

APPENDIX A: Quality control

In the following tables, the detailed information about rejected records is given. The order in the calculation is the same as in the shown in the first table in which the meaning of each type of error is clarified

Error	Meaning
e1	Record length different from $D/\Delta t$
e 2	Vertical acceleration $> g/2$
e 3	3 consecutives second derivatives = 0
e_50	$H_s < 0.5m$
e4	$\eta_{max\ crest} > 2.83 \cdot \eta_{crest,s}$ in one isolated data point
e_al	$f_{Nyq}/f_m < 2.2$
e_bump	$E(0) > 0.004 m^2 / Hz$
e_sh	$h < L_0/2$
visual	Rejected after visual check

ROSES											
Year	Initial	e1	e2	e3	e_50	e4	e_al	e_bump	e_sh	visual	Final
2001	452	0	48	87	124	0	0	27	0	0	166
2002	8.725	0	2.258	2.820	1.441	1	0	117	4	0	2.084
2003	7.678	0	2.444	2.289	955	0	0	117	5	0	1.868
2004	5.847	0	565	2.164	1.299	3	0	67	1	0	1.748
2005	5.592	3	3.967	715	396	77	0	76	0	0	358
2006	7.962	12	4.585	1.592	662	0	0	190	4	0	917
TOTAL	36.256	15	13.867	9.667	4.877	81	0	594	14	0	7.141

BLANES											
Year	Initial	e1	e2	e3	e_50	e4	e_al	e_bump	e_sh	visual	Final
2002	5.647	1	197	2.181	941	0	0	54	0	0	2.273
2003	8.227	1	2.732	1.404	1.351	7	0	70	0	0	2.662
2004	6.373	1	631	1.855	1.354	1	0	109	9	4	2.409
2005	8.119	0	497	2.678	1.763	0	0	139	0	2	3.040
2006	8.457	4	2.240	3.018	863	0	0	15	0	0	2.317
TOTAL	36.823	7	6.297	11.136	6.272	8	0	387	9	6	12.701

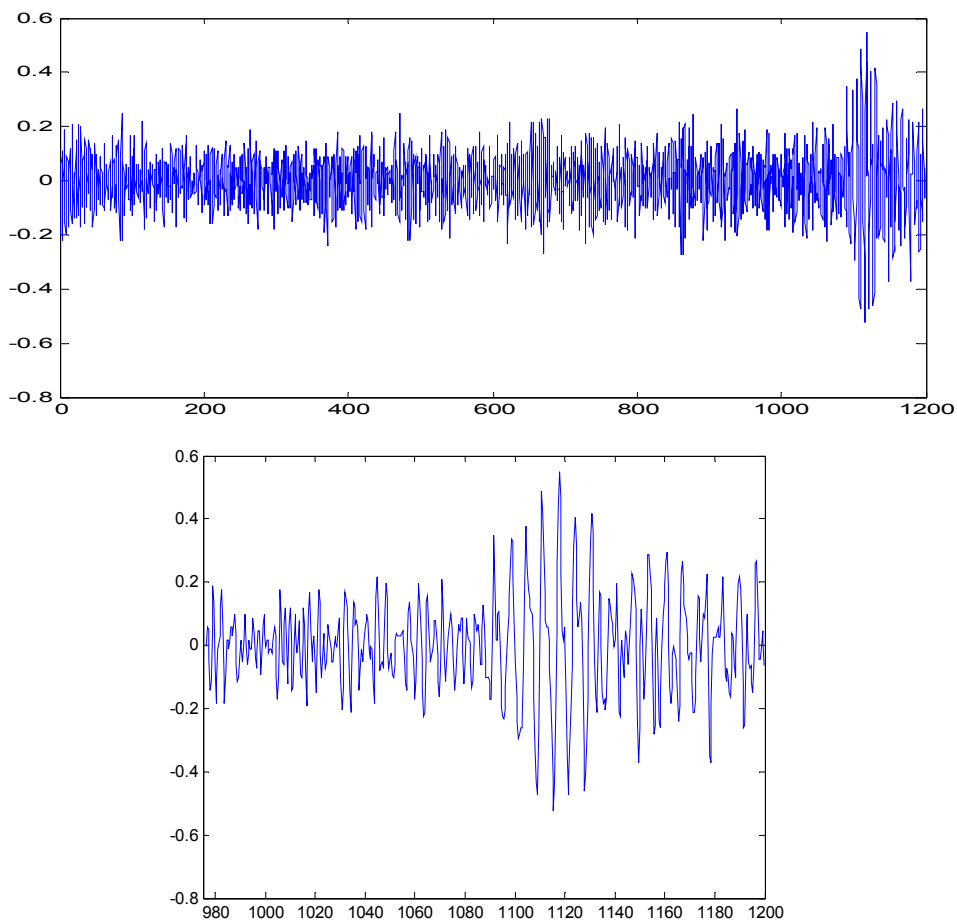
LLOBREGAT											
Year	Initial	e1	e2	e3	e_50	e4	e_al	e_bump	e_sh	visual	Final
2001	1.939	0	711	408	296	0	0	11	13	0	500
2002	7.051	0	2.256	2.092	769	0	0	20	0	0	1.914
2003	8.332	2	3.512	2.212	765	0	0	32	13	0	1.796
2004	274	0	239	25	5	0	0	0	0	0	5
	17.322	2	6.479	4.712	1.830	0	0	63	26	0	4.215

TORTOSA											
Year	Initial	e1	e2	e3	e_50	e4	e_al	e_bump	e_sh	visual	Final
1991	1.003	0	71	5	471	0	76	0	0	0	380
1992	1.935	0	75	16	593	0	139	0	0	0	1.112
1993	2.990	4	62	14	1.016	1	218	0	0	0	1.675
1994	3.219	3	69	22	997	1	185	2	0	0	1.940
1995	1.132	1	17	9	290	0	31	0	0	0	784
1996	2.098	2	63	24	704	0	40	0	0	0	1.265
1997	829	1	18	9	331	0	34	0	0	0	436
1998	-	-	-	-	-	-	-	-	-	-	-
1999	-	-	-	-	-	-	-	-	-	-	-
2000	-	-	-	-	-	-	-	-	-	-	-
2001	6.706	7	2.396	20	1.690	25	480	7	0	1	2.080
2002	3.101	0	897	15	933	7	250	1	0	0	998
2003	-	-	-	-	-	-	-	-	-	-	-
2004	6.924	1	2.696	108	1.431	11	537	18	0	8	2.114
2005	7.009	2	2.417	59	1.964	15	418	6	0	1	2.127
2006	7.762	8	1.653	6	2.221	13	452	0	0	0	3.409
	44.708	29	10.434	307	12.641	73	2.860	34	0	10	18.320

