m) Buoy
Hs (m) WASA
Hs (m) POL-DNMI
Hs (m)
0
1
2
3
4
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6
7
8
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15
16
17
18
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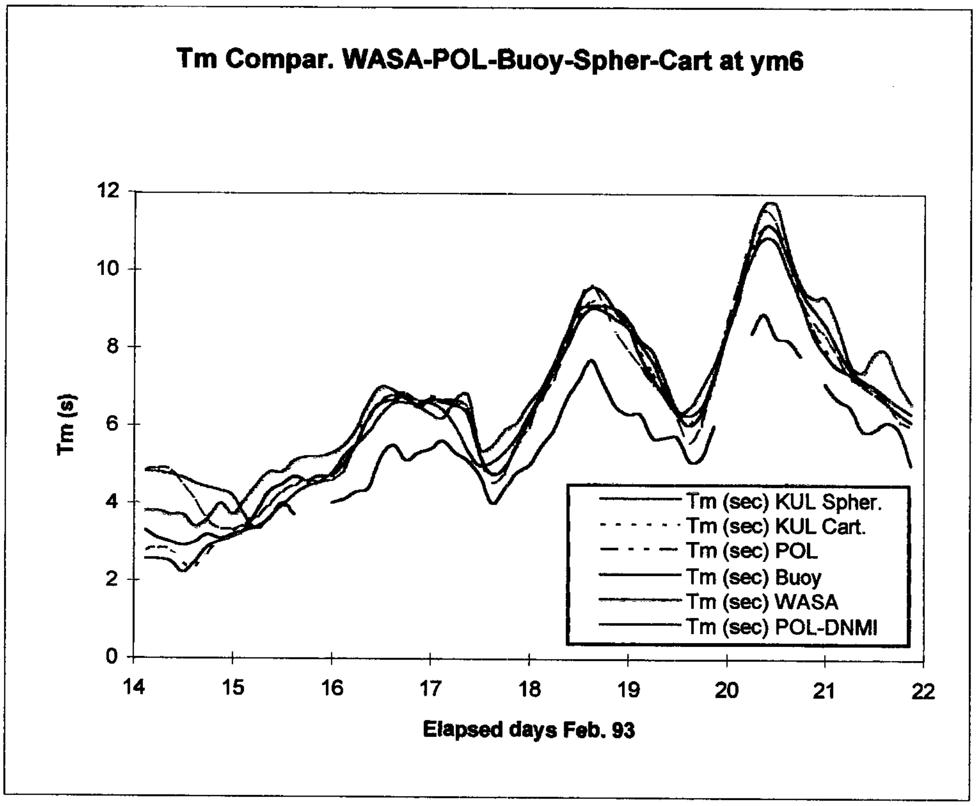
20
21
22
Elapsed days Feb. 93

Fig. 4b


Tm Compar. WASA-POL-Buoy-Spher-Cart at ym6
Tm (sec) KUL Spher.
Tm (sec) KUL Cart.
Tm (sec) POL
Tm (sec) Buoy
Tm (sec) WASA
Tm (sec) POL-DNMI
Tm (s)
0
2
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21
22
Elapsed days Feb. 93

Fig. 5a

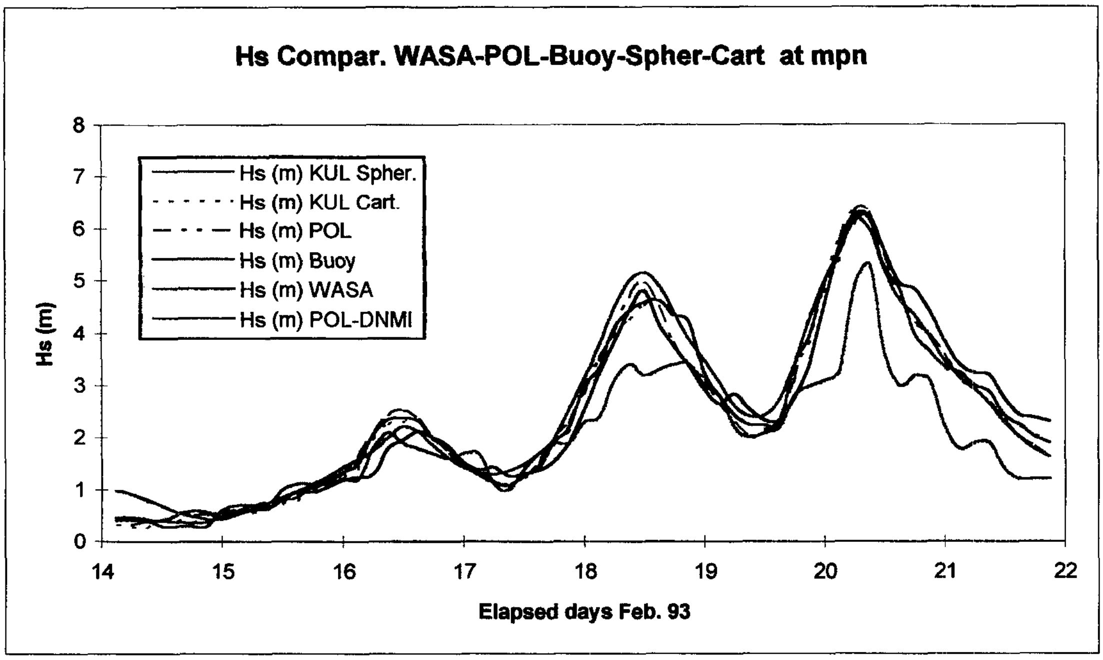
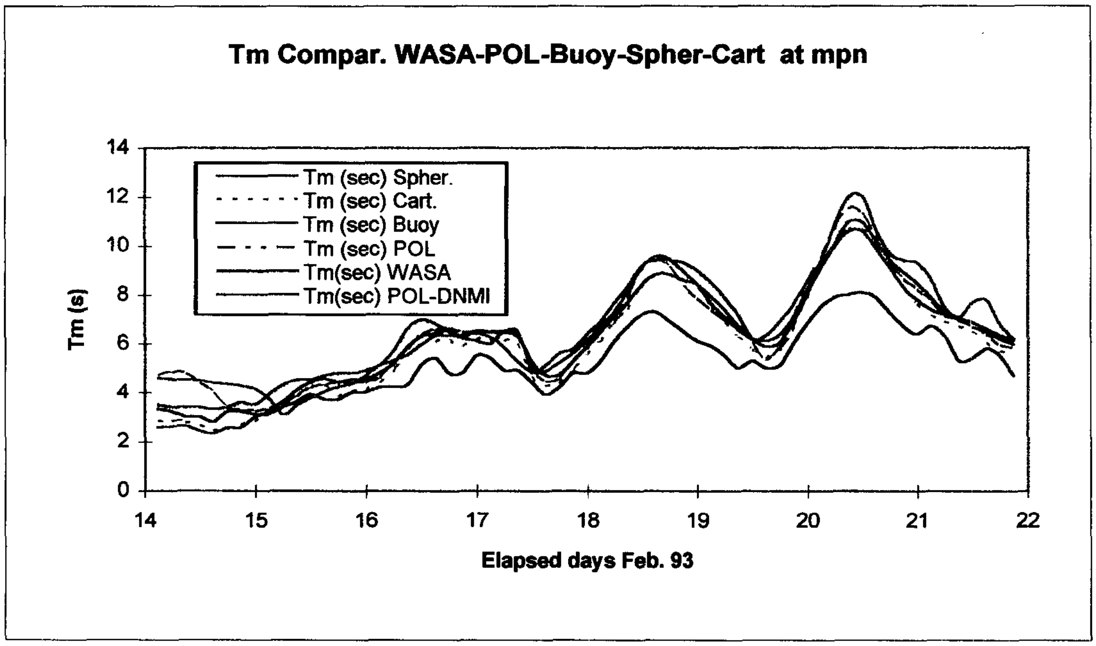

Hs Compar. WASA-POL-Buoy-Spher-Cart at mpn
Hs (m)
8
7
6
5
4
3
2
1
0
Hs (m) KUL Spher.
Hs (m) KUL Cart.
Hs (m) POL
Hs (m) Buoy
Hs (m) WASA
Hs (m) POL-DNMI
14
15
16
17
18
19
20
21
22
Elapsed days Feb. 93

Fig. 5b


Tm Compar. WASA-POL-Buoy-Spher-Cart at mpn
Tm (s)
14
12
10
8
6
4
2
0
Tm (sec) Spher.
Tm (sec) Cart.
Tm (sec) Buoy
Tm (sec) POL
Tm(sec) WASA
Tm(sec) POL-DNMI
14
15
16
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21
22
Elapsed days Feb. 93

Fig. 6

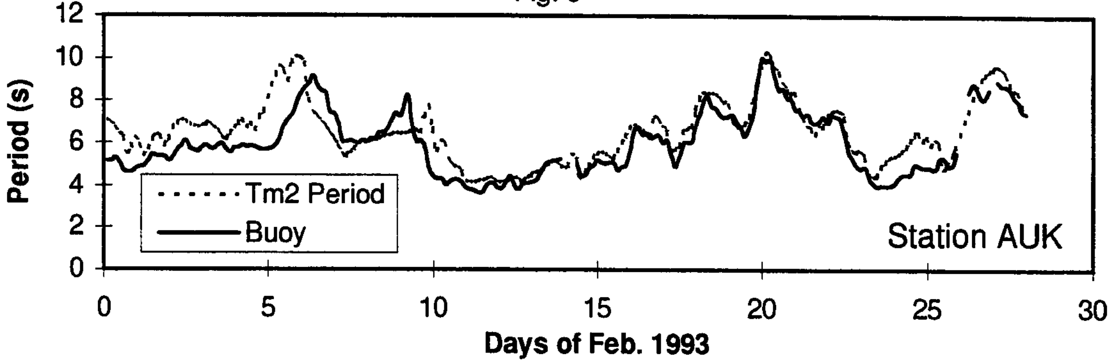


Fig. 7

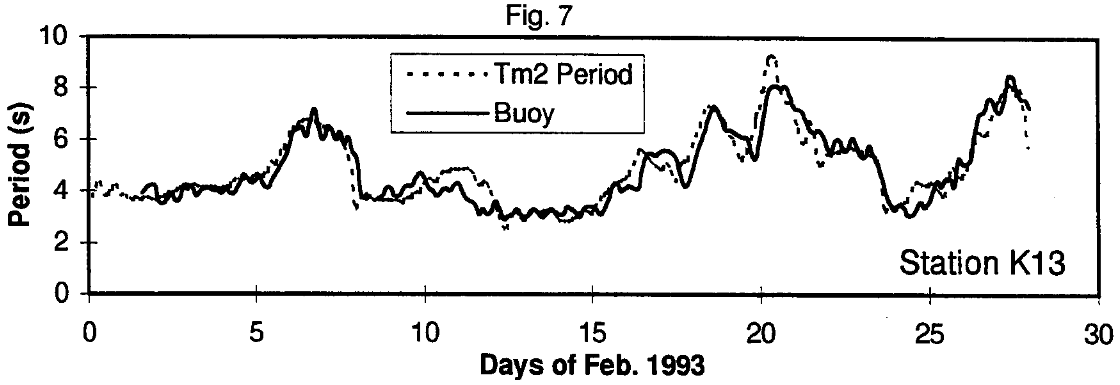


Fig. 8

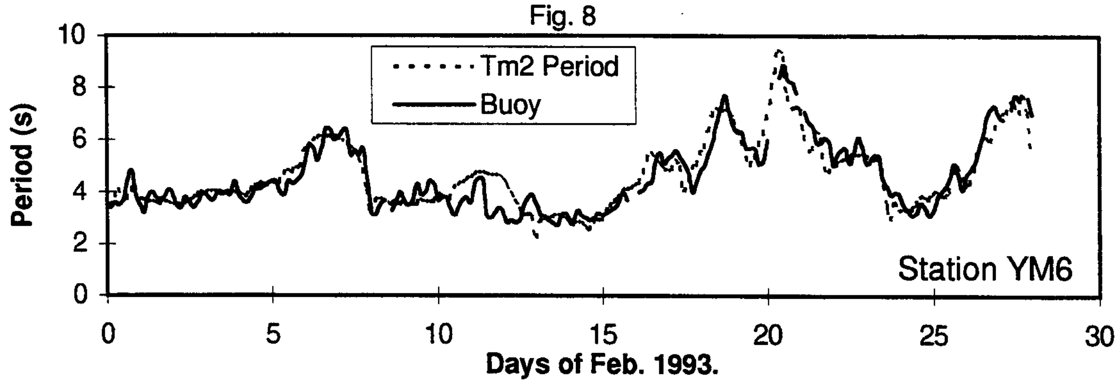


Fig. 9

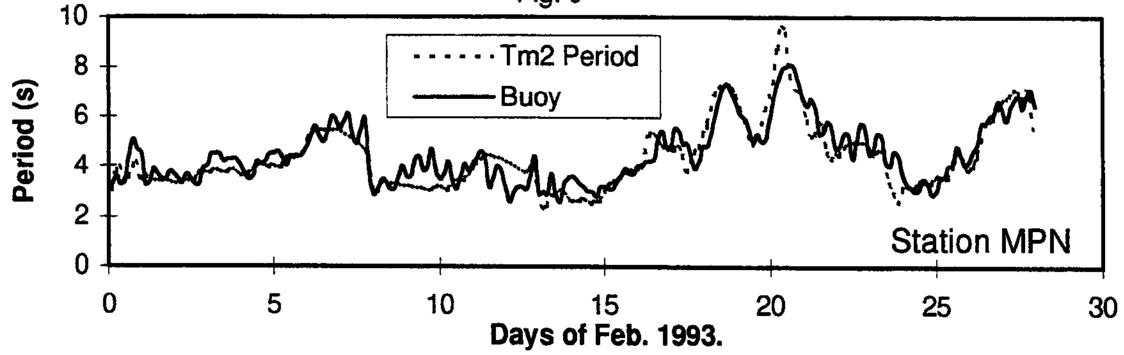
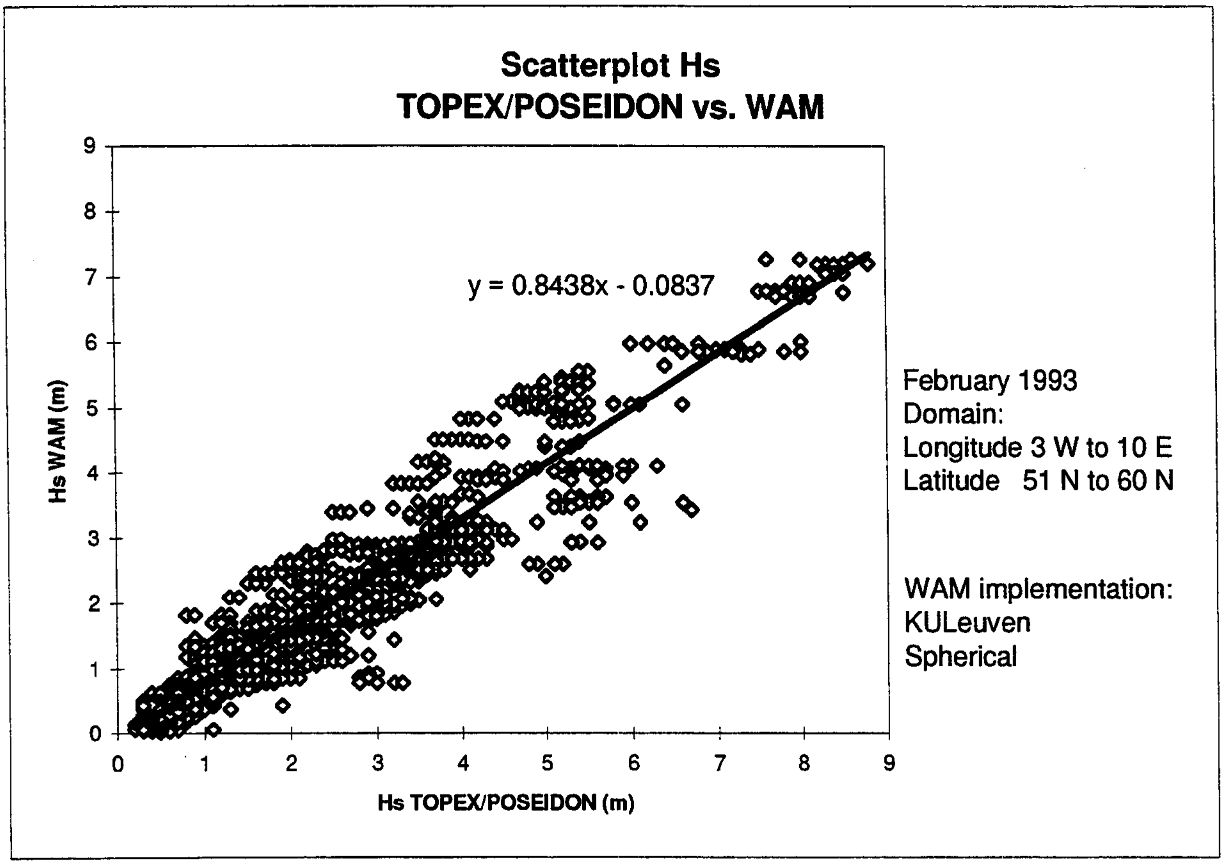


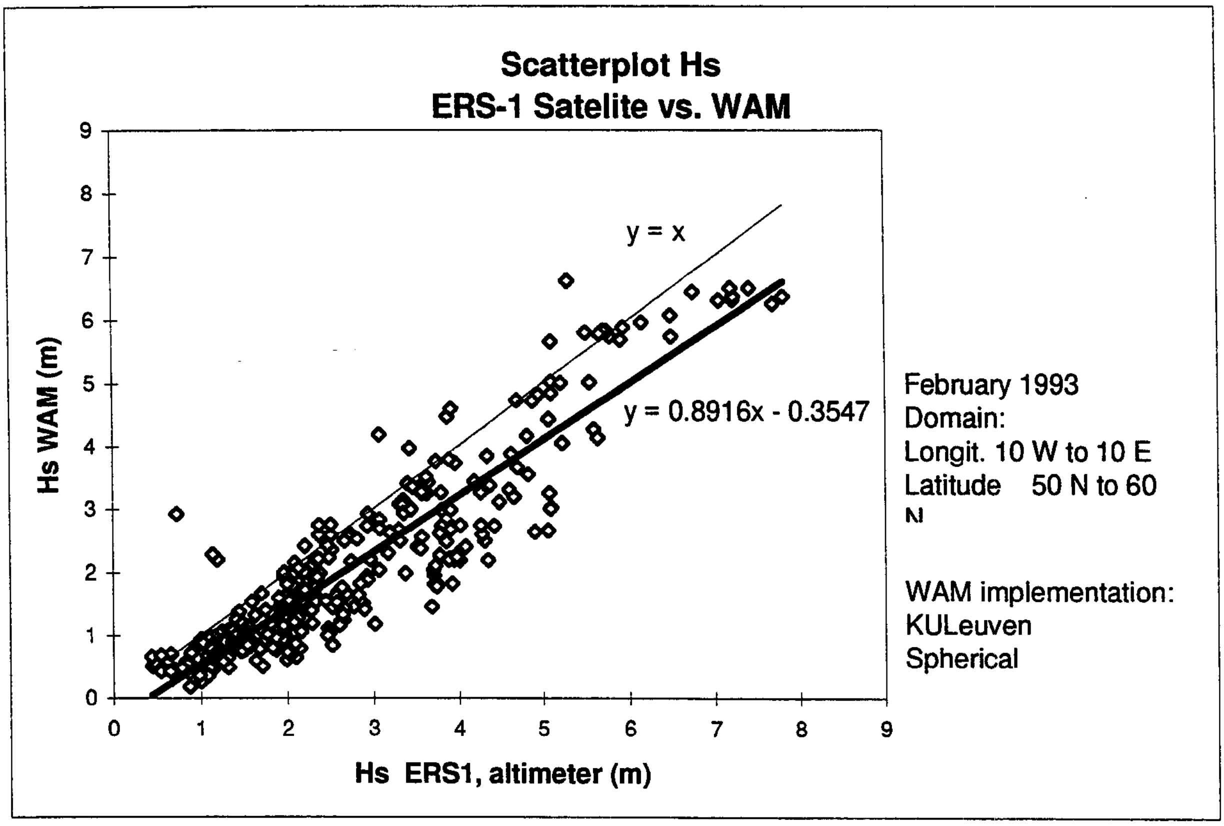
Fig. 10 Scatterplot Hs TOPEX/POSEIDON vs. WAM



February 1993
Domain:
Longitude 3 W to 10 E
Latitude 51 N to 60 N

WAM implementation:
KULeuven
Spherical

Fig. 11 Scatterplot ERS1 vs. WAM



February 1993
Domain:
Longit. 10 W to 10 E
Latitude 50 N to 60 N

WAM implementation:
KULeuven
Spherical

APPENDIX A: STATISTICAL DEFINITIONS

The statistical formulations for the analysis in the present report are taken from Luo (1995). The parameters used and their definitions are described as follows. The X_i and Y_i represent the observation values and the output values from the model, respectively. The number of observed and computed values is denoted by N.

. Mean

$$\bar{X}=\frac{1}{N}\sum X_i \qquad \text{(A-1)}$$

. Bias The difference between the mean of the observations and the mean of the model results.

$$Bias=\bar{X}-\bar{Y} \qquad \text{(A-2)}$$

.RMSE root-mean-square error, it is the root of the squared error between the observations and model results.

$$RMSE=\left(\frac{1}{N}\sum (Y_i-X_i)^2\right)^{1/2} \qquad \text{(A-3)}$$

.S.I. scatter index, it is the ratio of the RMSE and the square root of the product of the mean of the mean of the model and the mean of the observation.

$$S.I.=\frac{RMSE}{\sqrt{\bar{X}\bar{Y}}} \qquad \text{(A-4)}$$

APPENDIX B: DEFINITIONS OF INTEGRATED WAVE PARAMETERS

The momentum m_i of order I, where I is an integer, are difined as

$$m_i = \int\int F(f,\theta) f^i df d\theta \qquad \text{(B-1)}$$

where $F(f, \theta)$ is the two-dimensional wave energy density spectrum, f is the wave frequency and θ is the wave propagation direction. The one-dimesional energy density spectrum $E(f)$ is defined as

$$E(f) = \int F(f,\theta) d\theta \qquad \text{(B-2)}$$

The significant wave height is defined as

$$H_s = 4\sqrt{m_0} \qquad \text{(B-3)}$$

The periods are

$$T_{m1} = m_0/m_1, \quad T_{m2} = \sqrt{m_0/m_2}, \quad T_{mean} = T_{m_{-1}} = m_{-1}/m_0 \qquad \text{(B-4)}$$

The Peakperiod T_P is defined as

$$T_P = f_{max}^{-1} \quad where \quad E(f_{max}) = \max_f [E(f)] \qquad \text{(B-5)}$$

The mean wave direction is given by

$$\bar{\theta} = atan2\ (s_0, c_0), \quad where \quad c_0 = \int\int F(f,\theta)\cos\theta df d\theta, \quad s_0 = \int\int F(f,\theta)\sin\theta df d\theta \qquad \text{(B-6)}$$

and the spread parameter S is given by

$$S = \left(2 - 2\left(\frac{s_0^2 + c_0^2}{m_0^2}\right)^{1/2}\right)^{1/2} \qquad \text{(B-7)}$$

APPENDIX C: SIX MONTHS SIMULATION KULeuven/MMUM

Table C-1 Results of the statistics for significant wave height at stations *auk*, *mpn*, *k13* and *ym6* for the period from October 1992 to March 1993 for both spherical and Cartesian grid runs.

		Hs (spherical grid)			Hs (Cartesian grid)		
		Bias	S.I.	RMSE	Bias	S.I.	RMSE
auk	Oct. 92	0.61	0.43	0.72	0.59	0.42	0.70
	Nov. 92	0.55	0.26	0.67	0.55	0.27	0.68
	Dec. 92	0.53	0.29	0.61	0.50	0.28	0.58
	Jan. 93	0.59	0.22	0.81	0.52	0.21	0.79
	Feb. 93	0.39	0.26	0.58	0.38	0.26	0.59
	March 93	0.40	0.28	0.55	0.33	0.29	0.57
	6 months	0.51	0.28	0.66	0.48	0.27	0.66
mpn	Oct. 92	0.12	0.25	0.31	0.43	0.50	0.52
	Nov. 92	0.06	0.28	0.44	0.47	0.50	0.68
	Dec. 92	-0.04	0.42	0.40	0.21	0.47	0.38
	Jan. 93	-0.19	0.31	0.52	0.32	0.39	0.56
	Feb. 93	0.04	0.19	0.20	0.32	0.56	0.51
	March 93	-0.05	0.21	0.18	0.17	0.37	0.27
	6 months	-0.01	0.30	0.37	0.32	0.48	0.51
k13	Oct. 92	0.47	0.35	0.55	0.49	0.39	0.57
	Nov. 92	0.34	0.24	0.47	0.39	0.26	0.50
	Dec. 92	0.26	0.28	0.38	0.30	0.31	0.41
	Jan. 93	0.19	0.18	0.35	0.26	0.23	0.43
	Feb. 93	0.10	0.22	0.32	0.17	0.25	0.36
	March 93	0.17	0.29	0.36	0.23	0.32	0.39
	6 months	0.27	0.27	0.42	0.32	0.29	0.45
ym6	Oct. 92	0.62	0.48	0.73	0.68	0.54	0.80
	Nov. 92	0.39	0.28	0.54	0.45	0.31	0.58
	Dec. 92	0.17	0.32	0.32	0.22	0.34	0.33
	Jan. 93	0.00	0.22	0.43	0.11	0.22	0.43
	Feb. 93	-0.19	0.42	0.42	-0.15	0.39	0.39
	March 93	-0.06	0.21	0.19	-0.03	0.20	0.18
	6 months	0.13	0.33	0.46	0.19	0.35	0.48
all	**6 months**	0.23	0.30	0.40	0.33	0.35	0.53

Table C-2 Results of the statistics for mean wave period at stations *auk*, *mpn*, *k13* and *ym6* for the period from October 1992 to March 1993 for both spherical and Cartesian grid runs.

		Tm (spherical grid)			Tm (Cartesian grid)		
		Bias	S.I.	RMSE	Bias	S.I.	RMSE
auk	Oct. 92	-0.19	0.10	0.60	-0.24	0.11	0.64
	Nov. 92	-0.49	0.11	0.72	-0.49	0.11	0.72
	Dec. 92	-0.40	0.14	0.84	-0.39	0.15	0.91
	Jan. 93	-0.79	0.14	1.02	-0.88	0.15	1.1
	Feb. 93	-0.49	0.15	0.96	-0.40	0.16	0.97
	March 93	-0.46	0.13	0.76	-0.47	0.13	0.76
	6 months	-0.48	0.13	0.83	-0.48	0.14	0.86
mpn	Oct. 92	-0.67	0.19	0.92	-0.27	0.16	0.76
	Nov. 92	-0.65	0.18	0.91	-0.18	0.14	0.69
	Dec. 92	-0.54	0.21	0.94	-0.03	0.18	0.77
	Jan. 93	-0.91	0.21	1.10	-0.46	0.22	1.12
	Feb. 93	-0.98	0.26	1.31	-0.59	0.23	1.09
	March 93	-0.77	0.24	1.12	-0.37	0.20	0.87
	6 months	-0.75	0.22	1.06	-0.31	0.19	0.90
k13	Oct. 92	-0.38	0.12	0.62	0.49	0.39	0.57
	Nov. 92	-0.58	0.14	0.77	0.39	0.26	0.50
	Dec. 92	-0.46	0.16	0.77	0.30	0.31	0.41
	Jan. 93	-0.59	0.16	0.82	0.26	0.23	0.43
	Feb. 93	-0.70	0.19	0.73	0.17	0.25	0.36
	March 93	-0.58	0.17	0.86	0.23	0.32	0.39
	6 months	-0.54	0.16	0.81	0.32	0.29	0.45
ym6	Oct. 92	-0.41	0.13	0.65	-0.42	0.14	0.73
	Nov. 92	-0.54	0.15	0.81	-0.53	0.15	0.82
	Dec. 92	-0.38	0.17	0.77	-0.32	0.18	0.82
	Jan. 93	0.80	0.18	0.99	-0.61	0.17	0.91
	Feb. 93	-0.93	0.25	1.23	-0.91	0.25	1.25
	March 93	-0.55	0.20	0.93	-0.53	0.19	0.92
	6 months	-0.62	0.18	0.92	-0.56	0.18	0.93
all	**6 months**	-0.60	0.09	0.91	-0.26	0.20	0.79

Displayed in Figs. C-1(a-f) to C-8(a-f) are the plots of the significant wave height and mean wave period against buoy data for the six month model results of KULeuven/MUMM at stations *auk*, *mpn*, *k13* and *ym6*. For Feburary 1993 at each station, WASA data were also included.