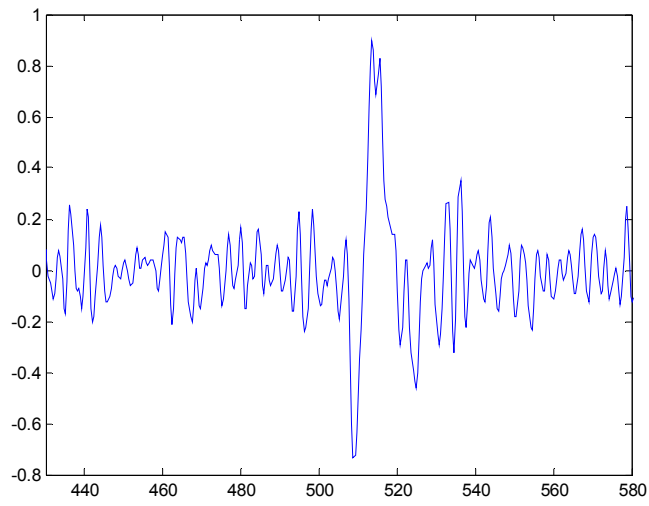
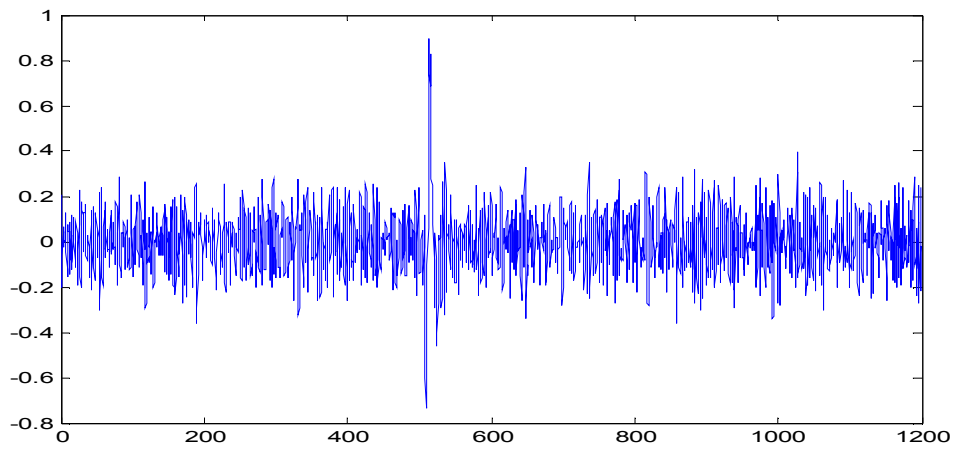
APPENDIX B: Freak waves

Freak waves have been defined as those with $H \geq 2.83H_s$. Although the particular analysis of freak waves occurrence is not covered in the present study, a complementary analysis is carried out by looking for all the freak waves present in the analysed data, attending to the above mentioned criterion. Three records have been detected in the Mediterranean data whereas none in those of North Sea. They are illustrated below (the first pictures are of the entire record whereas the second ones are an enlargement). The x-axis represents time (in seconds) and the y-axis surface elevation (in meters).

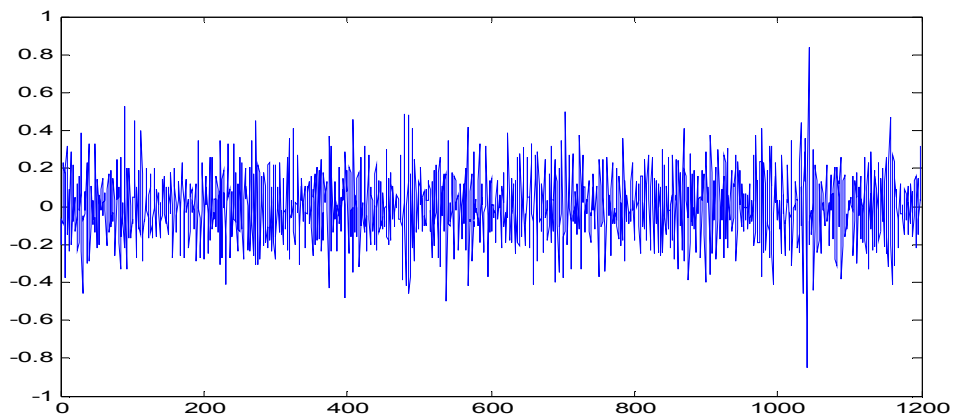
Llobregat: 01/06/02 03:20h

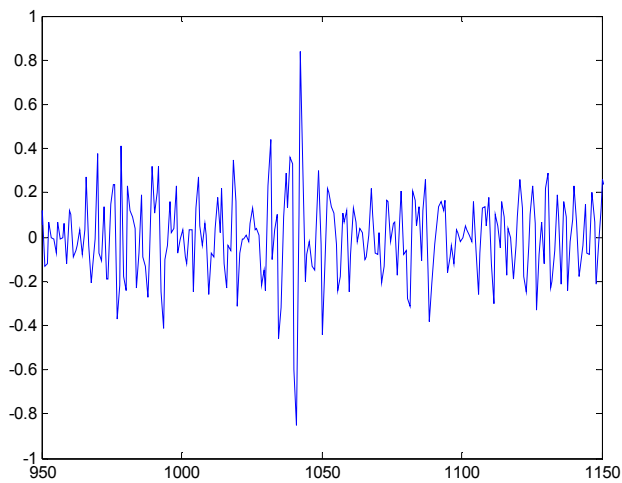


Roses: 13/07/03 18:20h



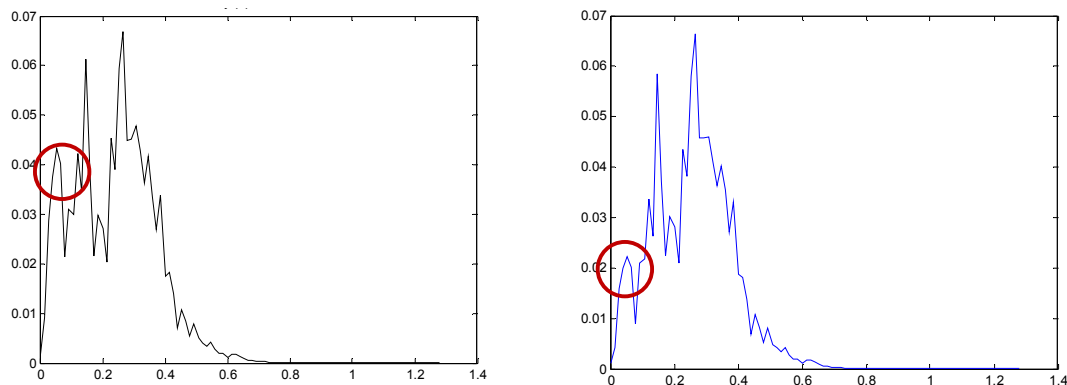
Tortosa: 30/12/05 08:00h





At first sight, the last two are more similar to the academic shape of a freak wave: a single wave which is extremely high compared to the ones around it. In the first case it is not clear. Instead of a freak wave it seems to be a non stationary wave record in which a constant standard deviation cannot be applied for all the record.

It is important to remark that these three freak waves were removed by the quality control because of their low significant wave height. Also, freak waves appear to be related to spectral energy at low frequencies. In the following pictures (x-axis frequency in Hz and y-axis spectral energy in m^2/Hz), there is the original spectrum (left) of the freak wave's record of Roses, and the same, after subtracting the freak wave (right).



If considering the amount of waves of the filtered data (about 12.6 million waves), the 3 freak waves represents 1 freak wave per 4.2 million waves. In linear theory, considering 4.2 million waves, the expected value for the normalized maximum wave height (normalized dividing by the significant wave height) is approx. 2.8, practically the same value as the threshold in the definition of freak wave. Therefore it seems that for this data, the freak waves can be predicted by the linear theory although it may be a coincidence.

APPENDIX C: MATLAB code

The Matlab code, that was developed for the present study, basically consists of two programs which process the total amount of data in an automatic way. Each buoy-year is analysed separately and then saved in *.mat* files. The first program reads all the raw data of the selected year-buoy and proceeds with a part of the quality analysis more related to rough errors. Afterwards, in the second program, the rest of the quality analysis is done and also the statistical and spectral analysis. Finally, in order to study particular facets or interactions between parameters, and plot some illustrative figures, smaller complementary programs have been designed and used, extracting the needed information of each file. An example of such complementary programs is the one which concatenate the records in order to obtain the observations of maximum wave heights for different number of waves.

For the Norwegian data the first part has been modified and adapted to the different file types.

1 First analysis

```
clear all
year=input('Year: ','s');
buoy=input('Buoy(Tortosa/Llobregat/Roses/Blanes): ','s');
%-----Define parameters
g=9.81;
%-----Define the parameters of the number of
errors
e1=0; %The lenght is not correct
e2=0; %The vertical acceleration is larger than a half g
e3=0; %There are "gaps"
%-----Define characteristics parameters of each
buoy/year
if strcmp(buoy,'Tortosa')==1
    dt=1/1.28;
    if
strcmp(year,'2001')==1|strcmp(year,'2002')==1|strcmp(year,'2004')==1|st
rcmp(year,'2005')==1|strcmp(year,'2006')==1
        len=1535;
    else
        len=1536;
    end
    ncolumn=4;
    colH=2;
    ext='.RAW';
else
    dt=1/2.56;
    if strcmp(buoy,'Llobregat')==1
        if
strcmp(year,'2001')==1|strcmp(year,'2002')==1|strcmp(year,'2003')==1|st
rcmp(year,'2004')==1
            ext='.1RW';
            len=3072;
            ncolumn=1;
```

```

        colH=1;
    else
        ext='.RAW';
        len=1535;
        ncolum=4;
        colH=1;
    end

    end

    if strcmp(buoy, 'Roses')==1
        ext='.2RW';
        len=3072;
        ncolum=1;
        colH=1;
    end

    if strcmp(buoy, 'Blanes')==1
        ext='.3RW';
        len=3072;
        ncolum=1;
        colH=1;
    end

    end

    end

%The interval time for all the buoys is the same. The duration may be
different
    D=dt*len;
    t=dt/2:dt:D-dt/2;
    t=t';
    data=[];
    cont_data2=[];
    cont_data3=[];
    cont=[];
    conter1=[];
    conter2=[];
    conter3=[];
    er3='No';
    er3bis='No';
    l=1;

%-----Quality control
%-----Yearly analysis
    filenames=dir(['D:/Els          meus          Documents/5è          de
camins/tesina/dvd/rawdata/', year, '/', buoy, '/', ext, ''])
    for i=1:length(filenames)
        fid=fopen(['D:/Els          meus          Documents/5è          de
camins/tesina/dvd/rawdata/', year, '/', buoy, '/', filenames(i).name, ''])
    );
        if strcmp(buoy, 'Tortosa')==1
            r=fscanf(fid, '%f,%f,%f,%f', [ncolum, len]);
        else
            r=fscanf(fid, '%f', [ncolum, len]);
        end
        fclose(fid);
        r=r';
        rcolumnH=r(:, colH)/100;%units m
        rtt=diff(rcolumnH, 2)/(dt^2);%second derivative
        rtt_ind=find(abs(rtt)<10^(-4));
        if length(rcolumnH)==len;%-----Length control

```

```

if max(abs(rtt)) < (1/2)*g%-----Spikes control
while l < length(rtt_ind)-1%-----"Gaps" control
    a=rtt_ind(l);
    b=rtt_ind(l+1)-1;
    c=rtt_ind(l+2)-2;
    if
a==b;%(rtt_ind(l)+2)==(rtt_ind(l+1)+1)==rtt_ind(l+2);
        if b==c;
            l1=1;
            l=2*length(rtt);
            l2=l1+3;
            %er3='Yes';
        end
    end
    l=l+1;
end
    l2=l1+3;
%
if l > length(rtt)
    while l2 < length(rtt_ind)-1;
        if strcmp(er3,'No')==1;
            a=rtt_ind(l2);
            b=rtt_ind(l2+1)-1;
            c=rtt_ind(l2+2)-2;
            if a==b;
                if b==c;
                    er3='Yes';
                    l=1;
                end
            end
            l2=l2+1;
        else
            l2=length(rtt_ind);
        end
    end
end
if strcmp(er3,'No')==1
    data=[data,rcolumH];
    siz=size(data);
    j=siz(1,2);
    cont=[cont;i,j];
else
    cont_data3=[cont_data3,rcolumH];
    disp(['Error',filenames(i).name,'']);
    conter3=[conter3;i];
    e3=e3+1;
end
else
    cont_data2=[cont_data2,rcolumH];
    disp(['The vertical acceleration is larger than
1/2g in the record ',filenames(i).name,'']);
    e2=e2+1;
    conter2=[conter2;i];
end
else
    disp(['The length of the time record is not the
appropriate ',filenames(i).name,'']);
    e1=e1+1;
end