Fig. C-1a

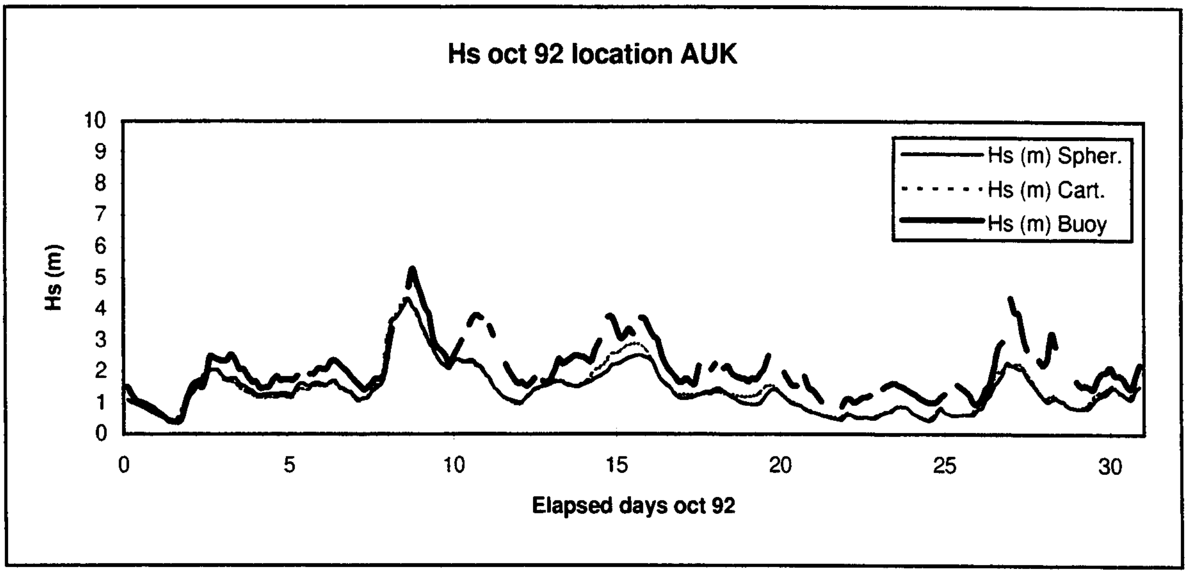


Fig. C-1b

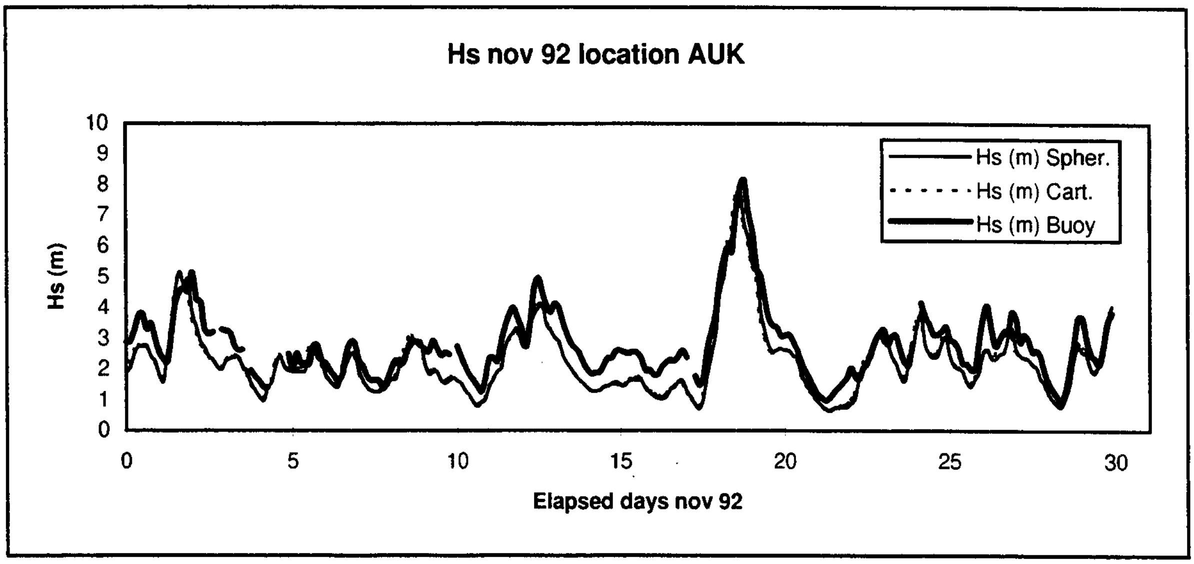


Fig. C-1c

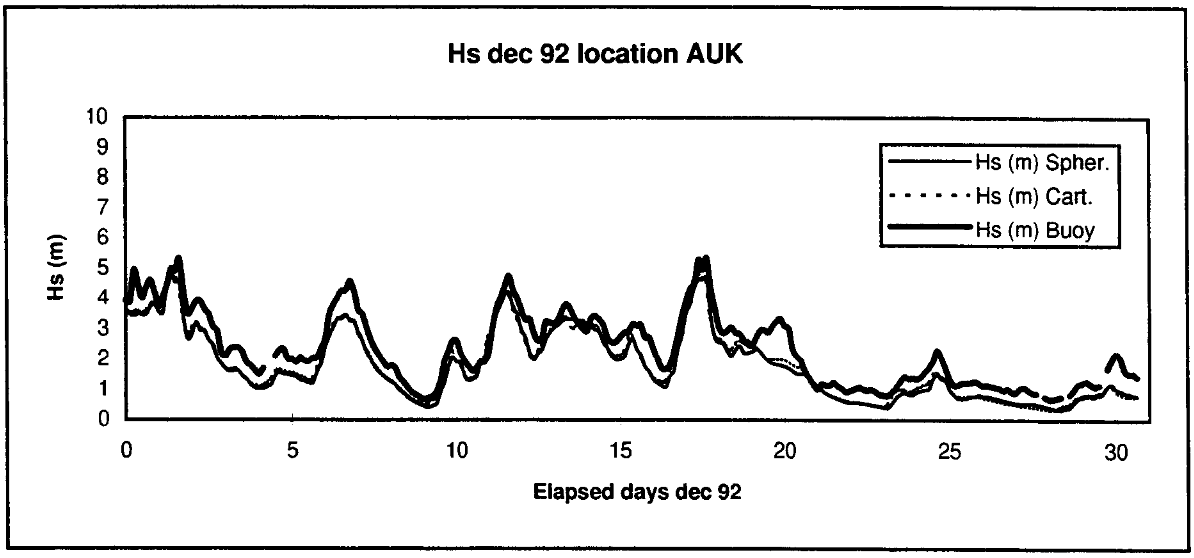


Fig. C-1d

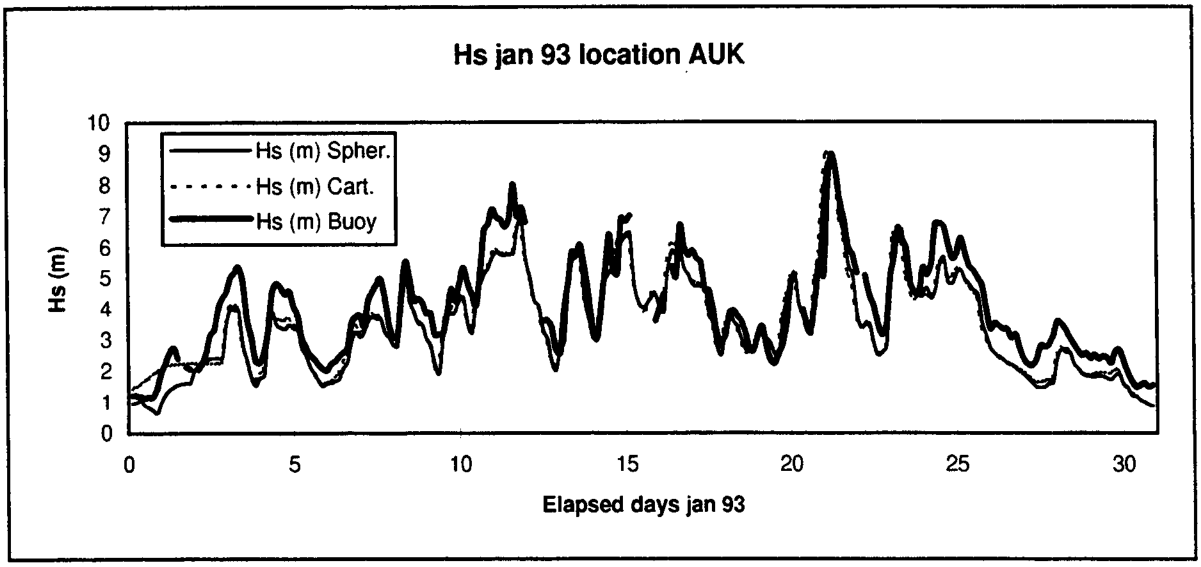


Fig. C-1e

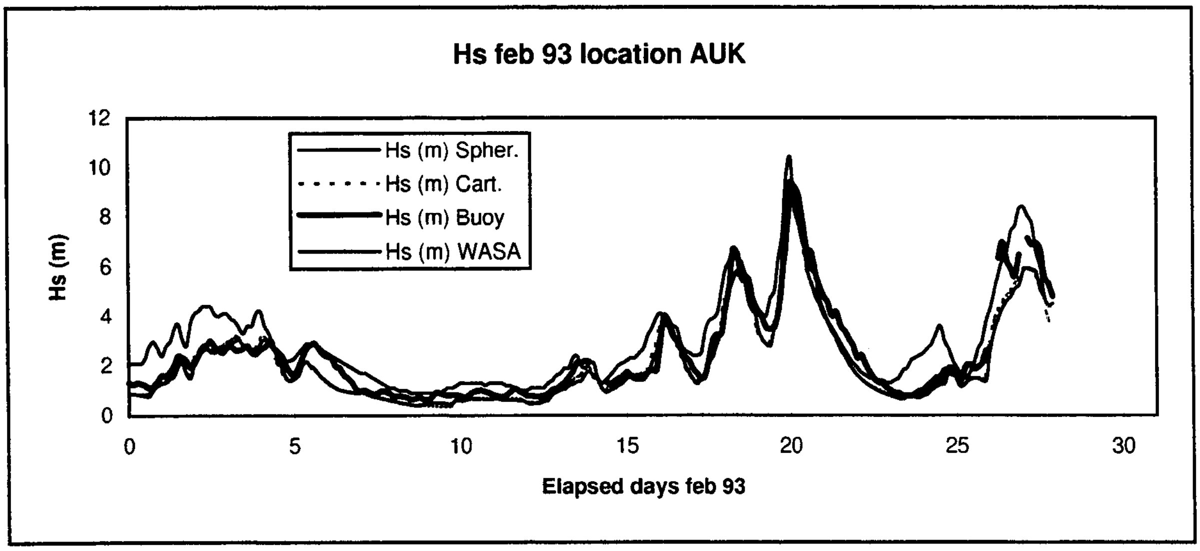


Fig. C-1f

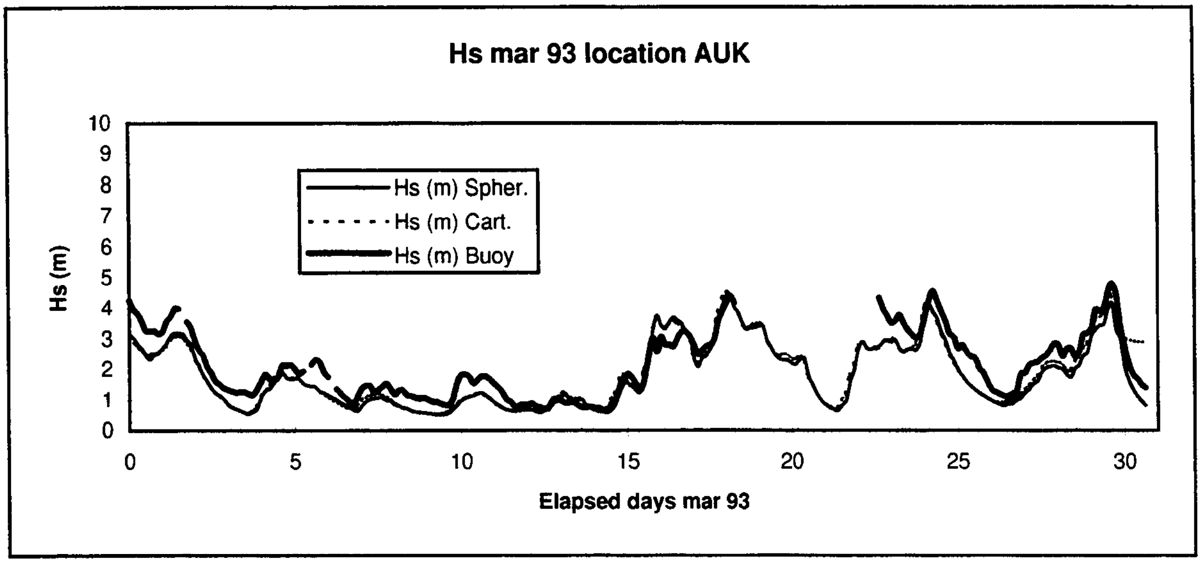


Fig. C-2a

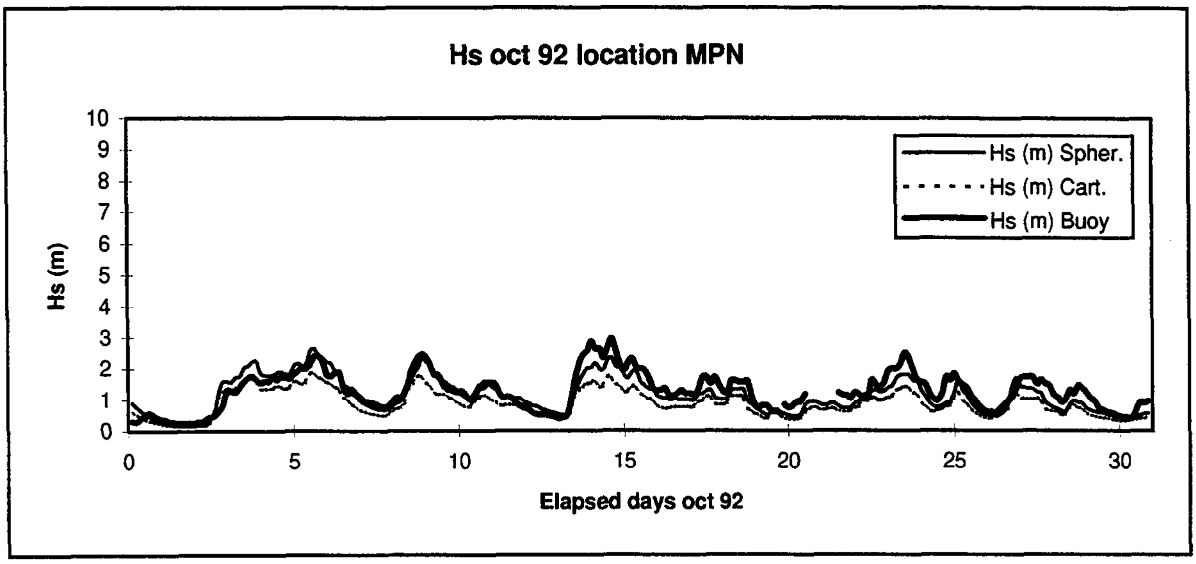


Fig. C-2b

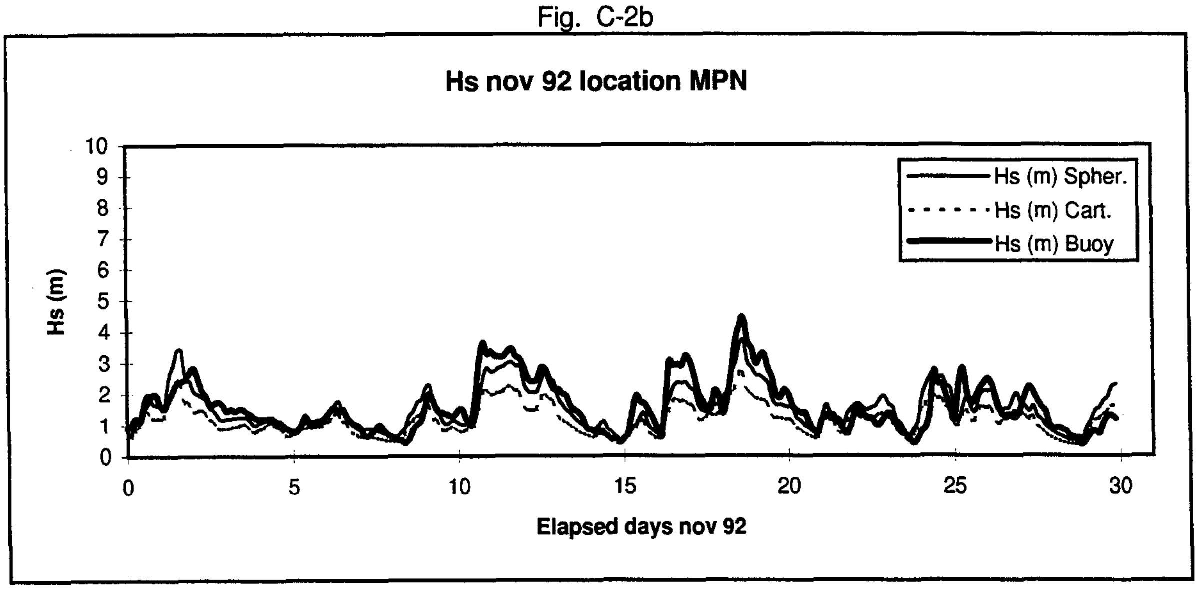


Fig. C-2c

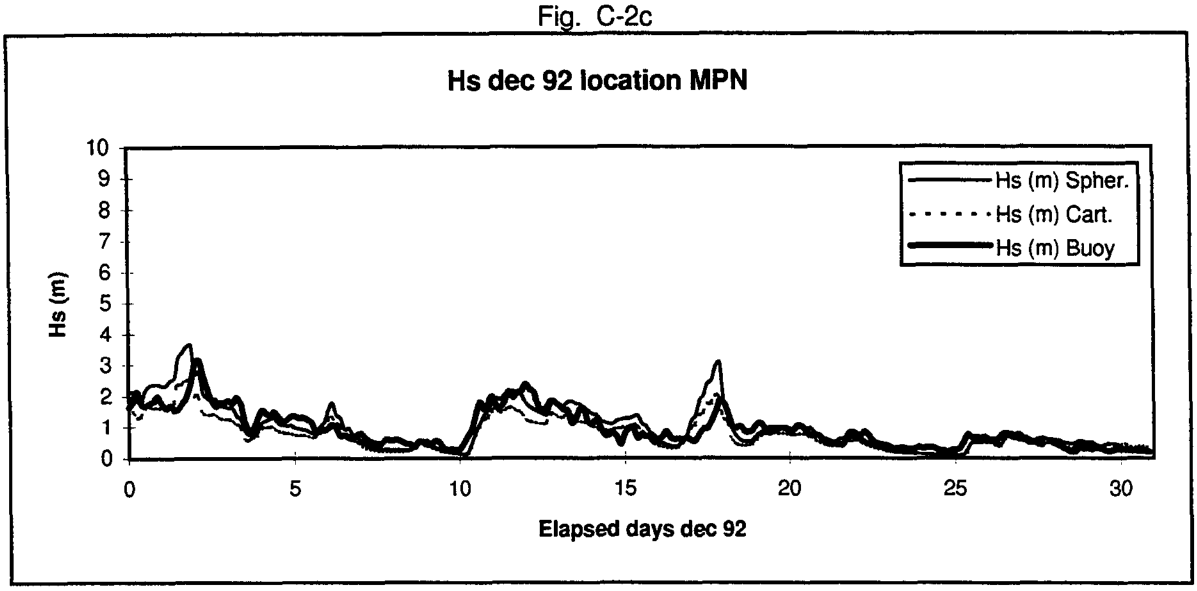


Fig. C-2d

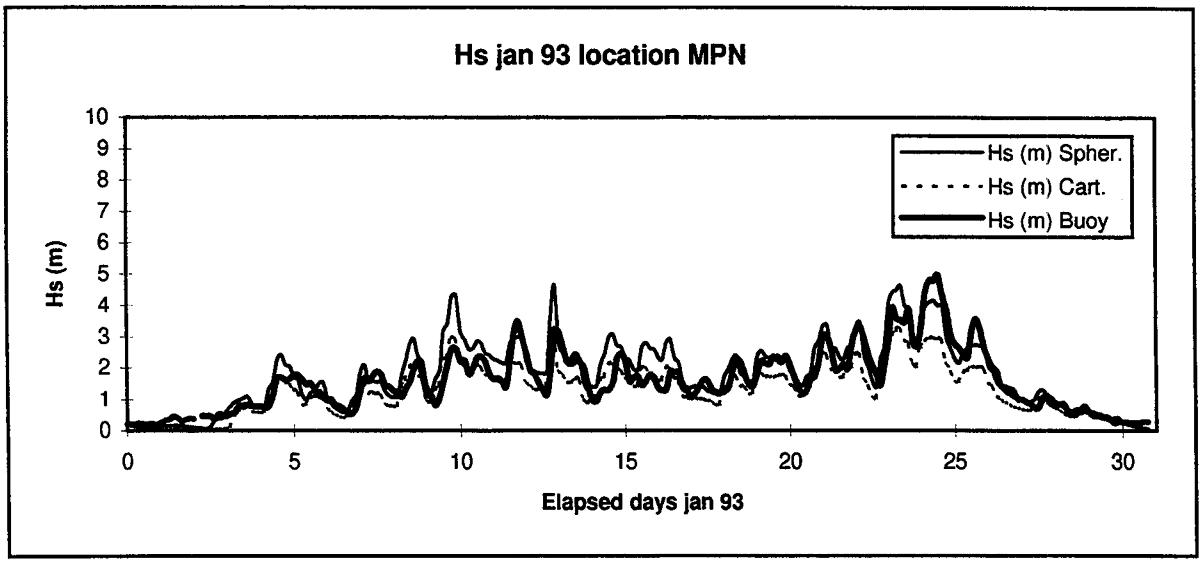


Fig. C-2e

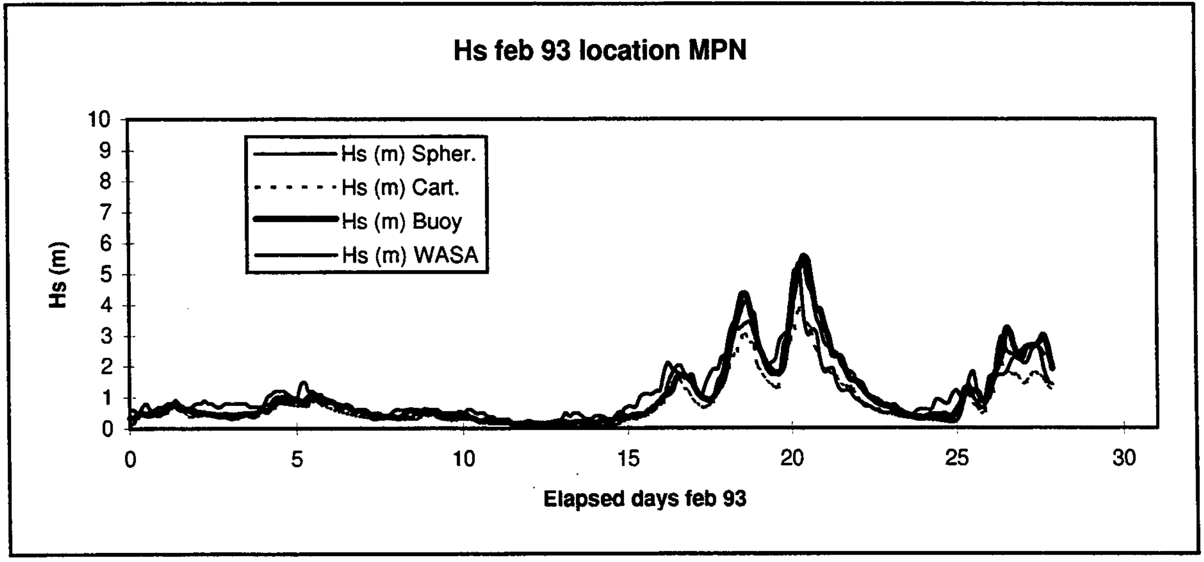


Fig. C-2f

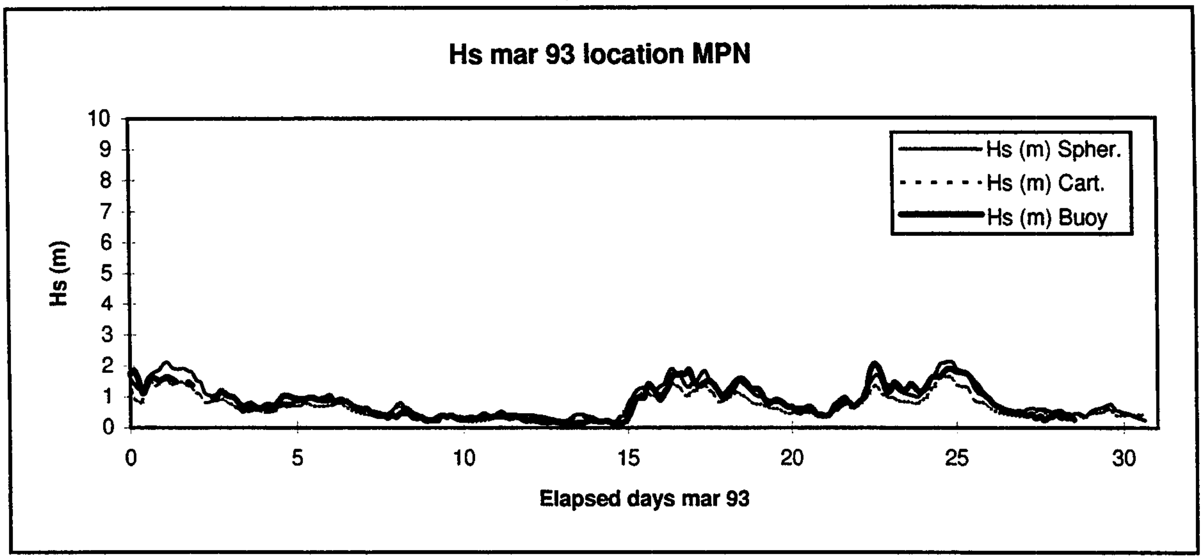


Fig. C-3a

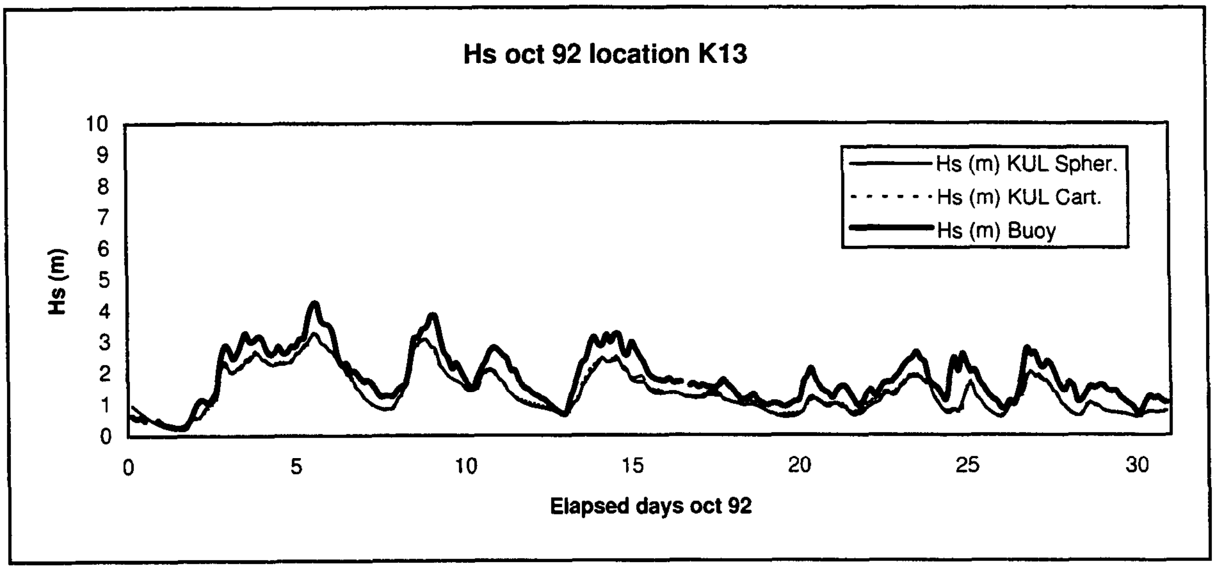