```

```

        conter1=[conter1;i];
    end
    %i=i+1;
    er3='No';
    l=1;
end
%-----Remove trend
y=detrend(data);
s=size(y);
n=s(1,2);%number of records
%-----Checking
check=10;%number of randomly chosen records
u=ceil(rand(check,1)*n);
figure(1)
for i=1:check;
    subplot(5,2,i),plot(t,y(:,u(i)));
    title(['',buoy,' ',filenames(cont(u(i),1)).name,' ',year,'']);
end
%Error 2
if e2>0
    uc2=ceil(rand(check,1)*length(conter2));
    figure(2)
    for i=1:check;
        subplot(5,2,i),plot(t,cont_data2(:,uc2(i)));
        title(['',buoy,' ',filenames(conter2(uc2(i),1)).name,'
',year,'']);
    end
end
%Error 3
if e3>0
    uc3=ceil(rand(check,1)*length(conter3));
    figure(3)
    for i=1:check;
        subplot(5,2,i),plot(t,cont_data3(:,uc3(i)));
        title(['',buoy,' ',filenames(conter3(uc3(i),1)).name,'
',year,'']);
    end
end
%-----Save the results
%save(['C:/THESISnew/RESULTS/data',year,buoy,'']);
save(['D:/Els meus Documents/5è de
camins/tesina/NOU/RESULTATSqualitycontrol/',year,buoy,'']);

```

2 Second analysis

```

clear all
year=input('Year: ','s');
buoy=input('Buoy(Tortosa/Llobregat/Roses/Blanes): ','s');
tap=input('Tapering?(Y/N) ','s');
load(['D:/Els meus Documents/5è de
camins/tesina/NOU/RESULTATSqualitycontrol/',year,buoy,'.mat']);
%Depth definition
if strcmp(buoy,'Tortosa')==1
    h=60;
elseif strcmp(buoy,'Roses')==1

```

```

        h=46;
    elseif strcmp(buoy, 'Llobregat')==1
        h=45;
    elseif strcmp(buoy, 'Blanes')==1
        h=74;
    end
    resp='No'

%=====Statistical analysis=====
    dev=std(y); %Standard deviation
    H=[];
    T=[];
    wave=[];
    not_wave=[];
    chicrest=[];
    chitrough=[];
    cont_prova=[];
    num_1third=[];
    Hmax=[];
    H1third=[];
    H1third_crest=[];
    chilthird=[];
    chilthird_trough=[];
    chilthird_H=[];
    chilthird_trough_H=[];
    chimax=[];
    chimin=[];
    num_not_wave=[];
    num_wave=[];
    Hmean=[];
    Tmean=[];
    T1third=[];
    Hrms=[];
    cont_new=[];
    cont_notrecord=[];
    chimean=[];
    chimean_trough=[];
    chirms=[];
    chirms_trough=[];
    relHchicrest=[];
    relHchitrough=[];
    relHchicrest2=[];
    relHchitrough2=[];
    e10=0;
    e_fix2=0;

    figure(1)%Rayleigh distribution (with Hnorm)
    subplot(1,2,1)
    plot((0:0.25:9),exp(log(-8*log(Ray((0:0.25:9)/4)))/2),'r');
    hold on
    subplot(1,2,2)
    semilogy((0:0.25:9),Ray((0:0.25:9)/4),'r');
    hold on
    ii=0;
    iii=0;
    for i=1:n;
        ind_zero=find(diff(sign(y(:,i)))==-2|diff(sign(y(:,i)))==-1);

```

```

for j=1:length(ind_zero)-1
    chi=y(ind_zero(j)+1:ind_zero(j+1),i)
    inc_t_zero1=y(ind_zero(j),i)*dt/(y(ind_zero(j),i)-
y(ind_zero(j)+1,i));
    inc_t_zero2=y(ind_zero(j+1),i)*dt/(y(ind_zero(j+1),i)-
y(ind_zero(j+1)+1,i));
    tchi_ini_aprox=t(ind_zero(j))+inc_t_zero1;
    tchi_fin_aprox=t(ind_zero(j+1))+inc_t_zero2;

    if (max(chi)-min(chi))>0.05%&tchi_fin_aprox-
tchi_ini_aprox>0%reject very small "waves
        if abs(max(chi))>0.025;
            if tchi_fin_aprox-tchi_ini_aprox>2*dt
                chicrest=[chicrest,max(chi)];
                chitrough=[chitrough,min(chi)];
                H=[H,max(chi)-min(chi)];
                T=[T,tchi_fin_aprox-tchi_ini_aprox];
                wave=[wave,j];
            else
                not_wave=[not_wave,j];
            end
        else
            not_wave=[not_wave,j];
        end
    else
        not_wave=[not_wave,j];
    end
end
num_1third=[num_1third,floor(length(H)/3)];
H=H';
[H_sort,indexH_sort]=sort(H);

[chicrest_sort,indexchicrest_sort]=sort(chicrest);

[chitrough_sort,indexchitrough_sort]=sort(chitrough);
H1third=[H1third,mean(H_sort((length(H)-
num_1third(length(num_1third)):length(H))))];
chilthird=[chilthird,mean(chicrest_sort((length(H)-
num_1third(length(num_1third)):length(H))))];

Hmax=[Hmax,max(H)];
[m indmax]=max(abs(y(:,i)));
indmax2=indmax+1;
indmax3=indmax-1;
if indmax==len;
    indmax2=indmax-2;%
end
if indmax==1;
    indmax3=indmax+2;
end
if H1third>0.5;
    if strcmp(resp,'No')
        if
abs(y(indmax,i))<2.83*(chilthird(length(chilthird))%&(max(abs(y(:,
length(Hmax))))<3*chilthird;%%%Threshold
            ii=ii+1;
            prova=sort(H'./chicrest);

```

```

relHchicrest=[relHchicrest,prova(floor(length(H)/2))];
relHchitrough=[relHchitrough,mean(H'./abs(chitrough))];
relHchicrest2=[relHchicrest2,mean(H')/mean(chicrest)];
relHchitrough2=[relHchitrough2,
mean(H')/mean(abs(chitrough))];
chilthird=[chilthird,mean(chicrest_sort((length(H)-
num_1third(length(num_1third)):length(H))))];
chilthird_trough=[chilthird_trough,abs(mean(chitrough_s
ort((1:num_1third(length(num_1third))))))];
chilthird_H=[chilthird_H,mean(chicrest(indexH_sort((len
gth(H)-num_1third(length(num_1third)):length(H)))));
chilthird_trough_H=[chilthird_trough_H,abs(mean(chitrou
gh(indexH_sort((length(H)-
num_1third(length(num_1third)):length(H))))));
H1third_crest=[H1third_crest,mean(H(indexchicrest_sort(
(length(H)-
num_1third(length(num_1third)):length(H)))));
chimax=[chimax,max(chicrest)];
chimin=[chimin,abs(min(chitrough))];
num_not_wave=[num_not_wave,length(not_wave)];
num_wave=[num_wave,length(wave)];
Hnorm_sort=H_sort/dev(i);
Hnorm_sort=sort(Hnorm);
Hmean=[Hmean,mean(H)];
chimean=[chimean,mean(chicrest)];
chimean_trough=[chimean_trough,abs(mean(chitrough))];
Hrms=[Hrms,sqrt(mean(H.^2))];
chirms=[chirms,sqrt(mean(chicrest.^2))];
chirms_trough=[chirms_trough,sqrt(mean(chitrough.^2))];
Tmean=[Tmean,mean(T)];
T1third=[T1third,mean(T(indexH_sort((length(H)-
num_1third(length(num_1third)):length(H)))));

ind=[1:length(H)];
P=ind./length(H);
subplot(1,2,1)
plot(Hnorm_sort,exp(log(-8*log(1-P))/2))
hold on
subplot(1,2,2)
semilogy(Hnorm_sort,1-P)
hold on
cont_new=[cont_new;cont(i,:),ii];
elseif
abs(y(indmax2,i))>2.83*(chilthird(length(chilthird)))&abs(y
(indmax3,i))>2.83*(chilthird(length(chilthird)))
    ii=ii+1;
    prova=sort(H'./chicrest);

    relHchicrest=[relHchicrest,prova(floor(length(H)/2))]
    ;
    relHchitrough=[relHchitrough,mean(H'./abs(chitrough))
];
    relHchicrest2=[relHchicrest2,mean(H')/mean(chicrest)]
;
    relHchitrough2=[relHchitrough2,
mean(H')/mean(abs(chitrough))];

```

```

chilthird=[chilthird,mean(chicrest_sort((length(H)-
num_1third(length(num_1third)):length(H)))];
chilthird_trough=[chilthird_trough,abs(mean(chitrough_s
ort((1:num_1third(length(num_1third))))));
chilthird_H=[chilthird_H,mean(chicrest(indexH_sort((len
gth(H)-num_1third(length(num_1third)):length(H))))];
chilthird_trough_H=[chilthird_trough_H,abs(mean(chitrou
gh(indexH_sort((length(H)-
num_1third(length(num_1third)):length(H))))]);
H1third_crest=[H1third_crest,mean(H(indexchicrest_sort(
(length(H)-
num_1third(length(num_1third)):length(H))))];
chimax=[chimax,max(chicrest)];
chimin=[chimin,abs(min(chitrough))];
num_not_wave=[num_not_wave,length(not_wave)];
num_wave=[num_wave,length(wave)];
Hnorm_sort=H_sort/dev(i);
Hmean=[Hmean,mean(H)];
chimean=[chimean,mean(chicrest)];
chimean_trough=[chimean_trough,abs(mean(chitrough))];
Hrms=[Hrms,sqrt(mean(H.^2))];
chirms=[chirms,sqrt(mean(chicrest.^2))];
chirms_trough=[chirms_trough,sqrt(mean(chitrough.^2))];
Tmean=[Tmean,mean(T)];
T1third=[T1third,mean(T(indexH_sort((length(H)-
num_1third(length(num_1third)):length(H))))];
ind=[1:length(H)];
P=ind./length(H);
subplot(1,2,1)
plot(Hnorm_sort,exp(log(-8*log(1-P))/2))
hold on
subplot(1,2,2)
semilogy(Hnorm_sort,1-P)
hold on
cont_new=[cont_new;cont(i,:),ii];
cont_prova=[cont_prova;i];
else
iii=iii+1;
num_1third(length(num_1third))=[];
H1third(length(H1third))=[];
jaja=chilthird;
jeje=max(chicrest);
jojo=max(abs(chitrough));
chilthird(length(chilthird))=[];
Hmax(length(Hmax))=[];
dev(length(Hmax))=[];
y(:,length(Hmax))=[];
cont_notrecord=[cont_notrecord,i];
end
else
e_fix2=e_fix2+1;
num_1third(length(num_1third))=[];
H1third(length(H1third))=[];
chilthird(length(chilthird))=[];
Hmax(length(Hmax))=[];
cont_notrecord=[cont_notrecord;cont(i,:)];
cont_notrecord=[cont_notrecord,i];
%

```

```

        end
    else
%
        e10=e10+1;

        num_1third(length(num_1third))=[];
        H1third(length(H1third))=[];
        chilthird(length(chilthird))=[];
        Hmax(length(Hmax))=[];
        cont_notrecord=[cont_notrecord,i];
    end

    T=[];
    H2=H;
    H=[];
    not_wave=[];
    wave=[];
    chicrest=[];
    chitrough=[];
end
perc_not_wave=(num_not_wave./num_wave)*100;
perc_not_wave_mean=mean(perc_not_wave);
saveas(1,['D:/Els          meus          Documents/5è          de
CAMINS/tesina/NOU/RESULTATSanalysis1NOU/Figures/Hprob/',year,buoy,''],'
fig')
saveas(1,['D:/Els          meus          Documents/5è          de
CAMINS/tesina/NOU/RESULTATSanalysis1NOU/Figures/Hprob/',year,buoy,''],'
emf')
hold off

if length(cont_notrecord)>0.5
    y(:,cont_notrecord)=[];
    dev(:,cont_notrecord)=[];
    s=size(y);
    n=s(1,2);

end
kurt=kurtosis(y);
ske=skewness(y);

%Gaussian distribution
[pr prr]=sort(Hmax);

i=ceil(rand(1,9)*s(1,2));

for l=1:length(i)
    surf=linspace(min(y(:,i(l))),max(y(:,i(l)))));
    p=(1/(sqrt(2*pi)*dev(i(l))))*exp(-
(surf.^2)/(2*(dev(i(l))^2)));
    for j=2:length(p)
        int_p(j)=trapz(surf(1:j),p(1:j));
    end

    figure(2)%cdf (normal plot)
    subplot(3,3,1)
    normplot(y(:,i(l)))