Fig. C-3b

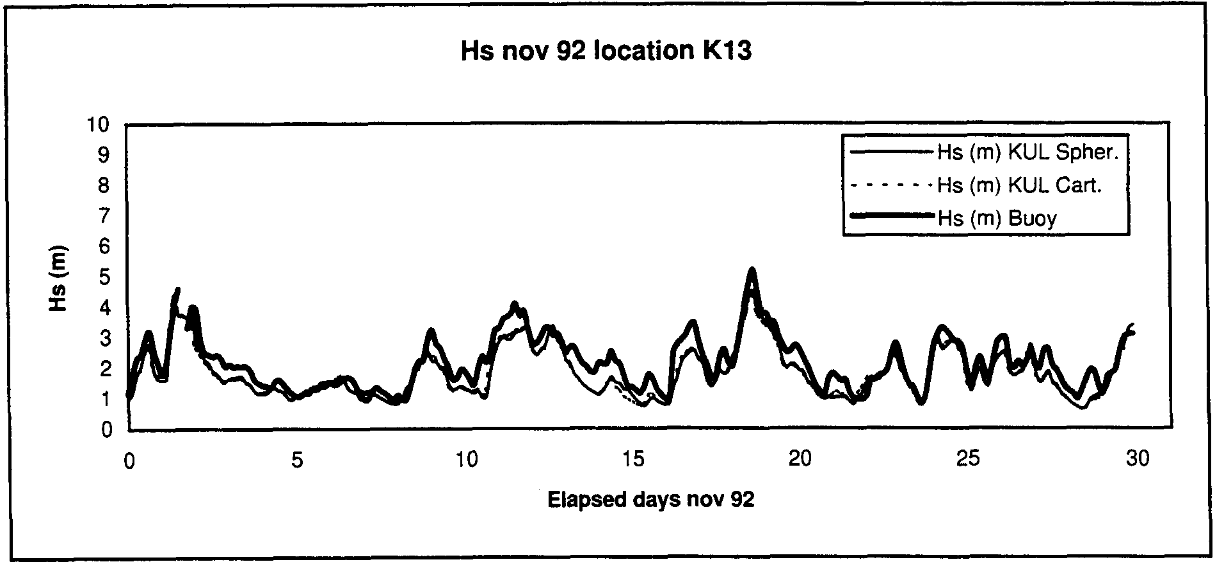


Fig. C-3c

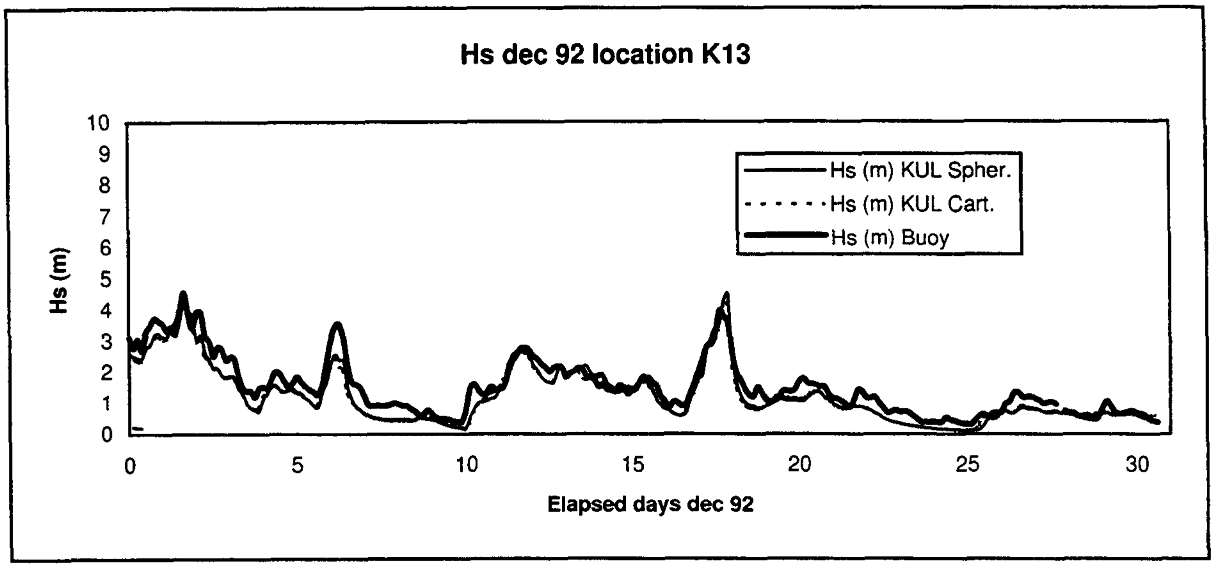


Fig. C-3d

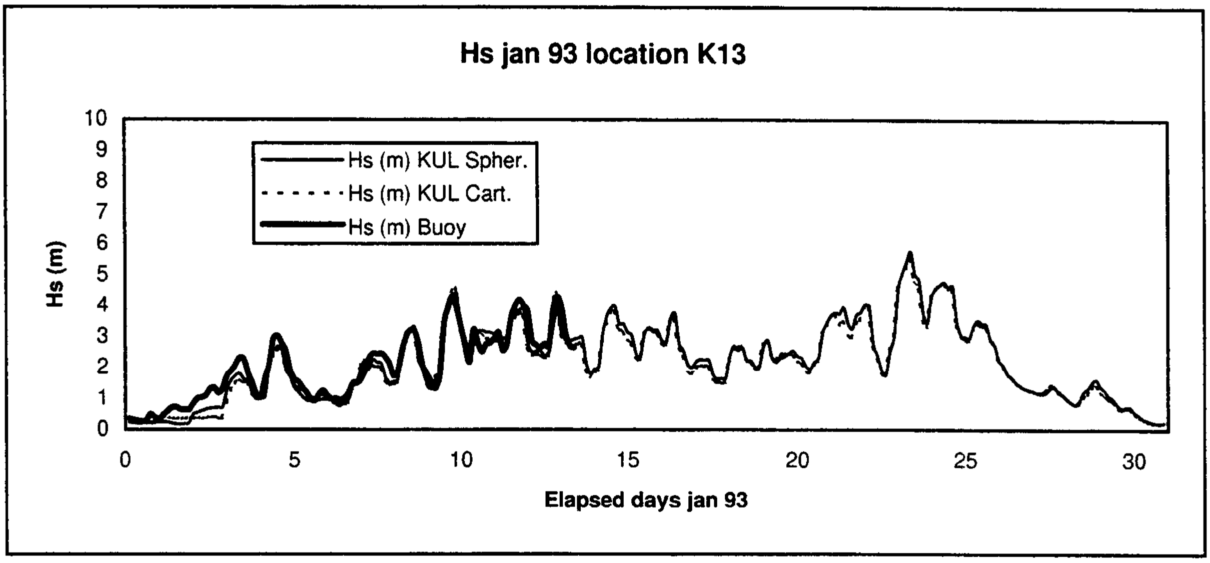

Hs jan 93 location K13

Fig. C-3e

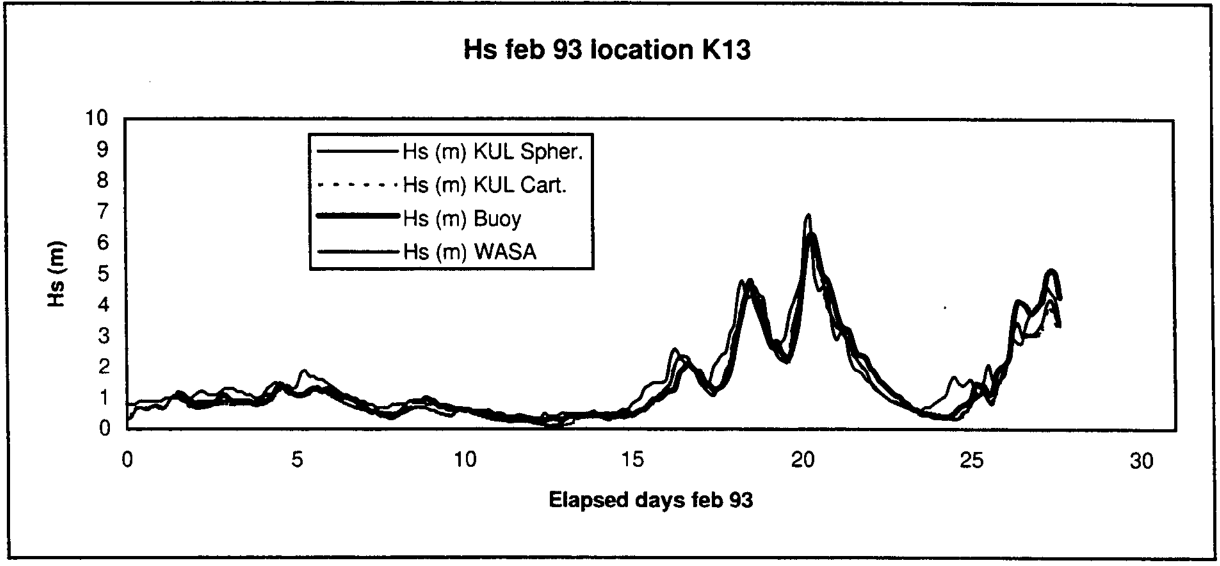

Hs feb 93 location K13

Fig. C-3f

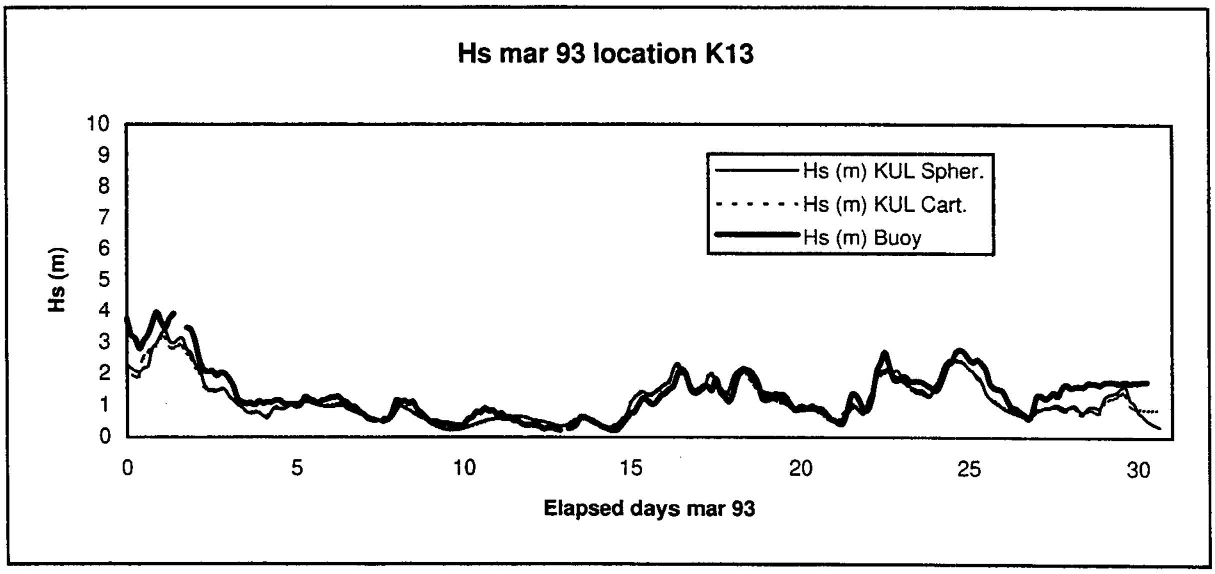

Hs mar 93 location K13

Fig. C-4a

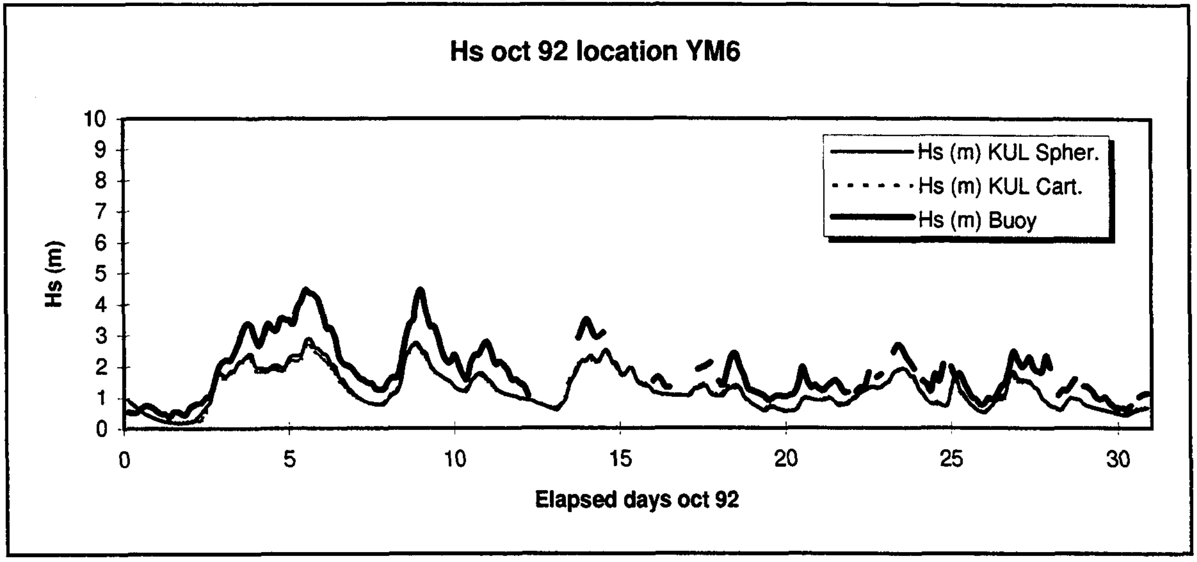


Fig. C-4b

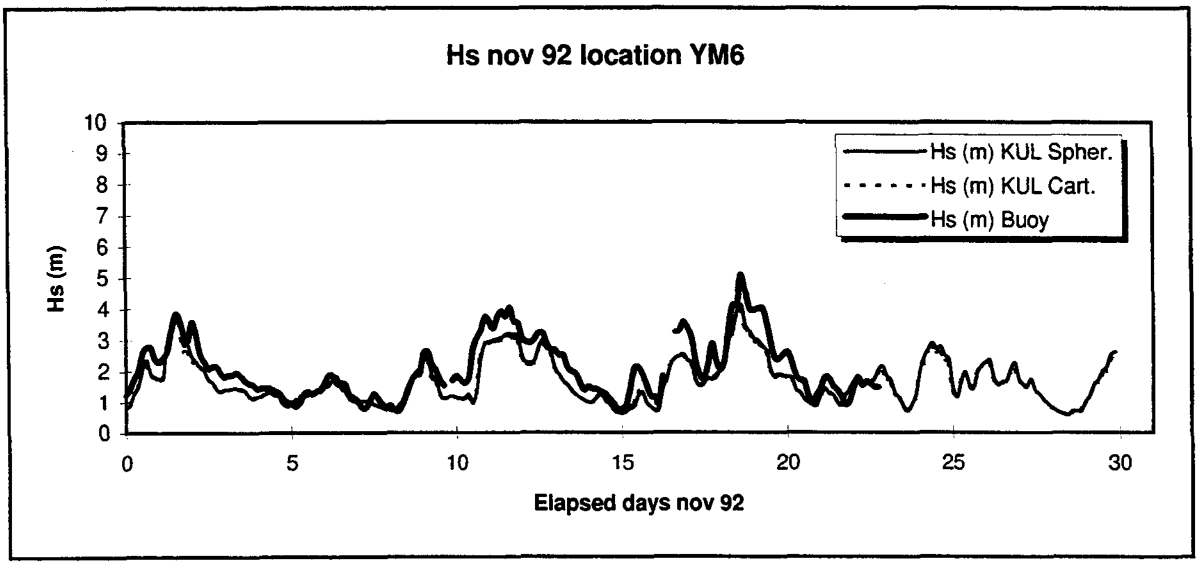


Fig. C-4c

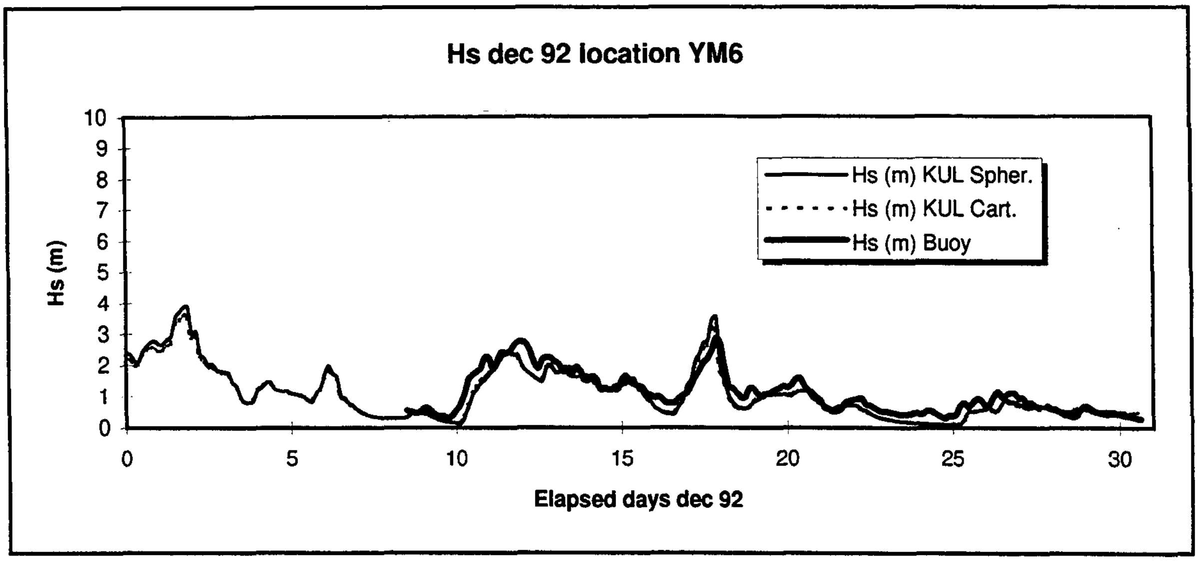


Fig. C-4d

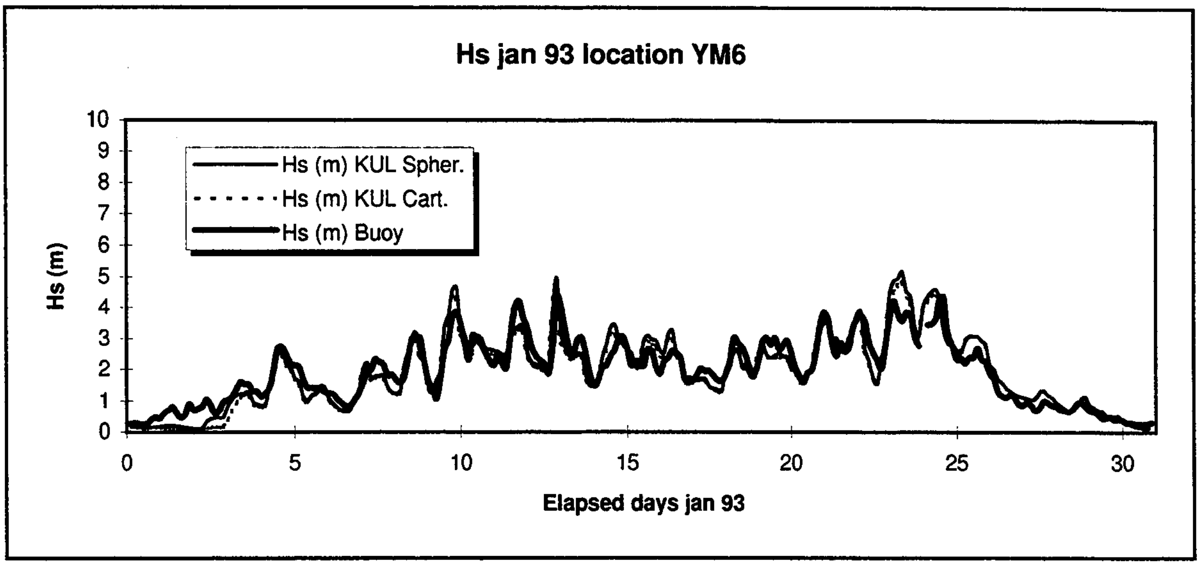


Fig. C-4e

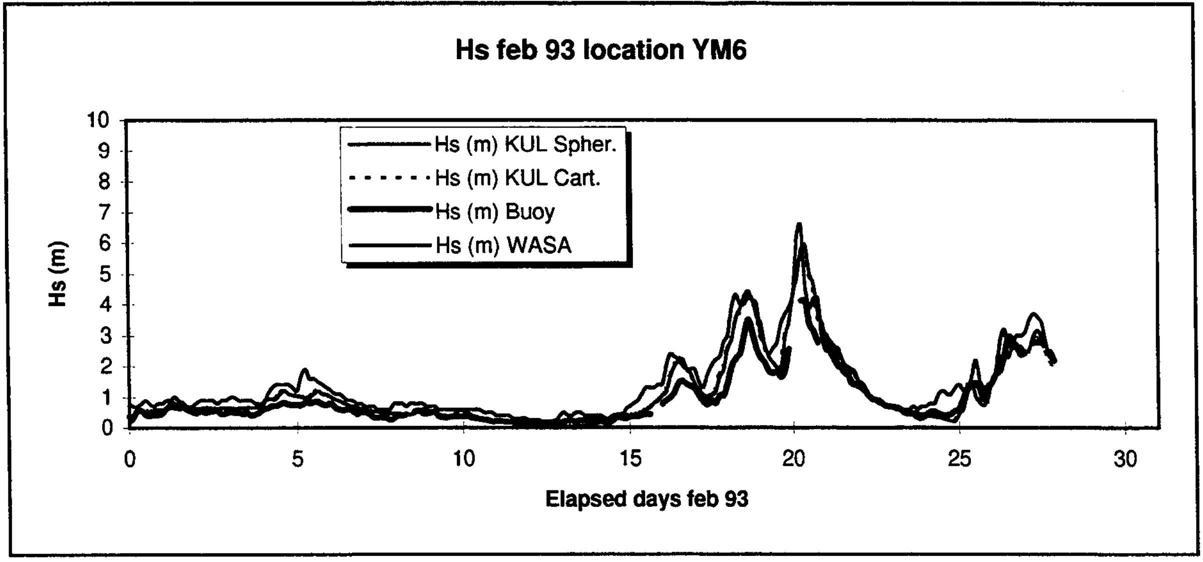


Fig. C-4f

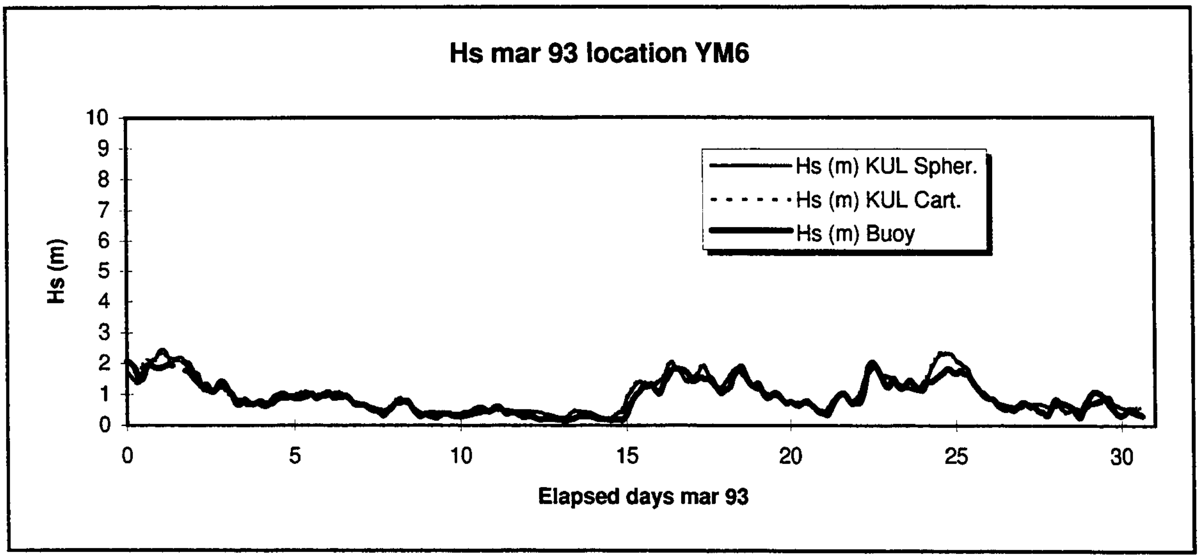


Fig. C-5a