```

```

        title(['kurt:          ', num2str(kurt(i(1))), ',          skew:
', num2str(ske(i(1))), ','])
        saveas(2, ['D:/Els          meus          Documents/5è          de
CAMINS/tesina/NOU/RESULTATSanalysis1NOU/Figures/cdfgaus/', year, buoy, '']
, 'fig')
        saveas(2, ['D:/Els          meus          Documents/5è          de
CAMINS/tesina/NOU/RESULTATSanalysis1NOU/Figures/cdfgaus/', year, buoy, '']
, 'emf')

        figure(3)%pdf (histogram)
        subplot(3,3,1)
        [bincounts binpositions]=hist(y(:,i(1)),20);
        delta=abs(binpositions(1)-binpositions(2));
        area_hist=delta*len;
        y_norm=normpdf(sort(y(:,i(1))),0,dev(i(1)));
        hist(y(:,i(1)),20)
        hold on
        plot(sort(y(:,i(1))),area_hist*y_norm,'r','LineWidth',2);
        title(['kurt:          ', num2str(kurt(i(1))), ',          skew:
', num2str(ske(i(1))), ','])
        saveas(3, ['D:/Els          meus          Documents/5è          de
CAMINS/tesina/NOU/RESULTATSanalysis1NOU/Figures/pdfgaus/', year, buoy, '']
, 'fig')
        saveas(3, ['D:/Els          meus          Documents/5è          de
CAMINS/tesina/NOU/RESULTATSanalysis1NOU/Figures/pdfgaus/', year, buoy, '']
, 'emf')

%=====Spectral analysis=====
Y=[];
E=[];
G=1;

%-----Tapering (optional)
if strcmp(tap, 'Y')==1
%   pertap=input('% tapering? ');
    pertap=10;
    r=pertap/100;
    for i=1:s(1,2)
        ytap(:,i)=y(:,i).*tukeywin(len,r);
    end
    ybef=y;
    y=ytap;
    G=1-5/(8*(1/r));
end

%-----Without splitting the record
if strcmp(buoy, 'Tortosa')==1
    len2=1536;
else
    len2=3072;
end
fftw('planner','hybrid');%optimise the fft method

Y=fft(y,len2);
df=1/D;
D2=len2*dt;
df2=1/D2;

```

```

    freq2=[0:len2-1]*df2;
    %define the density spectrum
    E=(1/G)*(1/df)*(1/2)*(abs(Y)/(len/2)).^2;
    E([1,2],:)=zeros(2,n);

%-----Splitting
    p=16;%24;%input('Number of segments: ');
    dsf2=p*df2;
    num2=(len2)/p;
    freqq2=[0:num2-1]*dsf2;

    for i=1:num2
        for j=1:n
            EE(i,j)=(1/p)*sum(E(1+(i-1)*p:i*p,j));
        end
    end
    dsf=p*df;

%Definition of the "real" spectrum (0.03Hz-Nyq freq)
    S=EE(1:num2/2+1,:);%I do not consider f<0.03Hz
    Sini=E(1:len2/2+1,:);
    f=freqq2(1:num2/2+1);
    fini=freq2(1:len2/2+1);
    fNyq=1/(2*dt);
    EE=[];
    Y=[];

%Aliasing
    m=[];
    for i=1:5
        for j=1:s(1,2)
            int=(f'.^(i-1)).*S(:,j);
            m(i,j)=trapz(f,int);
        end
    end
    m0=m(1,:); m1=m(2,:); m2=m(3,:);
    Tm=m0./m1;
    fm=1./Tm;
    ind_aliasing=find(fNyq./fm<2.2);
    e_aliasing=length(ind_aliasing);

    H1third(ind_aliasing)=[];
    ch1third(ind_aliasing)=[];
    relHchicrest(ind_aliasing)=[];
    Hmax(ind_aliasing)=[];
    num_1third(ind_aliasing)=[];
    relHchitrough(ind_aliasing)=[];
    relHchicrest2(ind_aliasing)=[];
    relHchitrough2(ind_aliasing)=[];
    ch1third_trough(ind_aliasing)=[];
    ch1third_H(ind_aliasing)=[];
    ch1third_trough_H(ind_aliasing)=[];
    H1third_crest(ind_aliasing)=[];
    chimin(ind_aliasing)=[];
    chimax(ind_aliasing)=[];
    num_not_wave(ind_aliasing)=[];

```

```

num_wave(ind_aliasing)=[];

m0(ind_aliasing)=[];
m1(ind_aliasing)=[];
m2(ind_aliasing)=[];

Hmean(ind_aliasing)=[];
chimean(ind_aliasing)=[];
chimean_trough(ind_aliasing)=[];
Hrms(ind_aliasing)=[];
chirms(ind_aliasing)=[];
chirms_trough(ind_aliasing)=[];
Tmean(ind_aliasing)=[];
Tlthird(ind_aliasing)=[];
perc_not_wave(ind_aliasing)=[];
kurt(ind_aliasing)=[];
ske(ind_aliasing)=[];
dev(ind_aliasing)=[];
y(:,ind_aliasing)=[];
ybef(:,ind_aliasing)=[];
S(:,ind_aliasing)=[];
Sini(:,ind_aliasing)=[];
cont_new(ind_aliasing,:)=[];

s=size(y);
n=s(1,2);

%Bump
E_zero=S(1,:);
ind_bump=find(E_zero>0.004);
e_bump=length(ind_bump);

prova=mean(4*sqrt(m0(ind_bump)))

Hlthird(ind_bump)=[];
chilthird(ind_bump)=[];
relHchicrest(ind_bump)=[];
Hmax(ind_bump)=[];
num_lthird(ind_bump)=[];
relHchitrough(ind_bump)=[];
relHchicrest2(ind_bump)=[];
relHchitrough2(ind_bump)=[];
chilthird_trough(ind_bump)=[];
chilthird_H(ind_bump)=[];
chilthird_trough_H(ind_bump)=[];
Hlthird_crest(ind_bump)=[];
chimin(ind_bump)=[];
chimax(ind_bump)=[];
num_not_wave(ind_bump)=[];
num_wave(ind_bump)=[];

m0(ind_bump)=[];
m1(ind_bump)=[];
m2(ind_bump)=[];

Hmean(ind_bump)=[];
chimean(ind_bump)=[];

```

```

chimean_trough(ind_bump)=[];
Hrms(ind_bump)=[];
chirms(ind_bump)=[];
chirms_trough(ind_bump)=[];
Tmean(ind_bump)=[];
Tlthird(ind_bump)=[];
perc_not_wave(ind_bump)=[];
kurt(ind_bump)=[];
ske(ind_bump)=[];
dev(ind_bump)=[];
y(:,ind_bump)=[];
ybef(:,ind_bump)=[];
S(:,ind_bump)=[];
Sini(:,ind_bump)=[];
cont_new(ind_bump,:)=[];

s=size(y);
n=s(1,2);

%Deep water
T0=sqrt(m0./m2);
L0=g*T0.^2/(2*pi);%Hypothesis: deep water

for i=1:length(L0);
    if h>=L0(i)/2 %Checking the hypothesis of deep water
        water(i)=1;%Deep water
    elseif h<L0/20
        water(i)=2;%Shallow water
    else
        water(i)=3;%Intermediate water
        dist(i)=L0(i)/2-h;
    end
end

ind_shallow=find(water>1);
e_shallow=length(ind_shallow);

Hlthird(ind_shallow)=[];
chilthird(ind_shallow)=[];
relHchicrest(ind_shallow)=[];
Hmax(ind_shallow)=[];
num_lthird(ind_shallow)=[];
relHchitrough(ind_shallow)=[];
relHchicrest2(ind_shallow)=[];
relHchitrough2(ind_shallow)=[];
chilthird_trough(ind_shallow)=[];
chilthird_H(ind_shallow)=[];
chilthird_trough_H(ind_shallow)=[];
Hlthird_crest(ind_shallow)=[];
chimin(ind_shallow)=[];
chimax(ind_shallow)=[];
num_not_wave(ind_shallow)=[];
num_wave(ind_shallow)=[];
Hmean(ind_shallow)=[];
chimean(ind_shallow)=[];

```

```

chimean_trough(ind_shallow)=[];
Hrms(ind_shallow)=[];
chirms(ind_shallow)=[];
chirms_trough(ind_shallow)=[];
Tmean(ind_shallow)=[];
Tlthird(ind_shallow)=[];
perc_not_wave(ind_shallow)=[];
kurt(ind_shallow)=[];
ske(ind_shallow)=[];
dev(ind_shallow)=[];
y(:,ind_shallow)=[];
ybef(:,ind_shallow)=[];
S(:,ind_shallow)=[];
Sini(:,ind_shallow)=[];
cont_new(ind_shallow,:)=[];

s=size(y);
n=s(1,2);

%Plot randomly spectra
check=10;%number of randomly chosen spectra
u=ceil(rand(check,1)*s(1,2));
figure(4)
for i=1:check;
    subplot(5,2,i),
    plot(fini(:),Sini(:,u(i)),'b')%%the area of interest is f=<fnyq
    hold on
    plot(f(:),S(:,u(i)),'k')
    title(['',buoy,' ',filenames(cont_new(u(i),1)).name,'
',year,'']);
    end
    saveas(4,['D:/Els meus Documents/5è de
CAMINS/tesina/NOU/RESULTATSanalysis1NOU/Figures/spectra/',year,buoy,'']
,'fig')
    saveas(4,['D:/Els meus Documents/5è de
CAMINS/tesina/NOU/RESULTATSanalysis1NOU/Figures/spectra/',year,buoy,'']
,'emf')
    hold off

%Spectral parameters
m=[];
for i=1:5
    for j=1:s(1,2)
        int=(f'.^(i-1)).*S(:,j);
        m(i,j)=trapz(f,int);
    end
end
m0=m(1,:); m1=m(2,:); m2=m(3,:); m3=m(4,:); m4=m(5,:);

Hm0=4*sqrt(m0);
chim0=Hm0/2;

HmR=((2*pi*m0).^(1/2));
HrmsR=((8*m0).^(1/2));

chimR=HmR/2;

```

```

chirmsR=Hrms/2;%I have to check if it is directly half the Hrms

%Other parameters
Tm=m0./m1;
T0=sqrt(m0./m2);%Mean period between downcrossings
Tc=sqrt(m2./m4);%Mean period between crests
eps_2=sqrt(1-((m2.^2)/(m0.*m4)));%Spectral width EPS4
nu=sqrt((m0.*m2)/(m1.^2))-1;%Spectral width EPS2
for j=1:s(1,2)
    Qp(j)=(2./(m0(j).^2)).*trapz(f,f'.*(S(:,j).^2%
    kappa(j)=sqrt((trapz(f,S(:,j)).*(cos(2.*pi.*f.*T0(j))))).^2+(tr
    apz(f,S(:,j)).*(sin(2.*pi.*f.*T0(j))))).^2./m0(j);
end

%Peak frequency
[Smax,indfp]=max(S);
fp=f(indfp);
fp=fp';

Ss=(2*pi*Hm0)/(g*(T0.^2));%Significant Steepness

L0=g*T0.^2/(2*pi);
k0=2*pi./(L0);

fftw('wisdom', []);

save(['D:/Els          meus          Documents/5è          de
CAMINS/tesina/NOU/RESULTATSanalysis1NOU/',year,buoy, '']);

```

3 Example of complementary program: Maximum wave height

```

clear all
BFI_tot=[];
BFI_tot2=[];
kurt_tot=[];
ske_tot=[];
num_wave_tot=[];
Hnmax_tot=[];
Hnmean_tot=[];
crestnmax_tot=[];
troughnmax_tot=[];
dev_tot=[];
crest1third_all=[];
H1third_all=[];
m0_all=[];

buoy='Tortosa';
any=[1991,1992,1993,1994,1995,1996,1997,2001,2002,2004,2005,2006];
% any=[2001,2002,2004,2005,2006];
for i=1:length(any);
    year=num2str(any(i));
    load(['D:/Els          meus          Documents/5è          de
CAMINS/tesina/NOU/RESULTATSanalysis1NOU/',year,buoy, '.mat'], 'm0', 'Hmean