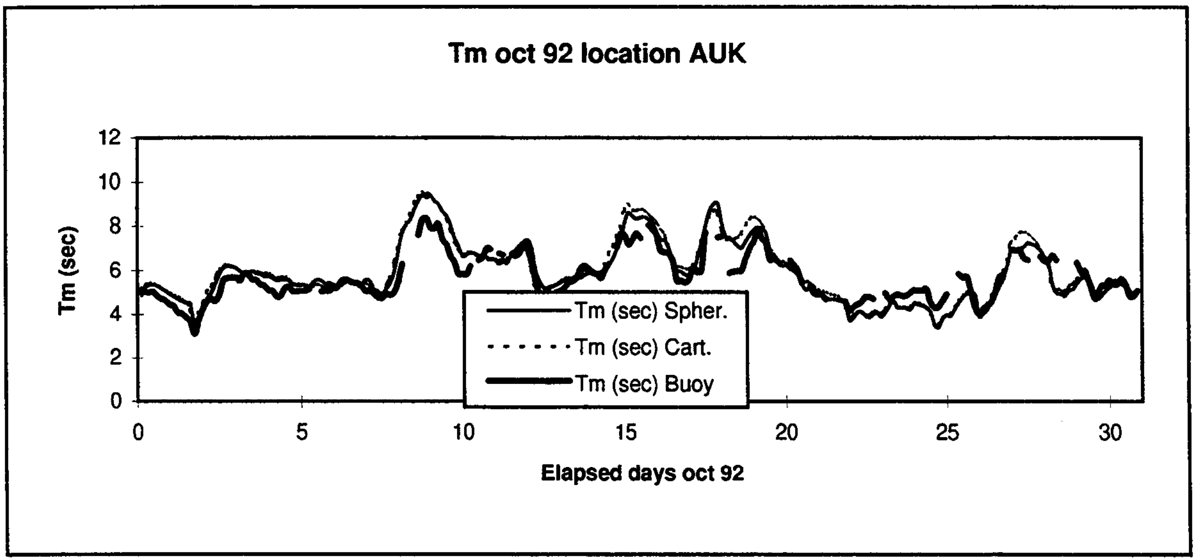


Fig. C-5b

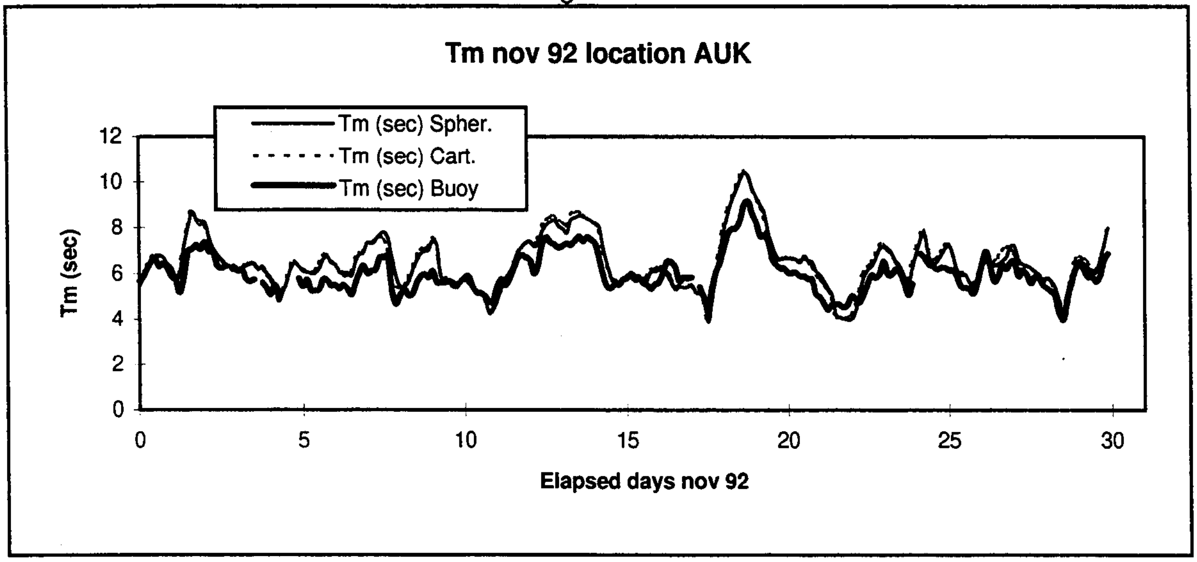


Fig. C-5c

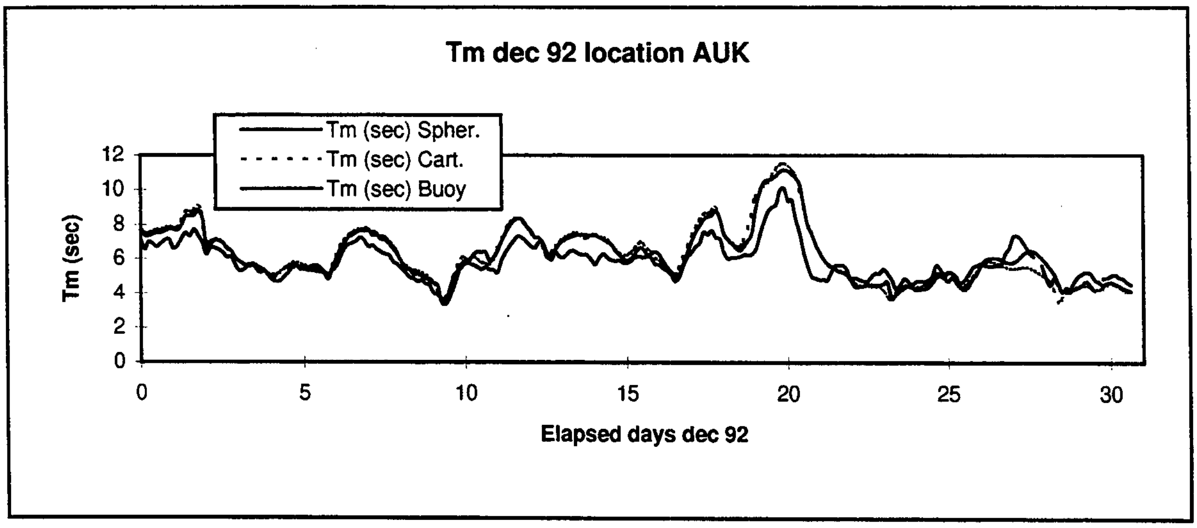


Fig. C-5d

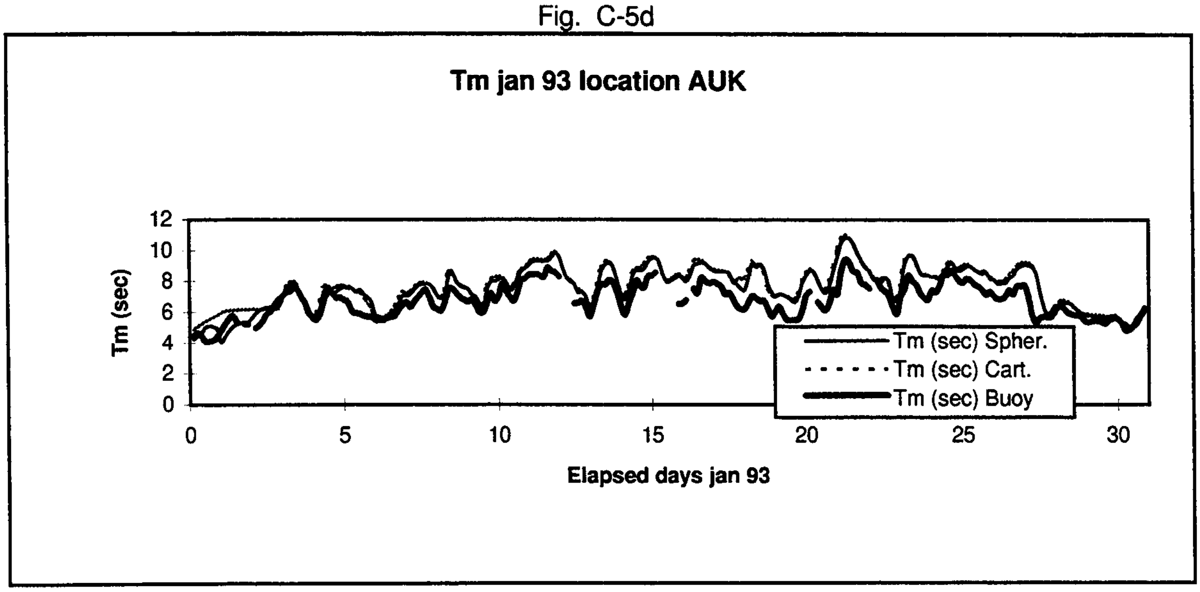


Fig. C-5e

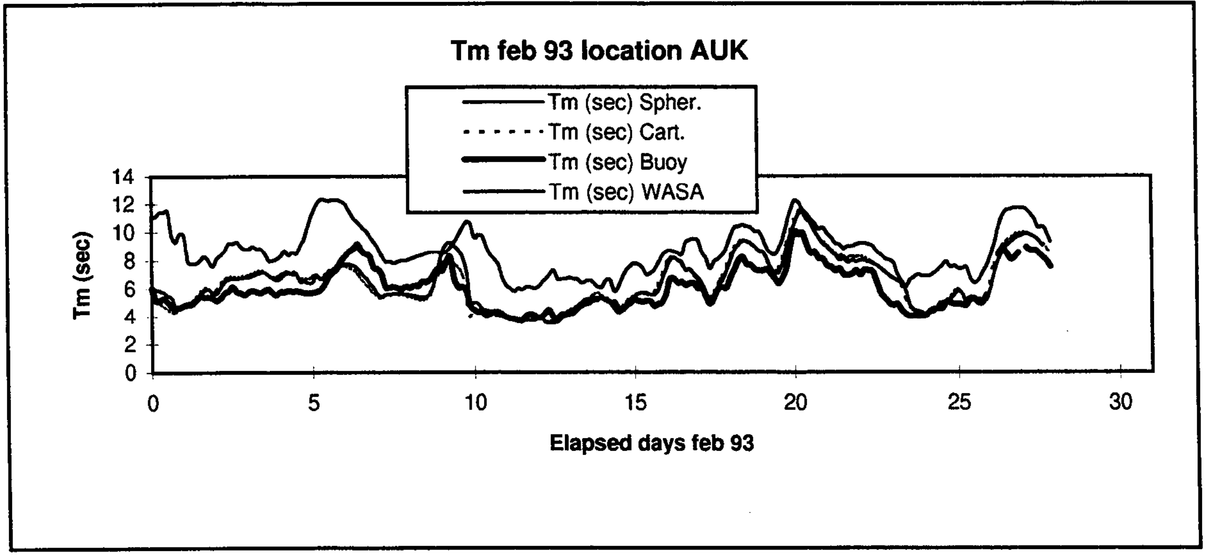


Fig. C-5f

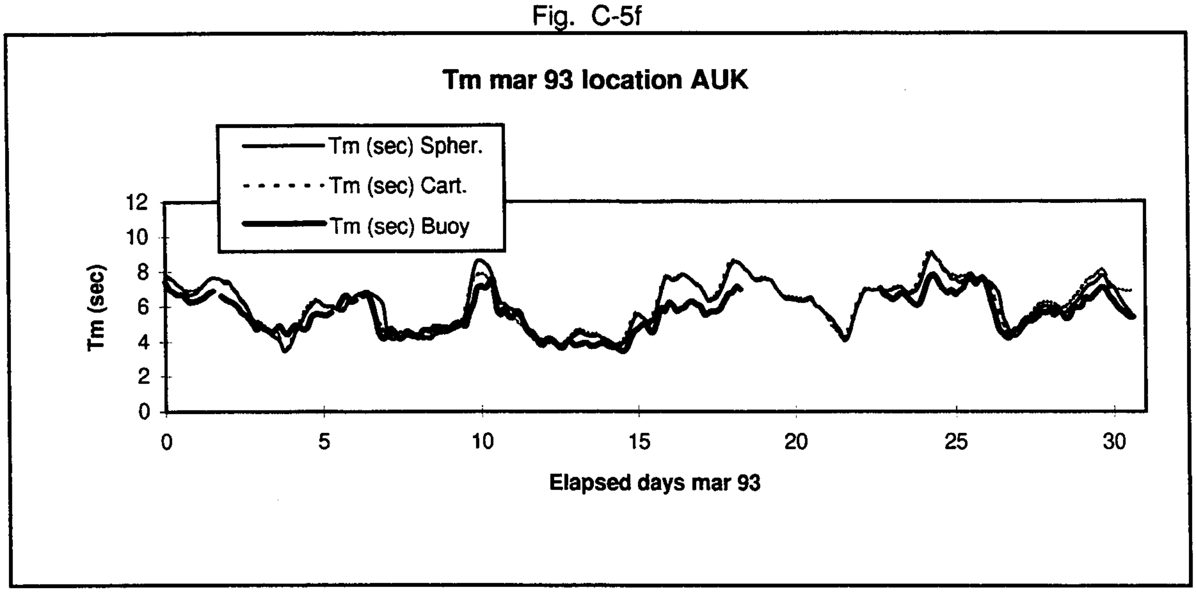


Fig. C-6a

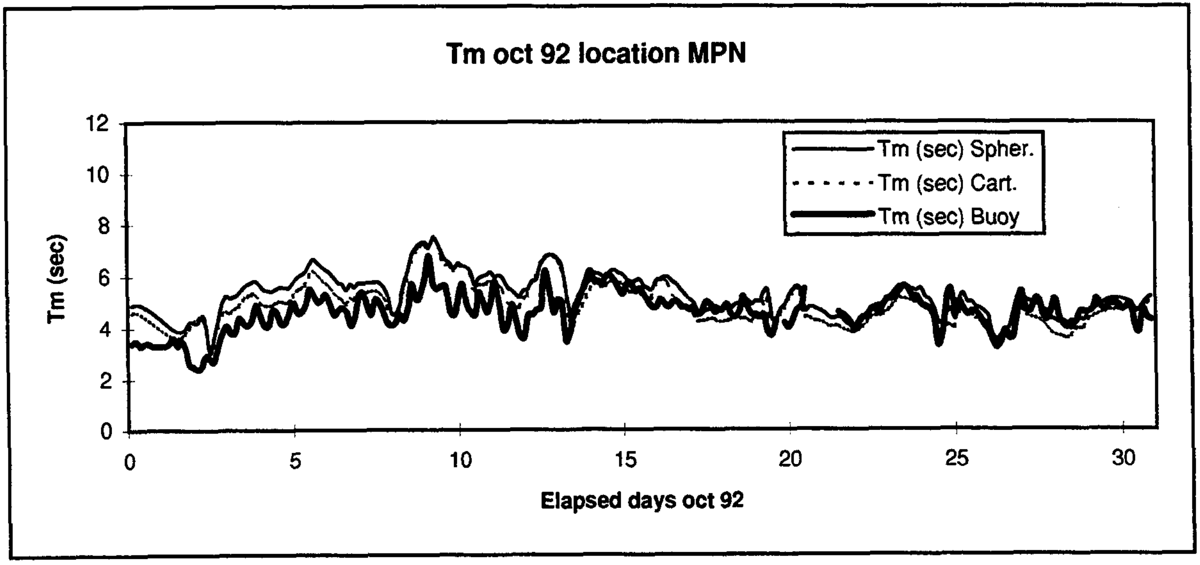


Fig. C-6b

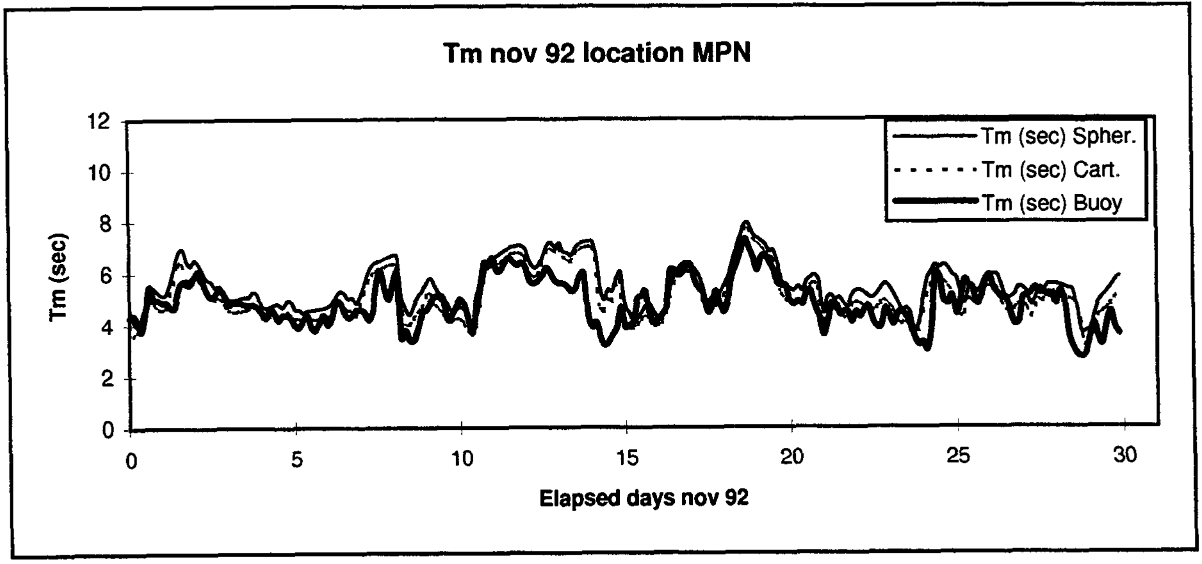


Fig. C-6c

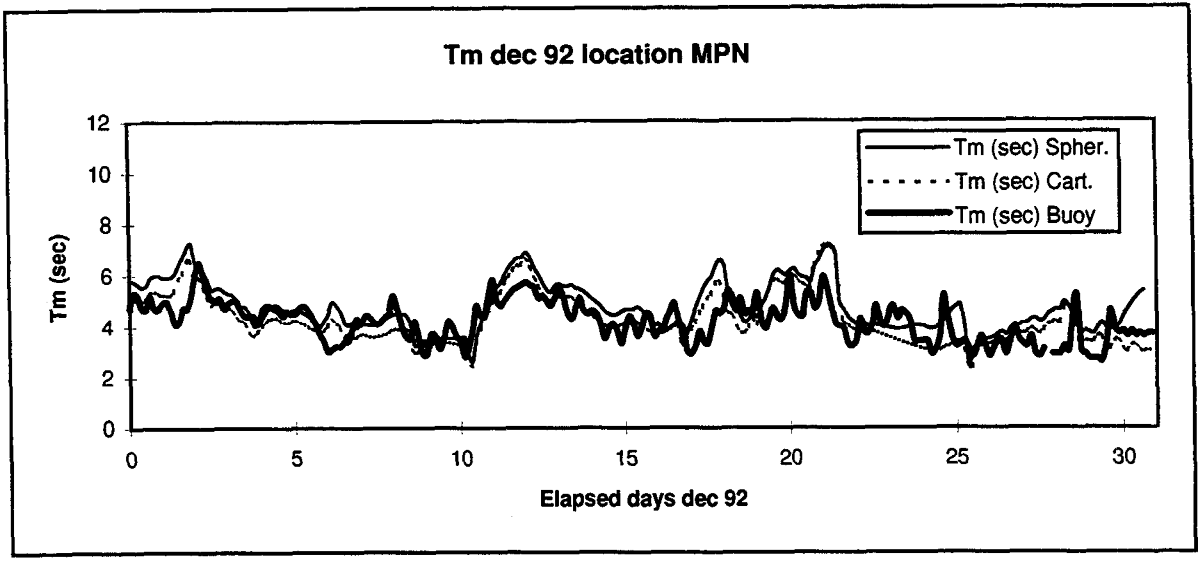


Fig. C-6d

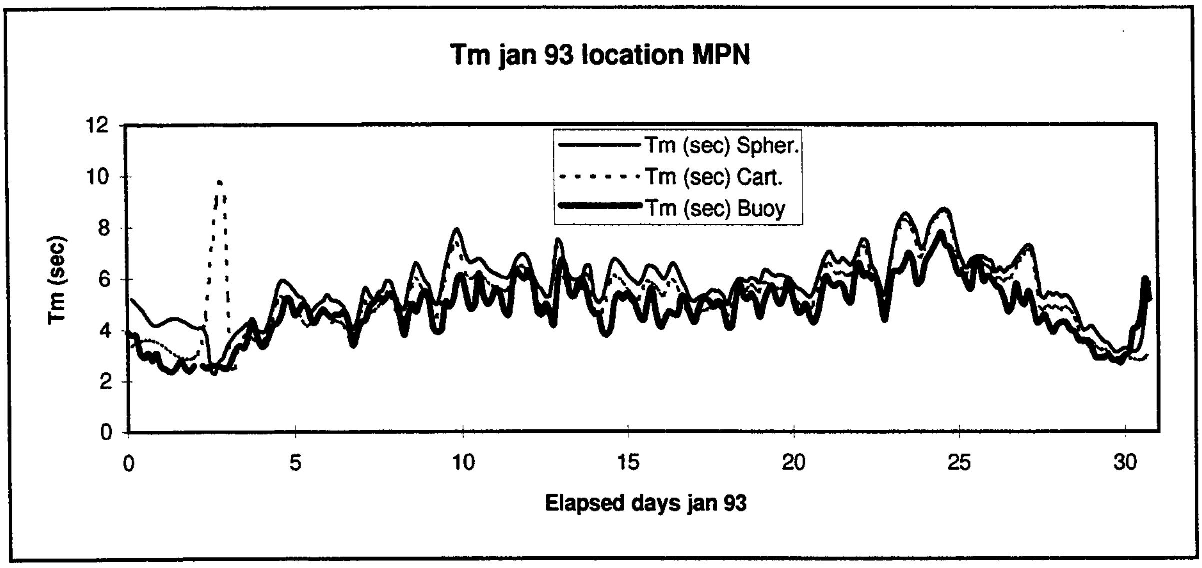


Fig. C-6e

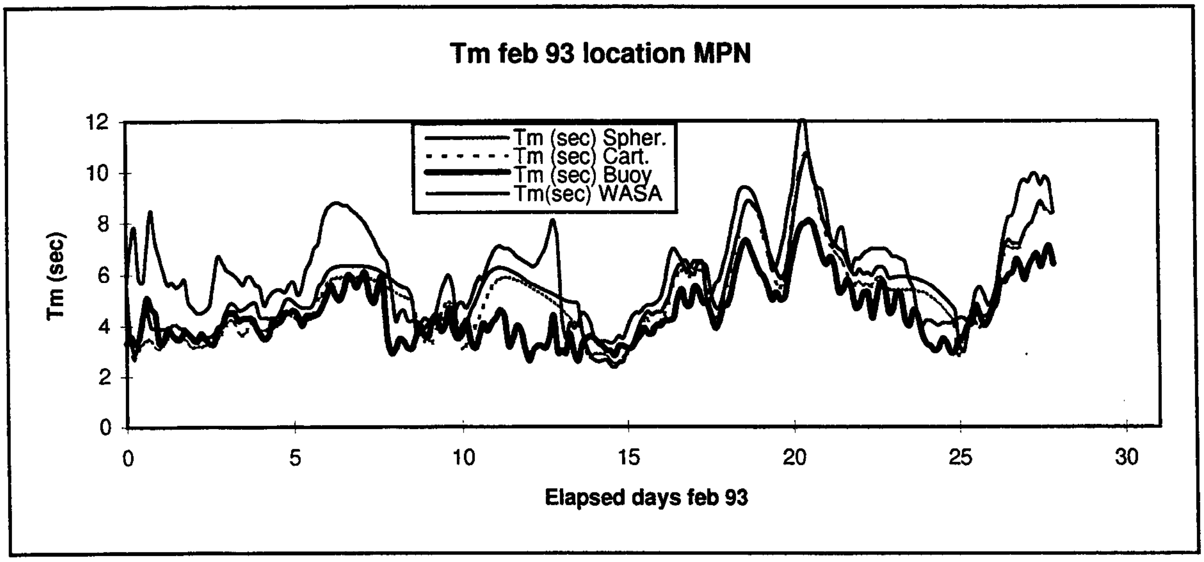


Fig. C-6f

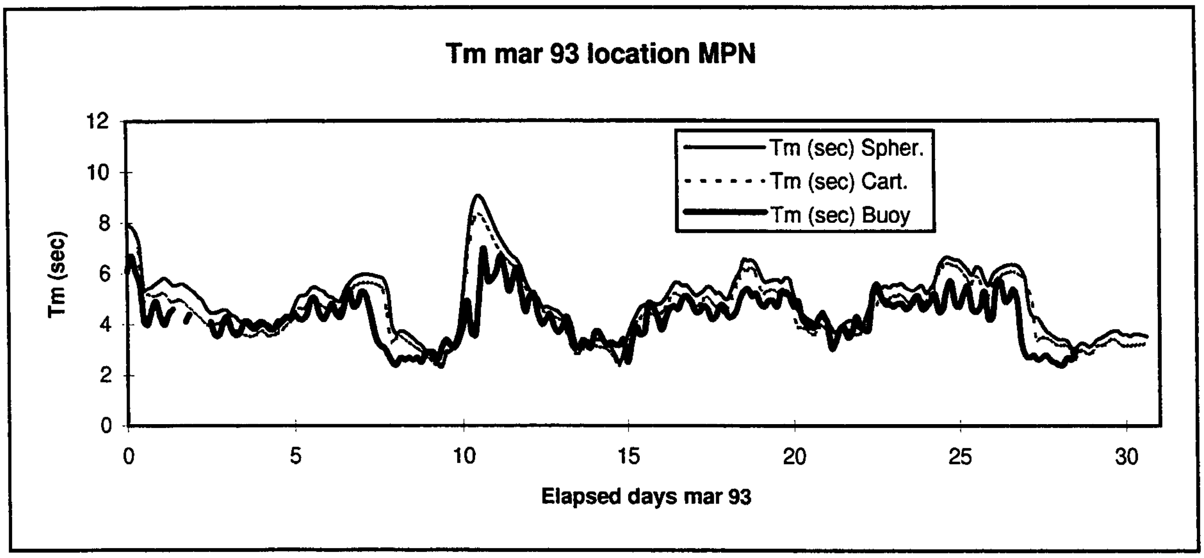
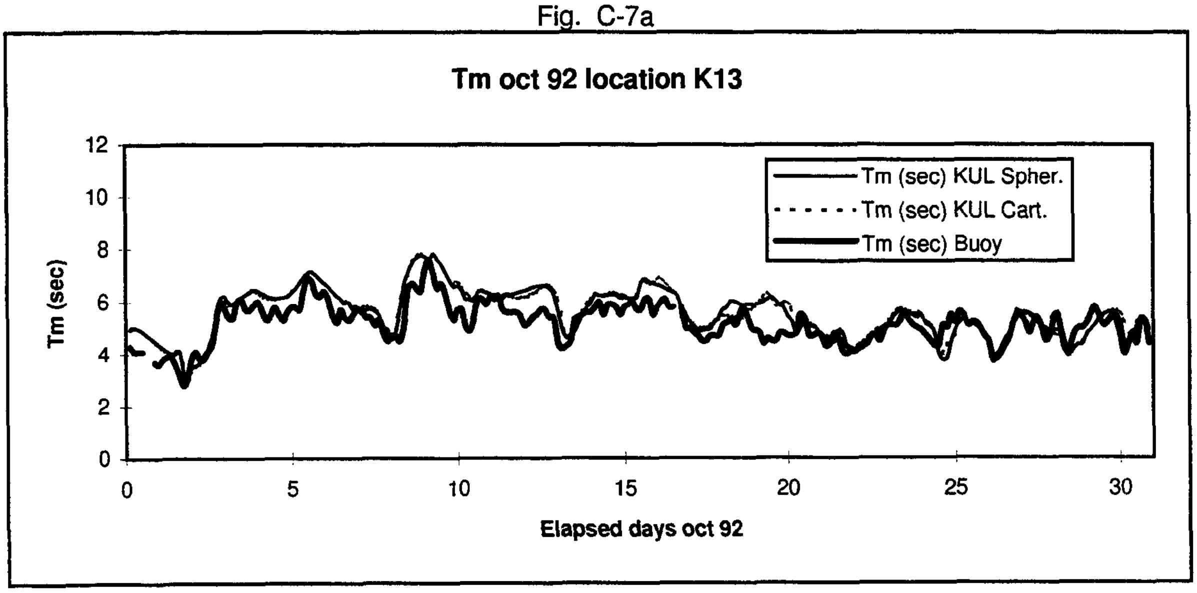
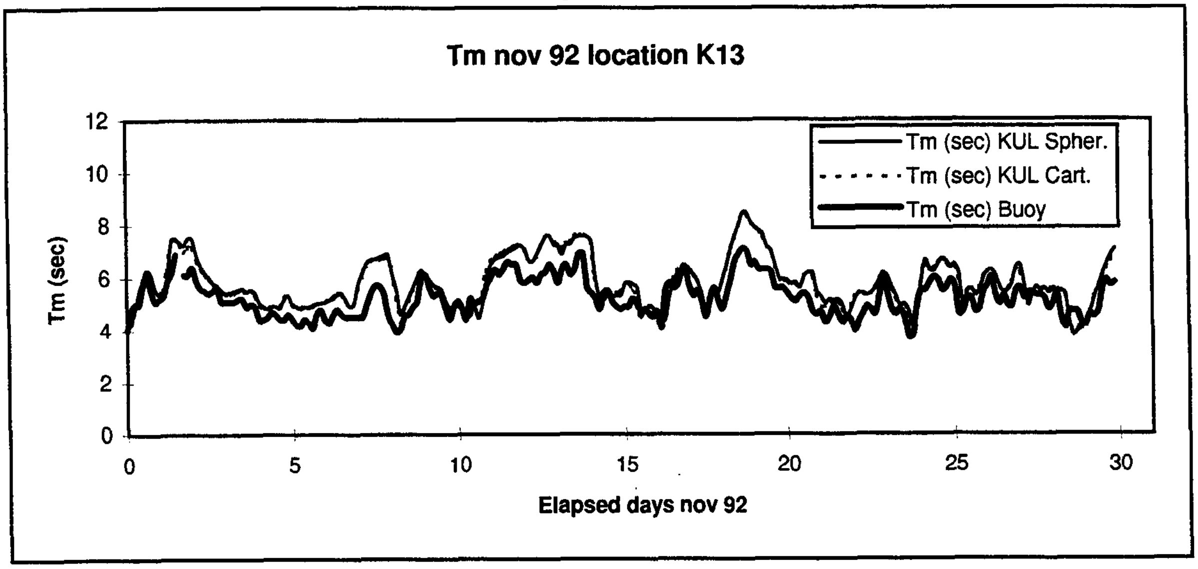


Fig. C-7a



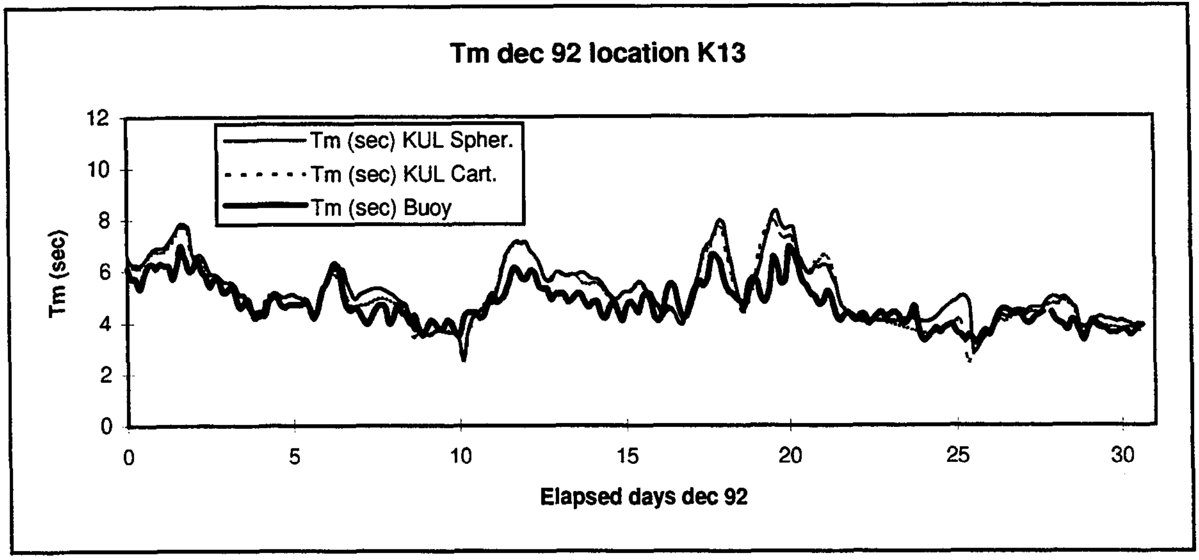
Tm oct 92 location K13

Fig. C-7b



Tm nov 92 location K13

Fig. C-7c



Tm dec 92 location K13

Fig. C-7d

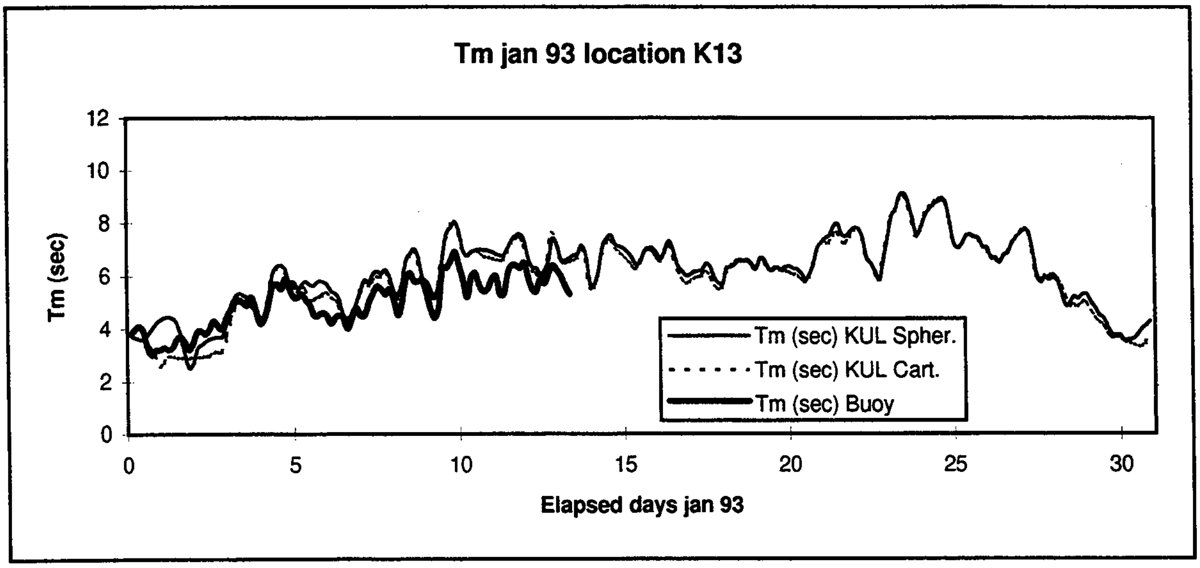


Fig. C-7e

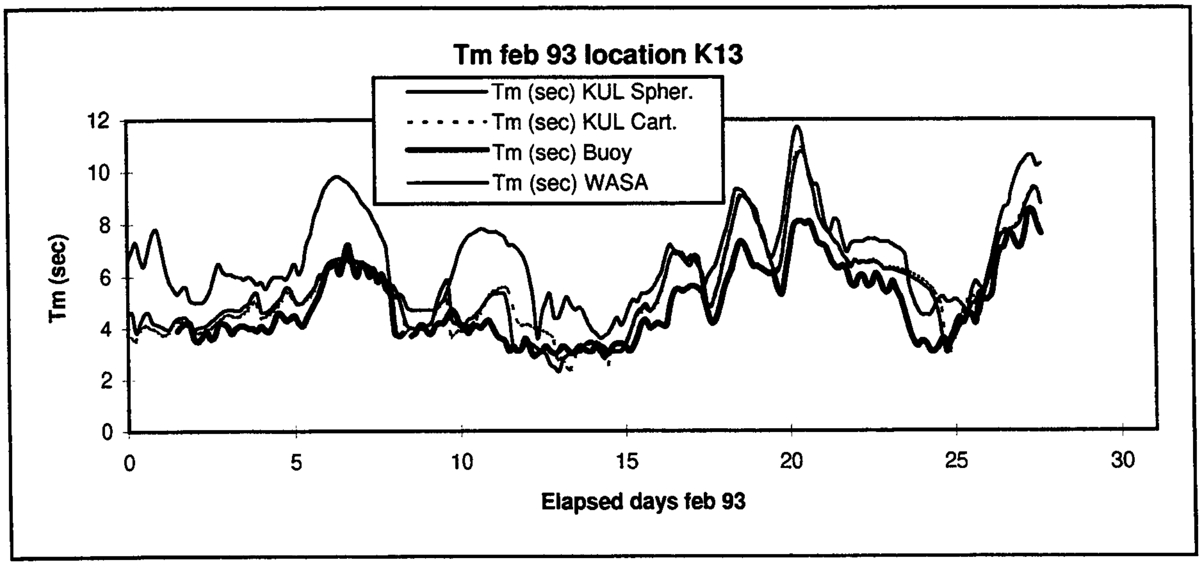


Fig. C-7f

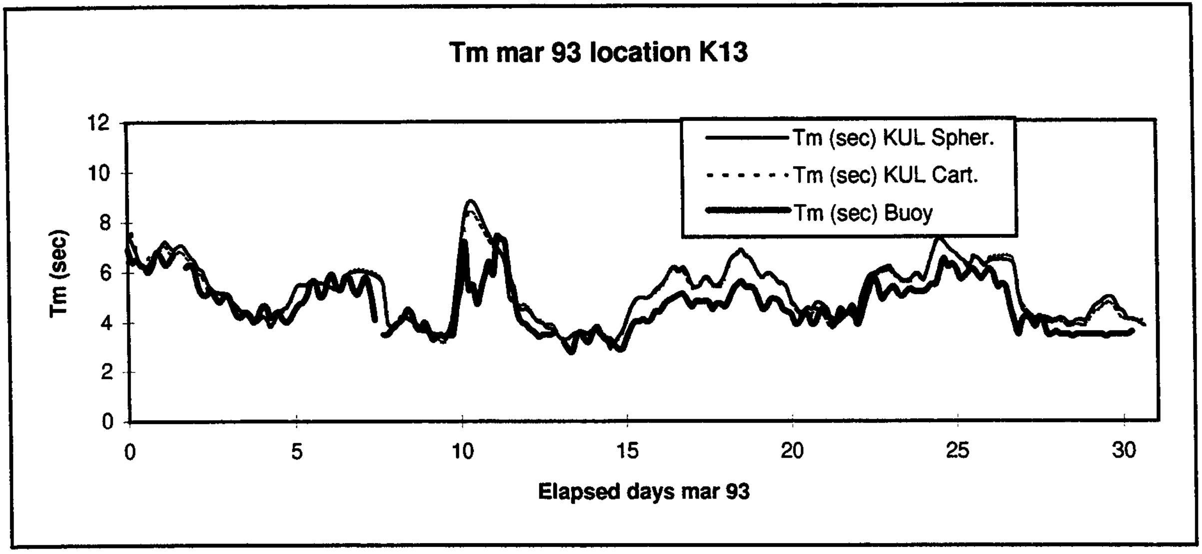


Fig. C-8a

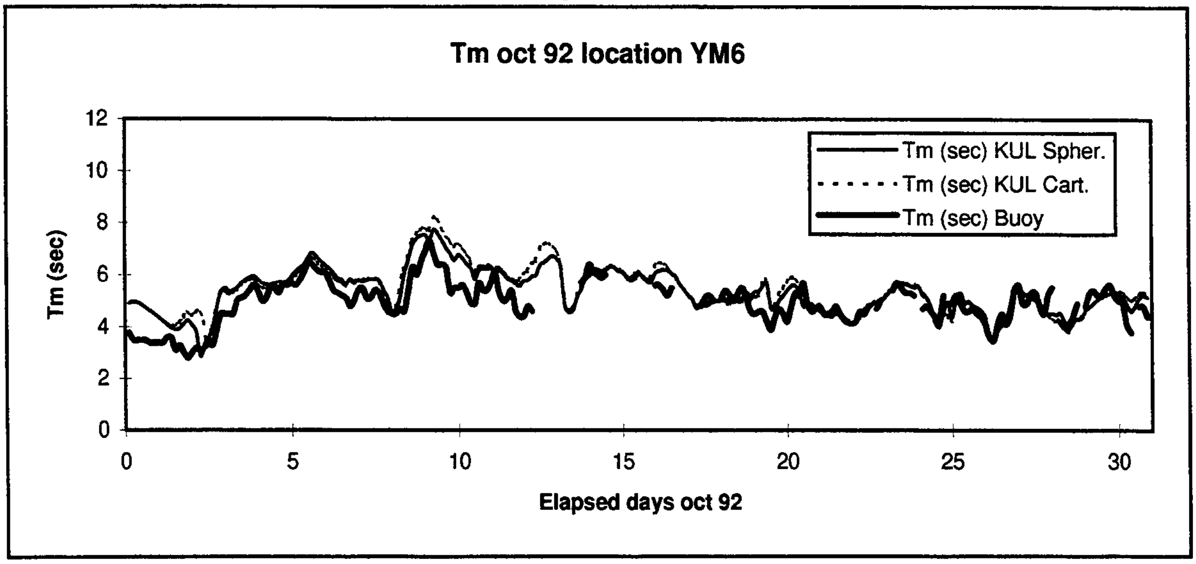


Fig. C-8b

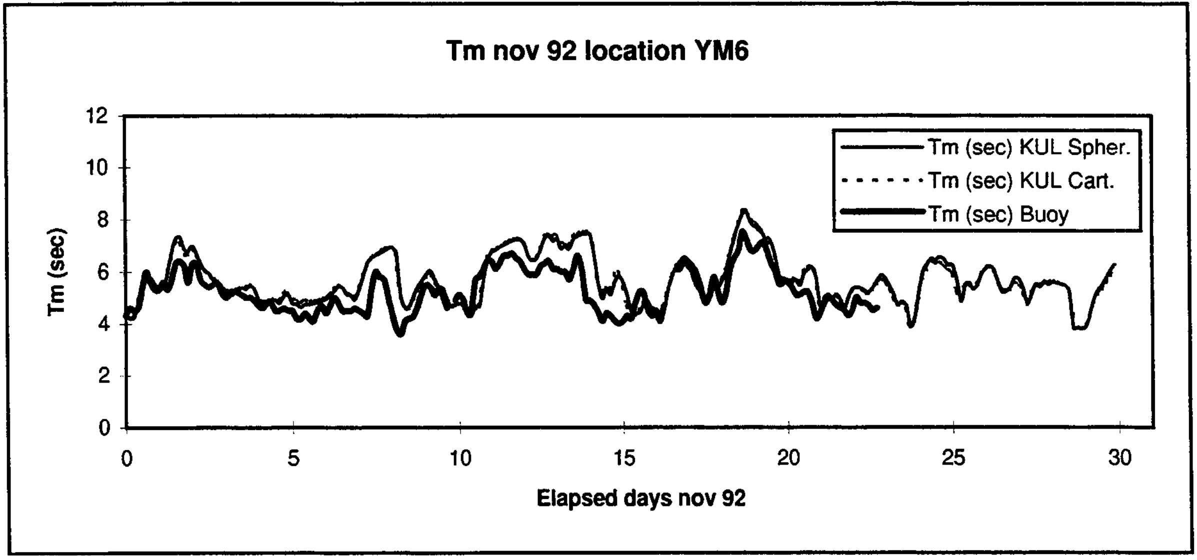


Fig. C-8c

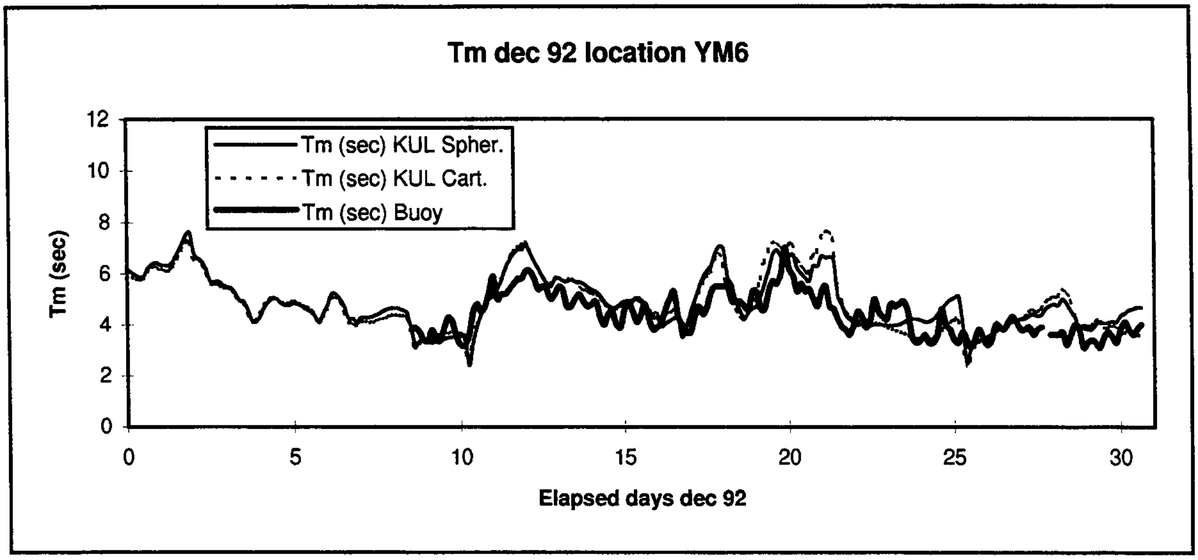
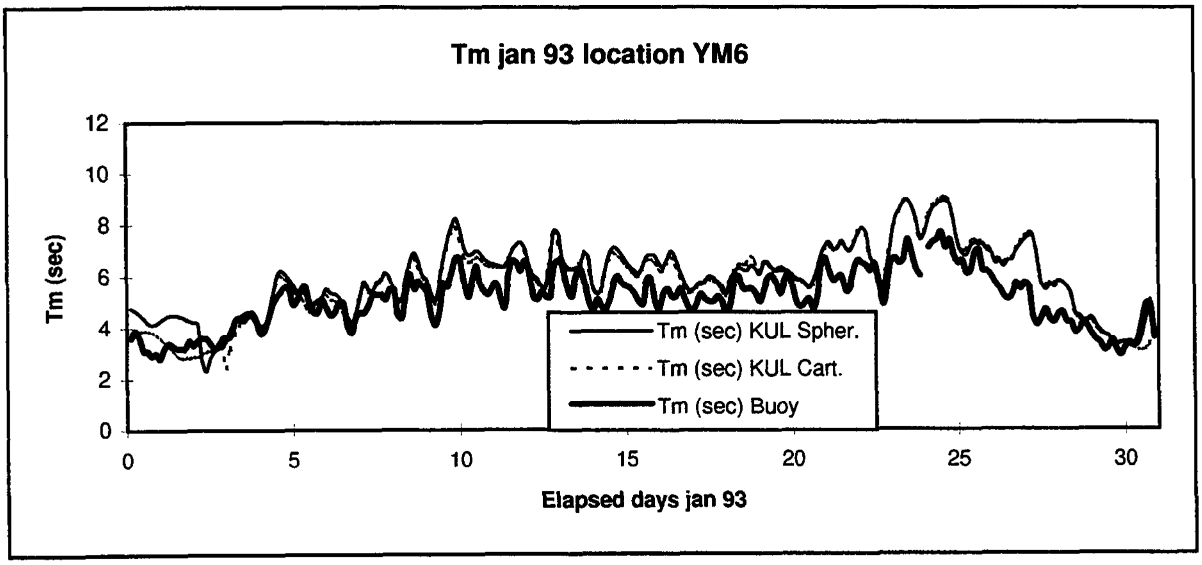
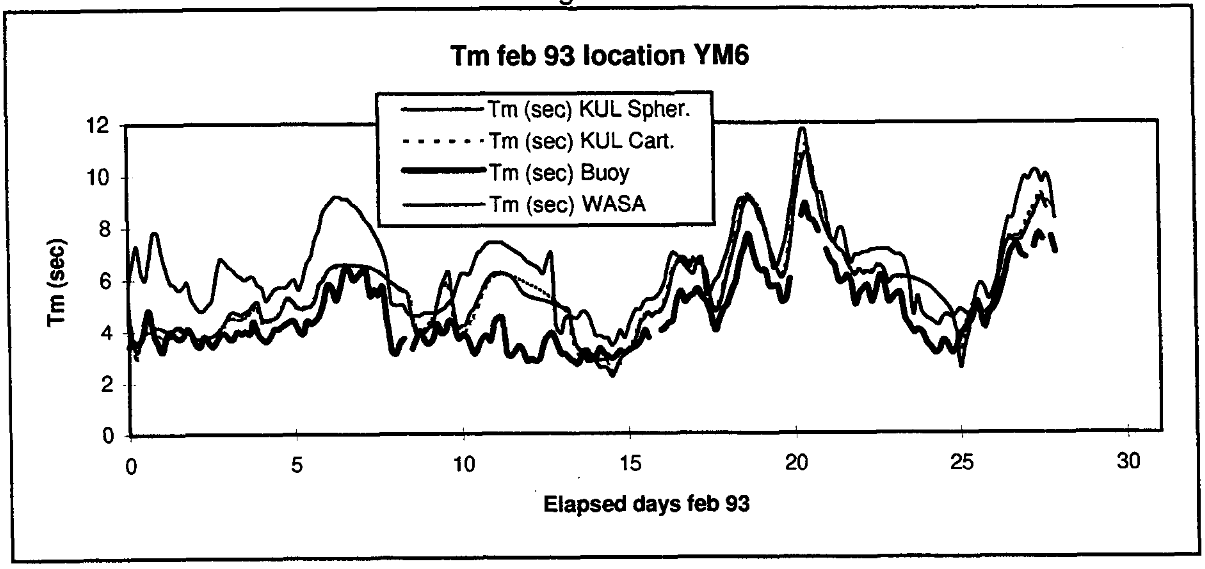


Fig. C-8d



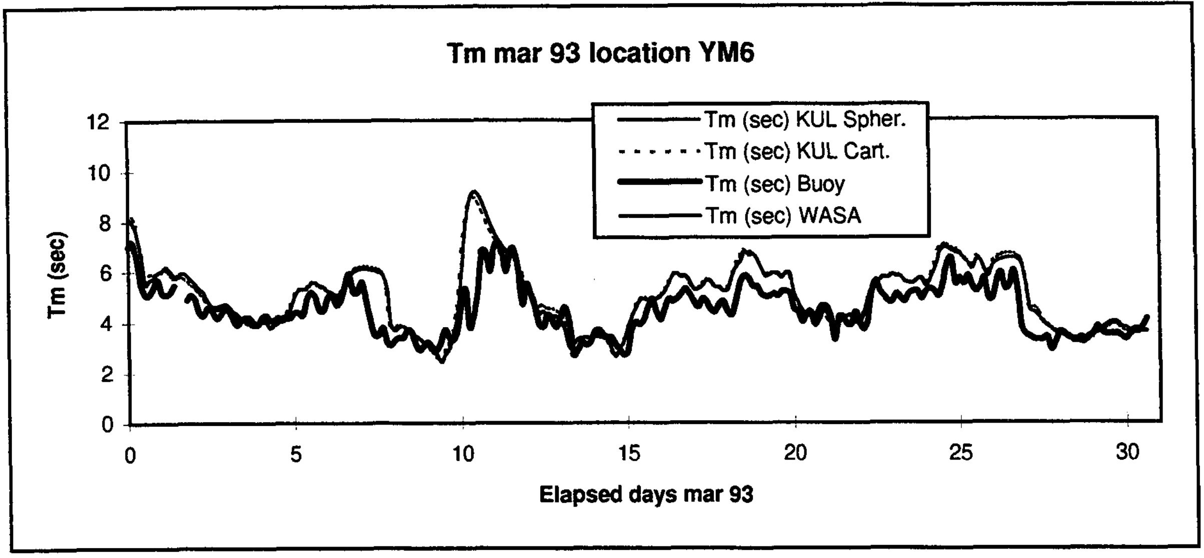
Tm jan 93 location YM6

Fig. C-8e



Tm feb 93 location YM6

Fig. C-8f



Tm mar 93 location YM6

APPENDIX D: CODE CHANGE DOCUMENTATION

There are altogether five diff-files listed here. The changes within these files are with respect to the original WAM Cycle 4 code.