```

```

', 'ske', 'BFI', 'kurt', 'num_wave', 's', 'Hmax', 'chimax', 'chimin', 'dev', 'Hm0
', 'chim0', 'H1third', 'chilthird', 'chilthird_trough', 'eps_2');
    eps_tot=[eps_tot,eps_2];
    m0_all=[m0_all,m0];
    H1third_all=[H1third_all,H1third];
    crest1third_all=[crest1third_all,chilthird];
    Hnmax_tot=[Hnmax_tot,Hmax./dev];
    Hnmean_tot=[Hnmean_tot,Hmean./dev];
    crestnmax_tot=[crestnmax_tot,chimax./dev];
    troughnmax_tot=[troughnmax_tot,chimin./dev];
    BFI_tot=[BFI_tot,BFI];
    kurt_tot=[kurt_tot,kurt];
    ske_tot=[ske_tot,ske];
    s_tot=[s_tot,s(1,2)];
    dev_tot=[dev_tot,dev];
    num_wave_tot=[num_wave_tot,num_wave];

end
lenT=length(crestnmax_tot);

buoy='Llobregat';
any=[2001,2002,2003,2004];
for i=1:length(any)

    year=num2str(any(i));
    load(['D:/Els meus Documents/5è de
CAMINS/tesina/NOU/RESULTATSanalysis1NOU/',year,buoy,'.mat'],'m0','Hmean
','ske','BFI','kurt','num_wave','s','Hmax','chimax','chimin','dev','Hm0
','chim0','H1third','chilthird','chilthird_trough','eps_2');
    eps_tot=[eps_tot,eps_2];
    m0_all=[m0_all,m0];
    H1third_all=[H1third_all,H1third];
    crest1third_all=[crest1third_all,chilthird];
    Hnmax_tot=[Hnmax_tot,Hmax./dev];
    Hnmean_tot=[Hnmean_tot,Hmean./dev];
    crestnmax_tot=[crestnmax_tot,chimax./dev];
    troughnmax_tot=[troughnmax_tot,chimin./dev];
    BFI_tot=[BFI_tot,BFI];
    kurt_tot=[kurt_tot,kurt];
    ske_tot=[ske_tot,ske];
    s_tot=[s_tot,s(1,2)];
    dev_tot=[dev_tot,dev];
    num_wave_tot=[num_wave_tot,num_wave];
end
lenL=length(crestnmax_tot)-(lenT);

buoy='Roses';
any=[2001,2002,2003,2004,2005,2006];
for i=1:length(any)

    year=num2str(any(i));
    load(['D:/Els meus Documents/5è de
CAMINS/tesina/NOU/RESULTATSanalysis1NOU/',year,buoy,'.mat'],'m0','ske',
'Hmean','BFI','kurt','num_wave','s','Hmax','chimax','chimin','dev','Hm0
','chim0','H1third','chilthird','chilthird_trough','eps_2');
    eps_tot=[eps_tot,eps_2];
    m0_all=[m0_all,m0];

```

```

H1third_all=[H1third_all,H1third];
crest1third_all=[crest1third_all,chilthird];
Hnmax_tot=[Hnmax_tot,Hmax./dev];
Hnmean_tot=[Hnmean_tot,Hmean./dev];
crestnmax_tot=[crestnmax_tot,chimax./dev];
troughnmax_tot=[troughnmax_tot,chimin./dev];
BFI_tot=[BFI_tot,BFI];
kurt_tot=[kurt_tot,kurt];
ske_tot=[ske_tot,ske];
s_tot=[s_tot,s(1,2)];
dev_tot=[dev_tot,dev];
num_wave_tot=[num_wave_tot,num_wave];
end
lenR=length(crestnmax_tot)-(lenL+lenT);

buoy='Blanes';
any=[2002,2003,2004,2005,2006];
for i=1:length(any)

    year=num2str(any(i));
    load(['D:/Els meus Documents/5è de
CAMINS/tesina/NOU/RESULTATSanalysis1NOU/',year,buoy,'.mat'],'m0','Hmean
','ske','BFI','kurt','num_wave','s','Hmax','chimax','chimin','dev','Hm0
','chim0','H1third','chilthird','chilthird_trough','eps_2');
    eps_tot=[eps_tot,eps_2];
    m0_all=[m0_all,m0];
    H1third_all=[H1third_all,H1third];
    crest1third_all=[crest1third_all,chilthird];
    Hnmax_tot=[Hnmax_tot,Hmax./dev];
    Hnmean_tot=[Hnmean_tot,Hmean./dev];
    crestnmax_tot=[crestnmax_tot,chimax./dev];
    troughnmax_tot=[troughnmax_tot,chimin./dev];
    BFI_tot=[BFI_tot,BFI];
    kurt_tot=[kurt_tot,kurt];
    ske_tot=[ske_tot,ske];
    s_tot=[s_tot,s(1,2)];
    dev_tot=[dev_tot,dev];
    num_wave_tot=[num_wave_tot,num_wave];
end
lenB=length(crestnmax_tot)-(lenR+lenT+lenL);

tot=sum(s_tot);
wave_tot=sum(num_wave_tot);

n_vector1=[5*1e2,1e3,2*1e3,5*1e3,1e4,2*1e4,5*1e4,1e5,2*1e5,5*1e5,1e
6,2*1e6,5*1e6,1e7];%2*1e7];

for c=1:length(n_vector1)
    num_clusters(c)=round(sum(num_wave_tot)/n_vector1(c));
    num_records_cluster(c)=floor(tot/num_clusters(c));
    for j=1:num_clusters(c)
        if j<num_clusters(c)
            Hnmax_cluster(j)=max(Hnmax_tot((j-
1)*num_records_cluster(c)+1:j*num_records_cluster(c)));
            chinmax_cluster(j)=max(crestnmax_tot((j-
1)*num_records_cluster(c)+1:j*num_records_cluster(c)));

```

```

        chinmin_cluster(j)=max(troughnmax_tot((j-
1)*num_records_cluster(c)+1:j*num_records_cluster(c)));
        N(j)=sum(num_wave_tot((j-
1)*num_records_cluster(c)+1:j*num_records_cluster(c)));
        else
            Hnmax_cluster(j)=max(Hnmax_tot((j-
1)*num_records_cluster(c)+1:tot));
            chinmax_cluster(j)=max(crestnmax_tot((j-
1)*num_records_cluster(c)+1:tot));
            chinmin_cluster(j)=max(troughnmax_tot((j-
1)*num_records_cluster(c)+1:tot));
            N(j)=sum(num_wave_tot((j-
1)*num_records_cluster(c)+1:tot));
        end
    end
    Hnmaxmean(c)=(mean(Hnmax_cluster'))';
    chinmaxmean(c)=(mean(chinmax_cluster'))';
    chinminmean(c)=(mean(chinmin_cluster'))';
    Nmean(c)=(mean(N'))';
    N=[];
    Hnmax_cluster=[];
    chinmax_cluster=[];
    chinmin_cluster=[];
end

N=linspace(min(Nmean),max(Nmean),10000);

EHnmax=2*(1+0.29./log(N)).*sqrt(2*log(N));
Ecrestnmax=(1+0.29./log(N)).*sqrt(2*log(N));

%Calculation of confidence intervals
% DH=sqrt(2);
% SH=DH./sqrt(N);

Dcrest=sqrt((1./(2*log(N))).*(1.6449-2.1515./(log(N))));
Screst=Dcrest./sqrt(wave_tot./N);

figure(1)
semilogx(N,Ecrestnmax,'b');
axis([min(N) max(N) 3 7.5])
axis manual
hold on
semilogx(N,Ecrestnmax+1.96*Screst,'b--');
semilogx(N,Ecrestnmax-1.96*Screst,'b--');
semilogx(Nmean,chinmaxmean,'or');
semilogx(Nmean,chinminmean,'ob');

```

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