preprowk.f_diff
presetwk.f_diff
wamodwk.f_diff
pspecwk.f_diff
pgridwk.f_diff

1. preprowk.f_diff

```
C
C  MAS3 - CT95 - 0025
C
C  PROMISE DISSEMINATION MW1: JAN. 31, 1997
C
C  CHANGES TO preprowk.f
C
C
-----------------------------------------------------------------------------

<       PARAMETER (NANG = 12, NFRE = 25, NGX =  41, NGY =  41,
<      1           NBLO =  4, NIBLO =  512, NOVER =  39,
<      2           MOUTP = 100, MOUTT = 100)
<
<       PARAMETER (NMAXC =  60, NMAXF =   1, NBINP =   1)
<       PARAMETER (NIBL1 = NIBLO,
<      1           NIBLD = NIBLO, NBLD = NBLO,
<      2           NIBLC = NIBLO, NBLC = NBLO)

through the code the above is replaced by

> Cjmoincl begin
>        INCLUDE './../PARAM_DISSEMINATION'
> Cjmoincl end

-----------------------------------------------------------------------------

<       PARAMETER (NDEPTH = 52)
---
through the code the above is replaced by

>       PARAMETER (NDEPTH = 54)

-----------------------------------------------------------------------------

<       PARAMETER (NCC =  45, NRC =  45)

through the code the above is replaced by

>       PARAMETER (NCC = 31, NRC = 67)

-----------------------------------------------------------------------------

within subroutine READCUR

4468c4378,4383
<      1     UCLO, UCLH, UCLW, UCLE, DUCLO, DUCLA, KRCI, KCCI
---
> Cjmo*bug begin
> C          DUCLO (longitude) and DUCLA (latitude) have been interchanged
> C
> C     1     UCLO, UCLH, UCLW, UCLE, DUCLO, DUCLA, KRCI, KCCI
>      1     UCLO, UCLH, UCLW, UCLE, DUCLA, DUCLO, KRCI, KCCI
```

```
> Cjmo*bug end

---------------------------------------------------------------------------

within subroutine UIPREP

5387c5287,5299
<       READ (LINE,'(6(1X,F10.3))') XDELLA, XDELLO, AMOSOP, AMONOP,
---
> Cjmodiss begin
>       READ (LINE,'(6(1X,F10.5))') XDELLA, XDELLO, AMOSOP, AMONOP,
5394c5306
<       WRITE (IU06,'(3X,''RESOLUTION LAT-LON '',2F8.3)') XDELLA, XDELLO
---
>       WRITE (IU06,'(3X,''RESOLUTION LAT-LON '',2F10.5)') XDELLA, XDELLO
5397c5309,5310
<      2  /,2X,4F14.3)') AMOSOP, AMONOP, AMOWEP, AMOEAP
---
>      2  /,2X,4F14.5)') AMOSOP, AMONOP, AMOWEP, AMOEAP
> Cjmodiss end
5535c5448,5451
<          READ (LINE,'(14X,4F11.3)') AMOSOC, AMONOC, AMOWEC, AMOEAC
---
> Cjmodiss begin
> C         READ (LINE,'(14X,4F11.3)') AMOSOC, AMONOC, AMOWEC, AMOEAC
>          READ (LINE,'(14X,4F11.5)') AMOSOC, AMONOC, AMOWEC, AMOEAC
> Cjmodiss end
5549,5552c5465,5492
<          IF ((MOD(WEST, XDELLO) .NE. 0) .OR.
<      1       (MOD(EAST, XDELLO) .NE. 0) .OR.
<      2       (MOD(AMOSOC - AMOSOP, XDELLA) .NE. 0) .OR.
<      3       (MOD(AMONOC - AMONOP, XDELLA) .NE. 0)) THEN
---
> C*jmo* June 12, 1996 begin
> c     the following four lines have been replaced by the lines below
> c     to allow for small numerical differences at the corner points
> c         IF ((MOD(WEST, XDELLO) .NE. 0) .OR.
> c     1       (MOD(EAST, XDELLO) .NE. 0) .OR.
> c     2       (MOD(AMOSOC - AMOSOP, XDELLA) .NE. 0) .OR.
> c     3       (MOD(AMONOC - AMONOP, XDELLA) .NE. 0)) THEN
>          D1 = MOD(WEST, XDELLO)
>          D2 = MOD(EAST, XDELLO)
>          D3 = MOD(AMOSOC - AMOSOP, XDELLA)
>          D4 = MOD(AMONOC - AMONOP, XDELLA)
>          PULO = XDELLO - 0.001
>          NLLO = -XDELLO + 0.001
>          PLLO = 0.001
>          NULO = -0.001
>          PULA = XDELLA - 0.001
>          NLLA = -XDELLA + 0.001
>          PLLA = 0.001
>          NULA = -0.001
>          IF ((D1.GT.PLLO.AND.D1.LT.PULO) .OR.
>      1       (D1.GT.NLLO.AND.D1.LT.NULO) .OR.
>      2       (D2.GT.PLLO.AND.D2.LT.PULO) .OR.
```

```
>      3        (D2.GT.NLLO.AND.D2.LT.NULO) .OR.
>      4        (D3.GT.PLLA.AND.D3.LT.PULA) .OR.
>      4        (D3.GT.NLLA.AND.D3.LT.NULA) .OR.
>      5        (D4.GT.PLLA.AND.D4.LT.PULA) .OR.
>      6        (D4.GT.NLLA.AND.D4.LT.NULA)) THEN
> c*jmo* June 12, 1996 end
-------------------------------------------------------------------------------------------
```

2. presetwk.f_diff

```
C
C  MAS3 - CT95 - 0025
C
C  PROMISE DISSEMINATION MW1: JAN. 31, 1997
C
C  CHANGES TO presetwk.f
C
C
-----------------------------------------------------------------------------
<       PARAMETER (NANG = 12, NFRE = 25, NGX =  41, NGY =  41,
<      1           NBLO =  4, NIBLO =  512, NOVER =  39,
<      2           MOUTP = 100, MOUTT = 100)
<
<       PARAMETER (NMAXC =  60, NMAXF =   1, NBINP =   1)
<       PARAMETER (NIBL1 = NIBLO,
<      1           NIBLD = NIBLO, NBLD = NBLO,
<      2           NIBLC = NIBLO, NBLC = NBLO)

throughout the code the above is replaced by

>       INCLUDE './../PARAM_DISSEMINATION'

----------------------------------------------------------------------------

<       PARAMETER (NC = 41, NR = 42)

throughout the code the above is replaced by

>       PARAMETER (NC = 31, NR = 67)

-----------------------------------------------------------------------------

<       PARAMETER (NDEPTH = 52)

throughout the code the above is replaced by

>       PARAMETER (NDEPTH = 54)

----------------------------------------------------------------------------
the original subroutine READWND is replaced by the following one

      SUBROUTINE READWND (IDTWIR, UWND, VWND, NC, NR)

C ---------------------------------------------------------------------
C
C**** *READWND* - PROGRAM TO GENERATE WINDFIELDS.
C
C     HEINZ GUNTHER    ECMWF   OCTOBER 1989
C     MODIFIED BY WEIMIN LUO (POL) FEB. 1996
C
C*    PURPOSE.
C     --------
```

```
C
C       TO GENERATE USER' DEFINED WINDFIELDS.
C
C**   INTERFACE.
C     ----------
C
C       *CALL READWND (IDTWIR, UWND, VWND, NC, NR)*
C         *IDTWIR* - DATE/TIME OF THE DATA READ.
C         *UWND*  - HORIZONTAL WIND COMPONENTS.
C         *VWND*  - VERTICAL WIND COMPONENTS.
C         *NC*    - NUMBER OF COLUMNS IN INPUT WIND ARRAYS (DIMENSION).
C         *NR*    - NUMBER OF ROWS    IN INPUT WIND ARRAYS (DIMENSION).
C
C     METHOD.
C     -------
C
C       THE SUB. EXPECTS A SEQUENTIAL, UNFORMATED WIND INPUT FILE
C       WHICH IS ASSIGNED TO UNIT IU01 = 1.
C       IN ITS PRESENT SET UP A HEADER IS ONLY READ WHEN THE
C       SUB IS CALLED THE FIRST TIME. INFORMATION ABOUT THE WINDS
C       AND THE WIND GRID IS STORED IN COMMON WNDGRD.
C       FOR EACH CALL A WINDFIELD IS READ TOGETHER WITH THE
C       DATE/TIME GROUP.
C       THE OUTPUT ARRAYS MUST CONTAIN THE WIND COMPONENTS AND MUST
C       BE ORGANISED AS FOLLOWS:
C
C                  ARRAY INDICES |  LONGITUDE  LATITUDE
C                  --------------|----------------------
C                      1     1   |    RLONL      RLATS
C                   KCOL     1   |    RLONR      RLATS
C                      1  KROW   |    RLONL      RLATN
C                   KCLO  KROW   |    RLONR      RLATN
C
C       NOTE: THIS SUBROUTINE HAS TO BE MODIFIED BY THE USER
C             FOR HIS SPECIAL WIND FORMATS.
C
C
C     EXTERNALS.
C     ----------
C
C       *INCDATE*   - INCREMENT DATE/TIME GROUP.
C
C ----------------------------------------------------------------------
C
C*    *COMMON* *STATUS* - TIME STATUS OF INTEGRATION, WIND INPUT,
C                         OUTPUT OF RESULTS, AND MODEL OPTIONS.
C
      CHARACTER*10 IDATEA, IDATEE, IDTPRO, IDTRES,
     &             IDTINTT, IDTINTS, IDTSPT, IDTSPS
C
      COMMON /STATUS/ IDELPRO, IDELT, IDELWI, IDELWO,
     1                IREST, IDELRES, IDELINT, IDELINS,
     2                IDELSPT, IDELSPS,
     3                ICASE, ISHALLO, IREFRA,
     4                IDATEA, IDATEE, IDTPRO, IDTRES,
```

```
     5               IDTINTT, IDTINTS, IDTSPT, IDTSPS
C
C*    *COMMON* *TESTO* - PRINTER OUTPUT UNIT AND TEST FLAGS.
C
      COMMON /TESTO/ IU06, ITEST, ITESTB
C
C*    *COMMON* *WNDGRD* -  INPUT WIND GRID SPECIFICATIONS.
C
      COMMON /WNDGRD/ DLAM, DPHI, RLATS, RLATN, RLONL, RLONR,
     1               KCOL, KROW, IWPER, ICODE, ICOORD
C
C*     VARIABLE.   TYPE.     PURPOSE.
C      ---------   -------   --------
C      *DLAM*      REAL      STEPSIZE BETWEEN LONGITUDES IN DEG.
C      *DPHI*      REAL      STEPSIZE BETWEEN LATITUDES  IN DEG.
C      *RLATS*     REAL      LATITUDE  AT (., 1) = SOUTHERN LATITUDE.
C      *RLATN*     REAL      LATITUDE  AT (.,NR) = NORTHERN LATITUDE.
C      *RLONL*     REAL      LONGITUDE AT ( 1,.) = WEST MOST LONGITUDE.
C      *RLONR*     REAL      LONGITUDE AT (NC,.) = EAST MOST LONGITUDE.
C      *KCOL*      INTEGER   NUMBER OF COLUMNES IN WIND INPUT (USED).
C      *KROW*      INTEGER   NUMBER OF ROWS     IN WIND INPUT (USED).
C      *ICODE*     INTEGER   WIND CODE 1 = USTAR;  2 = USTRESS; 3 = U10
C      *IWPER*     INTEGER   INDICATOR PERIODICAL GRID.
C                            0= NON-PERIODICAL;    1= PERIODICAL.
C      *ICOORD*    INTEGER   CODE FOR COORDINATE SYSTEM USED
C                            1= RECTANGULAR,EQUIDISTANT LON/LAT GRID.
C                            2= .......NOT IMPLEMENTED.
C
C ----------------------------------------------------------------------
C
C     LOGICAL  FRSTIME
      DIMENSION UWND(NC,NR), VWND(NC,NR)
      DATA ITEL /0/
C
      CHARACTER * 10 IDTWIR
C ----------------------------------------------------------------------
C
C*    1. FOR FIRST CALL, DETERMINE DATES.
C        -------------------------------
C
      IF (ITEL.EQ.0) THEN
         RLATS = 48.000
         RLATN = 70.000
         RLONL = -10.000
         RLONR = 10.000
         IDTWIR = IDATEA
         KCOL = NC
         KROW = NR
         IWPER = 0
         ICOORD = 1
         DLAM  = (RLONR-RLONL)/REAL(KCOL-1)
         DPHI  = (RLATN-RLATS)/REAL(KROW-1)
C        FRSTIME = .FALSE.
C     ELSE
C        CALL INCDATE(IDTWIR,IDELWI)
```

```
      ENDIF
 1000 CONTINUE
      ITEL = ITEL + 1
 602  FORMAT(A10,I4)
 605  FORMAT(I4)
 600  FORMAT(25F6.2)
 700  FORMAT(2I4,4F10.4,2I4)
C
C ----------------------------------------------------------------------
C
C*    2. READ WIND DATA.
C        ---------------
C
      IU01 = 1
 2000 CONTINUE
C
C*    2.1 DATE / TIME OF WIND.
C         --------------------
C
      READ (IU01, 602,ERR=3100, END=3100, IOSTAT=IOS) IDTWIR,ICODE
C      CALL INCDATE(IDTWIR, IDELWI)
      IF (ITEST.GT.0) THEN
         WRITE (IU06,*) '  '
         WRITE (IU06,*) ' SUB. READWND: NEW WIND DATE READ IDTWIR = ',
     1                   IDTWIR
      ENDIF
C
C*    2.2 READ HORIZONTAL COMPONENTS.
C         ---------------------------
      READ (IU01, 600, ERR=3200, END=3200, IOSTAT=IOS)
     1      ((UWND(I,J),I=1,KCOL),J=1,KROW)
      IF (ITEST.GT.0) WRITE (IU06,*) ' U: ',(UWND(I,1),I=1,10)
C
C*    2.3 READ VERTICAL COMPONENTS.
C         -------------------------
       KCODE = ICODE
      READ (IU01, 600, ERR=3300, END=3300, IOSTAT=IOS)
     1      ((VWND(I,J),I=1,KCOL),J=1,KROW)
      IF (ITEST.GT.0) WRITE (IU06,*) ' V: ',(VWND(I,1),I=1,10)
C
C*    2.4 CHECK WIND CODES.
C         -----------------
C
      IF (ICODE.NE.KCODE) THEN
         WRITE (IU06,*) ' *****************************************'
         WRITE (IU06,*) ' *                                       *'
         WRITE (IU06,*) ' *       FATAL ERROR IN SUB. READWND     *'
         WRITE (IU06,*) ' *       ===========================     *'
         WRITE (IU06,*) ' * CODES OF U AND V WIND COMPONENT ARE   *'
         WRITE (IU06,*) ' * DIFFERENT.                            *'
         WRITE (IU06,*) ' * CODE OF U COMPONENT IS ICODE = ', ICODE
         WRITE (IU06,*) ' * CODE OF V COMPONENT IS KCODE = ', KCODE
         WRITE (IU06,*) ' * DATE OF WIND INPUT IS IDTWIR = ', IDTWIR
         WRITE (IU06,*) ' * CODE HAS TO BE :                      *'
         WRITE (IU06,*) ' *    1  FOR FRICTION VELOCITIES         *'
```

```
         WRITE (IU06,*) ' *    2  FOR SURFACE STRESSES           *'
         WRITE (IU06,*) ' *    3  FOR WIND IN 10M HEIGHT         *'
         WRITE (IU06,*) ' *                                      *'
         WRITE (IU06,*) ' *   PROGRAM ABORTS  PROGRAM ABORTS     *'
         WRITE (IU06,*) ' *                                      *'
         WRITE (IU06,*) ' *****************************************'
         CALL ABORT
      ENDIF
      IF (ICODE.NE.1 .AND. ICODE.NE.2 .AND. ICODE.NE.3) THEN
         WRITE (IU06,*) ' *****************************************'
         WRITE (IU06,*) ' *                                      *'
         WRITE (IU06,*) ' *       FATAL ERROR IN SUB. READWND    *'
         WRITE (IU06,*) ' *       ==========================     *'
         WRITE (IU06,*) ' * WIND FIELD CODE IS NOT ALLOWED       *'
         WRITE (IU06,*) ' * CODE OF U COMPONENT IS ICODE = ', ICODE
         WRITE (IU06,*) ' * CODE OF V COMPONENT IS KCODE = ', KCODE
         WRITE (IU06,*) ' * DATE OF WIND INPUT IS IDTWIR = ', IDTWIR
         WRITE (IU06,*) ' * CODE HAS TO BE :                     *'
         WRITE (IU06,*) ' *    1  FOR FRICTION VELOCITIES        *'
         WRITE (IU06,*) ' *    2  FOR SURFACE STRESSES           *'
         WRITE (IU06,*) ' *    3  FOR WIND IN 10M HEIGHT         *'
         WRITE (IU06,*) ' *                                      *'
         WRITE (IU06,*) ' *   PROGRAM ABORTS  PROGRAM ABORTS     *'
         WRITE (IU06,*) ' *                                      *'
         WRITE (IU06,*) ' *****************************************'
         CALL ABORT
      ENDIF
      RETURN
C
C ----------------------------------------------------------------------
C
C*    3. ERROR MESSAGES.
C        ---------------
C
 3000 CONTINUE
         WRITE (IU06,*) ' *****************************************'
         WRITE (IU06,*) ' *                                      *'
         WRITE (IU06,*) ' *       FATAL ERROR IN SUB. READWND    *'
         WRITE (IU06,*) ' *       ==========================     *'
         WRITE (IU06,*) ' * READ ERROR OR EOF ON WIND FILE:      *'
         WRITE (IU06,*) ' * FILE HEADER EXPECTED                 *'
         WRITE (IU06,*) ' *                                      *'
         WRITE (IU06,*) ' *   PROGRAM ABORTS  PROGRAM ABORTS     *'
         WRITE (IU06,*) ' *                                      *'
         WRITE (IU06,*) ' *****************************************'
         CALL ABORT
 3100 CONTINUE
         WRITE (IU06,*) ' *****************************************'
         WRITE (IU06,*) ' *                                      *'
         WRITE (IU06,*) ' *       FATAL ERROR IN SUB. READWND    *'
         WRITE (IU06,*) ' *       ==========================     *'
         WRITE (IU06,*) ' * READ ERROR OR EOF ON WIND FILE:      *'
         WRITE (IU06,*) ' * WIND DATE EXPECTED                   *'
         WRITE (IU06,*) ' * PROGRAM TRIES TO READ THE ', ITEL,
     1                  ' WINDFIELD'
```

```
        WRITE (IU06,*) ' *                                       *'
        WRITE (IU06,*) ' *   PROGRAM ABORTS  PROGRAM ABORTS      *'
        WRITE (IU06,*) ' *                                       *'
        WRITE (IU06,*) ' *****************************************'
        CALL ABORT
3200 CONTINUE
        WRITE (IU06,*) ' *****************************************'
        WRITE (IU06,*) ' *                                       *'
        WRITE (IU06,*) ' *       FATAL ERROR IN SUB. READWND     *'
        WRITE (IU06,*) ' *       ===========================     *'
        WRITE (IU06,*) ' * READ ERROR OR EOF ON WIND FILE:       *'
        WRITE (IU06,*) ' * U COMPONENT EXPECTED                  *'
        WRITE (IU06,*) ' * DATE OF WIND INPUT IS IDTWIR = ', IDTWIR
        WRITE (IU06,*) ' * PROGRAM TRIES TO READ THE ', ITEL,
    1                  ' WINDFIELD'
        WRITE (IU06,*) ' *                                       *'
        WRITE (IU06,*) ' *   PROGRAM ABORTS  PROGRAM ABORTS      *'
        WRITE (IU06,*) ' *                                       *'
        WRITE (IU06,*) ' *****************************************'
        CALL ABORT
3300 CONTINUE
        WRITE (IU06,*) ' *****************************************'
        WRITE (IU06,*) ' *                                       *'
        WRITE (IU06,*) ' *       FATAL ERROR IN SUB. READWND     *'
        WRITE (IU06,*) ' *       ===========================     *'
        WRITE (IU06,*) ' * READ ERROR OR EOF ON WIND FILE:       *'
        WRITE (IU06,*) ' * V COMPONENT EXPECTED                  *'
        WRITE (IU06,*) ' * DATE OF WIND INPUT IS IDTWIR = ', IDTWIR
        WRITE (IU06,*) ' * PROGRAM TRIES TO READ THE ', ITEL,
    1                  ' WINDFIELD'
        WRITE (IU06,*) ' *                                       *'
        WRITE (IU06,*) ' *   PROGRAM ABORTS  PROGRAM ABORTS      *'
        WRITE (IU06,*) ' *                                       *'
        WRITE (IU06,*) ' *****************************************'
        CALL ABORT
      END
```

---

3. wamodwk.f_diff

```
C
C  MAS3 - CT95 - 0025
C
C  PROMISE DISSEMINATION MW1: JAN. 31, 1997
C
C  CHANGES TO wamodwk.f
C
C
---------------------------------------------------------------------------
<       PARAMETER (NANG = 12, NFRE = 25, NGX =  41, NGY =  41,
<      1          NBLO =  4, NIBLO =  512, NOVER =  39,
<      2          MOUTP = 100, MOUTT = 100)
<
<       PARAMETER (NMAXC =  60, NMAXF =   1, NBINP =   1)
<       PARAMETER (NIBL1 = NIBLO,
<      1          NIBLD = NIBLO, NBLD = NBLO,
<      2          NIBLC = NIBLO, NBLC = NBLO)
```

throughout the code the above is replaced by

```
>       INCLUDE './../PARAM_DISSEMINATION'

---------------------------------------------------------------------------

<       PARAMETER (NC = 41, NR = 42)
```

throughout the code the above is replaced by

```
>       PARAMETER (NC = 31, NR = 67)

---------------------------------------------------------------------------

<       PARAMETER (NDEPTH = 52)
```

throughout the code the above is replaced by

```
>       PARAMETER (NDEPTH = 54)

---------------------------------------------------------------------------
```

the original subroutine READWND is replaced by the following one

```
      SUBROUTINE READWND (IDTWIR, UWND, VWND, NC, NR)

C ---------------------------------------------------------------------
C
C**** *READWND* - PROGRAM TO GENERATE WINDFIELDS.
C
C     HEINZ GUNTHER    ECMWF   OCTOBER 1989
C     MODIFIED BY WEIMIN LUO (POL) FEB. 1996
C
C*    PURPOSE.
C     --------
```

```
C
C       TO GENERATE USER' DEFINED WINDFIELDS.
C
C**   INTERFACE.
C     ----------
C
C       *CALL READWND (IDTWIR, UWND, VWND, NC, NR)*
C         *IDTWIR* - DATE/TIME OF THE DATA READ.
C         *UWND*  - HORIZONTAL WIND COMPONENTS.
C         *VWND*  - VERTICAL WIND COMPONENTS.
C         *NC*    - NUMBER OF COLUMNS IN INPUT WIND ARRAYS (DIMENSION).
C         *NR*    - NUMBER OF ROWS    IN INPUT WIND ARRAYS (DIMENSION).
C
C     METHOD.
C     -------
C
C       THE SUB. EXPECTS A SEQUENTIAL, UNFORMATED WIND INPUT FILE
C       WHICH IS ASSIGNED TO UNIT IU01 = 1.
C       IN ITS PRESENT SET UP A HEADER IS ONLY READ WHEN THE
C       SUB IS CALLED THE FIRST TIME. INFORMATION ABOUT THE WINDS
C       AND THE WIND GRID IS STORED IN COMMON WNDGRD.
C       FOR EACH CALL A WINDFIELD IS READ TOGETHER WITH THE
C       DATE/TIME GROUP.
C       THE OUTPUT ARRAYS MUST CONTAIN THE WIND COMPONENTS AND MUST
C       BE ORGANISED AS FOLLOWS:
C
C                 ARRAY INDICES |   LONGITUDE  LATITUDE
C                 --------------|----------------------
C                     1      1  |     RLONL      RLATS
C                  KCOL      1  |     RLONR      RLATS
C                     1   KROW  |     RLONL      RLATN
C                  KCLO   KROW  |     RLONR      RLATN
C
C       NOTE: THIS SUBROUTINE HAS TO BE MODIFIED BY THE USER
C             FOR HIS SPECIAL WIND FORMATS.
C
C
C     EXTERNALS.
C     ----------
C
C       *INCDATE*   - INCREMENT DATE/TIME GROUP.
C
C ----------------------------------------------------------------------
C
C*    *COMMON* *STATUS* - TIME STATUS OF INTEGRATION, WIND INPUT,
C                         OUTPUT OF RESULTS, AND MODEL OPTIONS.
C
      CHARACTER*10 IDATEA, IDATEE, IDTPRO, IDTRES,
     &             IDTINTT, IDTINTS, IDTSPT, IDTSPS
C
      COMMON /STATUS/ IDELPRO, IDELT, IDELWI, IDELWO,
     1                IREST, IDELRES, IDELINT, IDELINS,
     2                IDELSPT, IDELSPS,
     3                ICASE, ISHALLO, IREFRA,
     4                IDATEA, IDATEE, IDTPRO, IDTRES,
```

```
     5                IDTINTT, IDTINTS, IDTSPT, IDTSPS
C
C*    *COMMON* *TESTO* - PRINTER OUTPUT UNIT AND TEST FLAGS.
C
      COMMON /TESTO/ IU06, ITEST, ITESTB
C
C*    *COMMON* *WNDGRD* -  INPUT WIND GRID SPECIFICATIONS.
C
      COMMON /WNDGRD/ DLAM, DPHI, RLATS, RLATN, RLONL, RLONR,
     1                KCOL, KROW, IWPER, ICODE, ICOORD
C
C*     VARIABLE.   TYPE.     PURPOSE.
C      ---------   -------   --------
C      *DLAM*      REAL      STEPSIZE BETWEEN LONGITUDES IN DEG.
C      *DPHI*      REAL      STEPSIZE BETWEEN LATITUDES  IN DEG.
C      *RLATS*     REAL      LATITUDE  AT (., 1)  = SOUTHERN LATITUDE.
C      *RLATN*     REAL      LATITUDE  AT (.,NR)  = NORTHERN LATITUDE.
C      *RLONL*     REAL      LONGITUDE AT ( 1,.)  = WEST MOST LONGITUDE.
C      *RLONR*     REAL      LONGITUDE AT (NC,.)  = EAST MOST LONGITUDE.
C      *KCOL*      INTEGER   NUMBER OF COLUMNES IN WIND INPUT (USED).
C      *KROW*      INTEGER   NUMBER OF ROWS     IN WIND INPUT (USED).
C      *ICODE*     INTEGER   WIND CODE 1 = USTAR;  2 = USTRESS; 3 = U10
C      *IWPER*     INTEGER   INDICATOR PERIODICAL GRID.
C                            0= NON-PERIODICAL;    1= PERIODICAL.
C      *ICOORD*    INTEGER   CODE FOR COORDINATE SYSTEM USED
C                            1= RECTANGULAR,EQUIDISTANT LON/LAT GRID.
C                            2= .......NOT IMPLEMENTED.
C
C ----------------------------------------------------------------------
C
C      LOGICAL  FRSTIME
       DIMENSION UWND(NC,NR), VWND(NC,NR)
       DATA ITEL /0/
C
       CHARACTER * 10 IDTWIR
C ----------------------------------------------------------------------
C
C*     1. FOR FIRST CALL, DETERMINE DATES.
C         -------------------------------
C
       IF (ITEL.EQ.0) THEN
          RLATS = 48.000
          RLATN = 70.000
          RLONL = -10.000
          RLONR = 10.000
          IDTWIR = IDATEA
          KCOL = NC
          KROW = NR
          IWPER = 0
          ICOORD = 1
          DLAM   = (RLONR-RLONL)/REAL(KCOL-1)
          DPHI   = (RLATN-RLATS)/REAL(KROW-1)
C         FRSTIME = .FALSE.
C      ELSE
C         CALL INCDATE(IDTWIR,IDELWI)
```

```
      ENDIF
 1000 CONTINUE
      ITEL = ITEL + 1
  602 FORMAT(A10,I4)
  605 FORMAT(I4)
  600 FORMAT(25F6.2)
  700 FORMAT(2I4,4F10.4,2I4)
C
C ----------------------------------------------------------------------
C
C*    2. READ WIND DATA.
C        ---------------
C
      IU01 = 1
 2000 CONTINUE
C
C*    2.1 DATE / TIME OF WIND.
C         --------------------
C
      READ (IU01, 602,ERR=3100, END=3100, IOSTAT=IOS) IDTWIR,ICODE
C      CALL INCDATE(IDTWIR, IDELWI)
      IF (ITEST.GT.0) THEN
         WRITE (IU06,*) '  '
         WRITE (IU06,*) ' SUB. READWND: NEW WIND DATE READ IDTWIR = ',
     1                  IDTWIR
      ENDIF
C
C*    2.2 READ HORIZONTAL COMPONENTS.
C         --------------------------
      READ (IU01, 600, ERR=3200, END=3200, IOSTAT=IOS)
     1      ((UWND(I,J),I=1,KCOL),J=1,KROW)
      IF (ITEST.GT.0) WRITE (IU06,*) ' U: ',(UWND(I,1),I=1,10)
C
C*    2.3 READ VERTICAL COMPONENTS.
C         ------------------------
       KCODE = ICODE
      READ (IU01, 600, ERR=3300, END=3300, IOSTAT=IOS)
     1      ((VWND(I,J),I=1,KCOL),J=1,KROW)
      IF (ITEST.GT.0) WRITE (IU06,*) ' V: ',(VWND(I,1),I=1,10)
C
C*    2.4 CHECK WIND CODES.
C         ----------------
C
      IF (ICODE.NE.KCODE) THEN
         WRITE (IU06,*) ' ******************************************'
         WRITE (IU06,*) ' *                                        *'
         WRITE (IU06,*) ' *       FATAL ERROR IN SUB. READWND      *'
         WRITE (IU06,*) ' *       ===========================      *'
         WRITE (IU06,*) ' * CODES OF U AND V WIND COMPONENT ARE    *'
         WRITE (IU06,*) ' * DIFFERENT.                             *'
         WRITE (IU06,*) ' * CODE OF U COMPONENT IS ICODE = ', ICODE
         WRITE (IU06,*) ' * CODE OF V COMPONENT IS KCODE = ', KCODE
         WRITE (IU06,*) ' * DATE OF WIND INPUT IS IDTWIR = ', IDTWIR
         WRITE (IU06,*) ' * CODE HAS TO BE :                       *'
         WRITE (IU06,*) ' *    1  FOR FRICTION VELOCITIES          *'
```

```
         WRITE (IU06,*) ' *    2  FOR SURFACE STRESSES             *'
         WRITE (IU06,*) ' *    3  FOR WIND IN 10M HEIGHT           *'
         WRITE (IU06,*) ' *                                        *'
         WRITE (IU06,*) ' *   PROGRAM ABORTS  PROGRAM ABORTS       *'
         WRITE (IU06,*) ' *                                        *'
         WRITE (IU06,*) ' ******************************************'
         CALL ABORT
      ENDIF
      IF (ICODE.NE.1 .AND. ICODE.NE.2 .AND. ICODE.NE.3) THEN
         WRITE (IU06,*) ' ******************************************'
         WRITE (IU06,*) ' *                                        *'
         WRITE (IU06,*) ' *       FATAL ERROR IN SUB. READWND      *'
         WRITE (IU06,*) ' *       ===========================      *'
         WRITE (IU06,*) ' * WIND FIELD CODE IS NOT ALLOWED         *'
         WRITE (IU06,*) ' * CODE OF U COMPONENT IS ICODE = ', ICODE
         WRITE (IU06,*) ' * CODE OF V COMPONENT IS KCODE = ', KCODE
         WRITE (IU06,*) ' * DATE OF WIND INPUT IS IDTWIR = ', IDTWIR
         WRITE (IU06,*) ' * CODE HAS TO BE :                       *'
         WRITE (IU06,*) ' *    1  FOR FRICTION VELOCITIES          *'
         WRITE (IU06,*) ' *    2  FOR SURFACE STRESSES             *'
         WRITE (IU06,*) ' *    3  FOR WIND IN 10M HEIGHT           *'
         WRITE (IU06,*) ' *                                        *'
         WRITE (IU06,*) ' *   PROGRAM ABORTS  PROGRAM ABORTS       *'
         WRITE (IU06,*) ' *                                        *'
         WRITE (IU06,*) ' ******************************************'
         CALL ABORT
      ENDIF
      RETURN
C
C ----------------------------------------------------------------------
C
C*    3. ERROR MESSAGES.
C        ---------------
C
 3000 CONTINUE
         WRITE (IU06,*) ' ******************************************'
         WRITE (IU06,*) ' *                                        *'
         WRITE (IU06,*) ' *       FATAL ERROR IN SUB. READWND      *'
         WRITE (IU06,*) ' *       ===========================      *'
         WRITE (IU06,*) ' * READ ERROR OR EOF ON WIND FILE:        *'
         WRITE (IU06,*) ' * FILE HEADER EXPECTED                   *'
         WRITE (IU06,*) ' *                                        *'
         WRITE (IU06,*) ' *   PROGRAM ABORTS  PROGRAM ABORTS       *'
         WRITE (IU06,*) ' *                                        *'
         WRITE (IU06,*) ' ******************************************'
         CALL ABORT
 3100 CONTINUE
         WRITE (IU06,*) ' ******************************************'
         WRITE (IU06,*) ' *                                        *'
         WRITE (IU06,*) ' *       FATAL ERROR IN SUB. READWND      *'
         WRITE (IU06,*) ' *       ===========================      *'
         WRITE (IU06,*) ' * READ ERROR OR EOF ON WIND FILE:        *'
         WRITE (IU06,*) ' * WIND DATE EXPECTED                     *'
         WRITE (IU06,*) ' * PROGRAM TRIES TO READ THE ', ITEL,
     1                  ' WINDFIELD'
```

```
      WRITE (IU06,*) ' *                                       *'
      WRITE (IU06,*) ' *   PROGRAM ABORTS  PROGRAM ABORTS      *'
      WRITE (IU06,*) ' *                                       *'
      WRITE (IU06,*) ' *****************************************'
      CALL ABORT
 3200 CONTINUE
      WRITE (IU06,*) ' *****************************************'
      WRITE (IU06,*) ' *                                       *'
      WRITE (IU06,*) ' *       FATAL ERROR IN SUB. READWND     *'
      WRITE (IU06,*) ' *       ===========================     *'
      WRITE (IU06,*) ' * READ ERROR OR EOF ON WIND FILE:       *'
      WRITE (IU06,*) ' * U COMPONENT EXPECTED                  *'
      WRITE (IU06,*) ' * DATE OF WIND INPUT IS IDTWIR = ', IDTWIR
      WRITE (IU06,*) ' * PROGRAM TRIES TO READ THE ', ITEL,
     1               ' WINDFIELD'
      WRITE (IU06,*) ' *                                       *'
      WRITE (IU06,*) ' *   PROGRAM ABORTS  PROGRAM ABORTS      *'
      WRITE (IU06,*) ' *                                       *'
      WRITE (IU06,*) ' *****************************************'
      CALL ABORT
 3300 CONTINUE
      WRITE (IU06,*) ' *****************************************'
      WRITE (IU06,*) ' *                                       *'
      WRITE (IU06,*) ' *       FATAL ERROR IN SUB. READWND     *'
      WRITE (IU06,*) ' *       ===========================     *'
      WRITE (IU06,*) ' * READ ERROR OR EOF ON WIND FILE:       *'
      WRITE (IU06,*) ' * V COMPONENT EXPECTED                  *'
      WRITE (IU06,*) ' * DATE OF WIND INPUT IS IDTWIR = ', IDTWIR
      WRITE (IU06,*) ' * PROGRAM TRIES TO READ THE ', ITEL,
     1               ' WINDFIELD'
      WRITE (IU06,*) ' *                                       *'
      WRITE (IU06,*) ' *   PROGRAM ABORTS  PROGRAM ABORTS      *'
      WRITE (IU06,*) ' *                                       *'
      WRITE (IU06,*) ' *****************************************'
      CALL ABORT
     END
```

4. pspecwk.f_diff

```
C
C  MAS3 - CT95 - 0025
C
C  PROMISE DISSEMINATION MW1: JAN. 31, 1997
C
C  CHANGES TO pspecwk.f
C
C
-------------------------------------------------------------------------------
within subroutine PRSPP


498c498
<        CHARACTER FORM1*50, FORM2*50, FORM3*50
---
>        CHARACTER FORM1*50, FORM2*50, FORM3*50,xdays*5
506a507,538
> C      LOCATIONS OF THE WAVESTATIONS
> C
> C      ylt* and ylg* (DEGREE) ARE RESPECTIVELY THE COORDINATES IN THE
> C      LATITUDE AND LONGITUDE DIRECTIONS OF THE DESIRED OUTPUT POINTS.
> C      PLEASE SEE THE OUTPUT FILE 'prepout' OF preprun FOR THE COORDINATE
> C      VALUES. NOTE THAT THE VALUES USED HERE ARE OUTPUT BY preprun AND
> C      MORE OR LESS DIFFER FROM THE INPUT VALUES GIVEN BY USER IN FILE
> C      preprowk.frm.
> C      THE FOLLOWING SIX PAIRS OF COORDINATE VALUES ARE JUST GIVEN AS AN
> C      EXAMPLE.
> C
>         ylt1 = 52.3333
>         ylg1 =  4.0000
>         ylt2 = 52.6666
>         ylg2 =  4.0000
>         ylt3 = 53.3333
>         ylg3 =  4.6667
>         ylt4 = 53.3333
>         ylg4 =  3.3333
>         ylt5 = 53.6666
>         ylg5 =  6.0000
>         ylt6 = 56.3333
>         ylg6 =  2.0000
> c       ylt7 =
> c       ylg7 =
> c       ylt8 =
> c       ylg8 =
> c       ylt9 =
> c       ylg9 =
> c       ylt10 =
> c       ylg10 =
> C
527c559,583
< C         ---------------
---
```

```
> C        ---------------
>         XDAYS (1:2)= IDATE(5:6)
>         xdays (3:3)=':'
>          xdays(4:5)=idate(7:8)
>         print*,'ooooooo',xlong, ylg1, xlat, ylt1
>        IF ((ABS(XLONG-ylg1).lt.0.01).AND.(ABS(XLAT-ylt1).lt.0.01))
>      1 WRITE(7,4105) XDAYS, WAVEHT, WAVEMFR, 1./WAVEMFR, WAVEDIR
>        IF ((ABS(XLONG-ylg2).lt.0.001).AND.(ABS(XLAT-ylt2).lt.0.001))
>      1 WRITE(8,4105) XDAYS, WAVEHT, WAVEMFR, 1./WAVEMFR, WAVEDIR
>        IF ((ABS(XLONG-ylg3).lt.0.001).AND.(ABS(XLAT-ylt3).lt.0.001))
>      1 WRITE(9,4105) XDAYS, WAVEHT, WAVEMFR, 1./WAVEMFR, WAVEDIR
>        IF ((ABS(XLONG-ylg4).lt.0.001).AND.(ABS(XLAT-ylt4).lt.0.001))
>      1 WRITE(10,4105) XDAYS, WAVEHT, WAVEMFR, 1./WAVEMFR, WAVEDIR
>        IF ((ABS(XLONG-ylg5).lt.0.001).AND.(ABS(XLAT-ylt5).lt.0.001))
>      1 WRITE(11,4105) XDAYS, WAVEHT, WAVEMFR, 1./WAVEMFR, WAVEDIR
>        IF ((ABS(XLONG-ylg6).lt.0.001).AND.(ABS(XLAT-ylt6).lt.0.001))
>      1 WRITE(12,4105) XDAYS, WAVEHT, WAVEMFR, 1./WAVEMFR, WAVEDIR
> c      IF ((ABS(XLONG-ylg7).lt.0.001).AND.(ABS(XLAT-ylt7).lt.0.001))
> c    1 WRITE(13,4105) XDAYS, WAVEHT, WAVEMFR, 1./WAVEMFR, WAVEDIR
> c      IF ((ABS(XLONG-ylg8).lt.0.001).AND.(ABS(XLAT-ylt8).lt.0.001))
> c    1 WRITE(14,4105) XDAYS, WAVEHT, WAVEMFR, 1./WAVEMFR, WAVEDIR
> c      IF ((ABS(XLONG-ylg9).lt.0.001).AND.(ABS(XLAT-ylt9).lt.0.001))
> c    1 WRITE(15,4105) XDAYS, WAVEHT, WAVEMFR, 1./WAVEMFR, WAVEDIR
> c      IF ((ABS(XLONG-ylg10).lt.0.001).AND.(ABS(XLAT-ylt10).lt.0.001))
> c    1 WRITE(16,4105) XDAYS, WAVEHT, WAVEMFR, 1./WAVEMFR, WAVEDIR
528a585
>  4105 FORMAT (a5,1X ,4(F10.4,1x))

-------------------------------------------------------------------------------
within subroutine PSPEC


667a725,738
> C*    1.4 OPEN THE OUTPUT FILE FOR EACH WAVE STATION.
> C         ------------------------------------------
> C
>         OPEN( 7,FILE = 'loc1.dat')
>         OPEN( 8,FILE = 'loc2.dat')
>         OPEN( 9,FILE = 'loc3.dat')
>         OPEN(10,FILE = 'loc4.dat')
>         OPEN(11,FILE = 'loc5.dat')
>         OPEN(12,FILE = 'loc6.dat')
> c       OPEN(13,FILE = 'loc7.dat')
> c       OPEN(14,FILE = 'loc8.dat')
> c       OPEN(15,FILE = 'loc9.dat')
> c       OPEN(16,FILE = 'loc10.dat')
> C
734a806
> c    print*,xlong
736,737c808,813
<           IF (ABS(MOD(XLONG(IS)-XLG+720.,360.)).LT.0.00001 .AND.
<       1      ABS(XLAT(IS)-XLT).LT.0.00001) THEN
---
>
> c         IF (ABS(MOD(XLONG(IS)-XLG+720.,360.)).LT.0.01 .AND.
```

```
> c     1       ABS(XLAT(IS)-XLT).LT.0.01) THEN
>           IF (ABS(XLONG(IS)-XLG).LT.0.01 .AND.
>      1       ABS(XLAT(IS)-XLT).LT.0.01) THEN
>
745a822,832
>         close (7)
>         close (8)
>         close (9)
>         close (10)
>         close (11)
>         close (12)
> c       close (13)
> c       close (14)
> c       close (15)
> c       close (16)
> c
```

---

5. pgridrun.wk_diff

```
C
C  MAS3 - CT95 - 0025
C
C  PROMISE DISSEMINATION MW1: JAN. 31, 1997
C
C  CHANGES TO pgridwk.f
C
C
----------------------------------------------------------------------------
<       PARAMETER (NGX=41, NGY=41, IDS=10, IDO = 100)

through the code the above is replaced by

>       PARAMETER (NGX = 31, NGY = 67, IDS=10, IDO = 100)

---------------------------------------------------------------------------

within subroutine OUTPP

477c477
<       NPTS=30
---
>       NPTS=31
501,502c501,502
<  302  FORMAT(7X,'I=',30I4)
<  303  FORMAT(5X,'LON=',30I4)
---
>  302  FORMAT(7X,'I=',31I4)
>  303  FORMAT(5X,'LON=',31I4)
504c504
<  305  FORMAT(1X,I2,F5.1,1X,30I4)
---
>  305  FORMAT(1X,I2,F5.1,1X,31I4)
```