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**

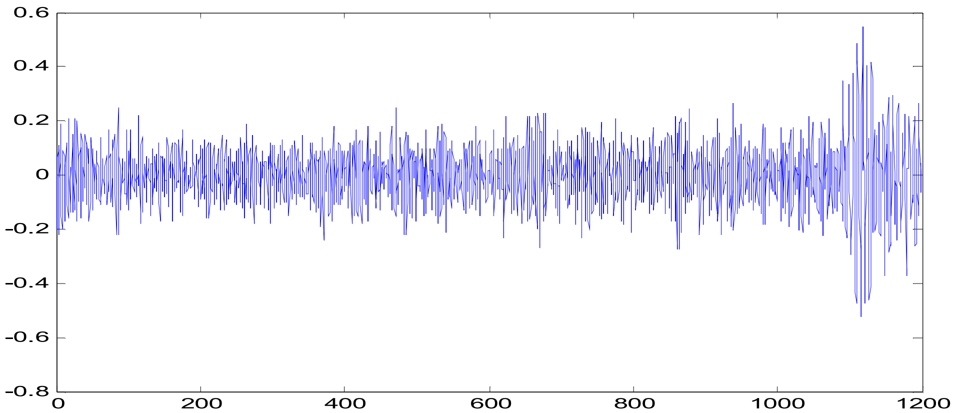
LLOBREGAT											
Year	**Initial**	**e1**	**e2**	**e3**	**e_50**	**e4**	**e_al**	**e_bump**	**e_sh**	**visual**	**Final**
2001	1.939	0	711	408	296	0	0	11	13	0	500
2002	7.051	0	2.256	2.092	769	0	0	20	0	0	1.914
2003	8.332	2	3.512	2.212	765	0	0	32	13	0	1.796
2004	274	0	239	25	5	0	0	0	0	0	5
	17.322	2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

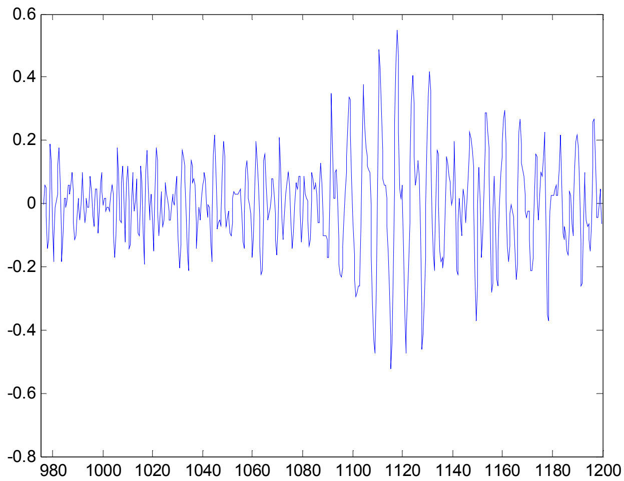
TORTOSA											
Year	**Initial**	**e1**	**e2**	**e3**	**e_50**	**e4**	**e_al**	**e_bump**	**e_sh**	**visual**	**Final**
1991	1.003	0	71	5	471	0	76	0	0	0	380
1992	1.935	0	75	16	593	0	139	0	0	0	1.112
1993	2.990	4	62	14	1.016	1	218	0	0	0	1.675
1994	3.219	3	69	22	997	1	185	2	0	0	1.940
1995	1.132	1	17	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

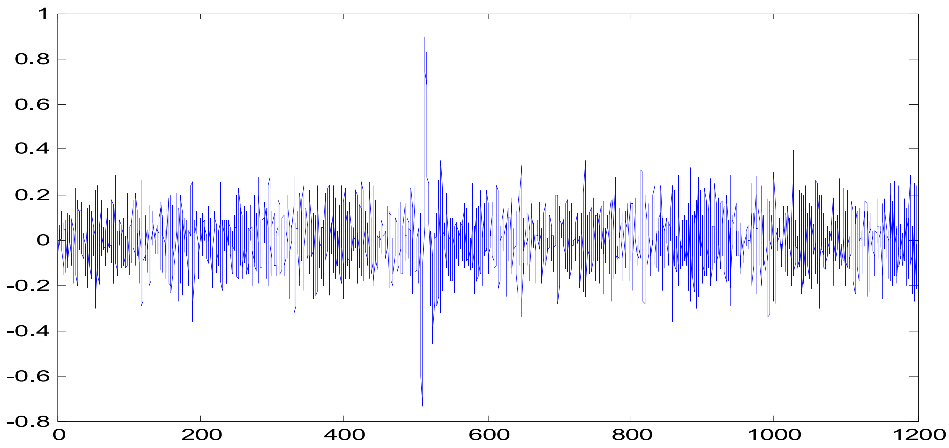
Freak waves have been defined as those with $H \geq 2.83H_s$. Although the particular analysis of freak waves occurrence is not covered in the present study, a complementary analysis is carried out by looking for all the freak waves present in the analysed data, attending to the above mentioned criterion. 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).

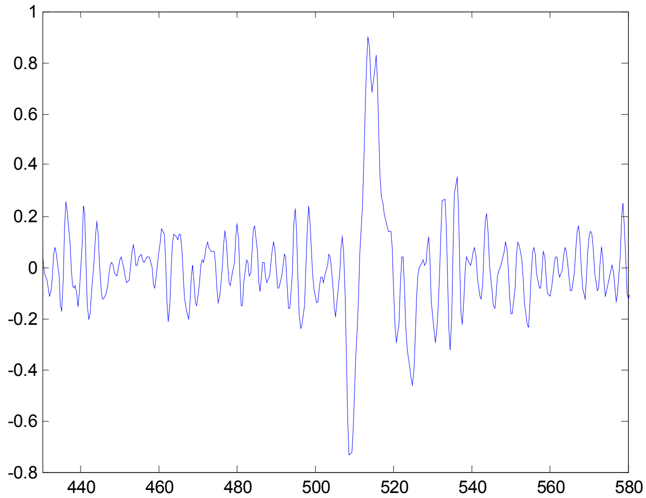
Llobregat: 01/06/02 03:20h



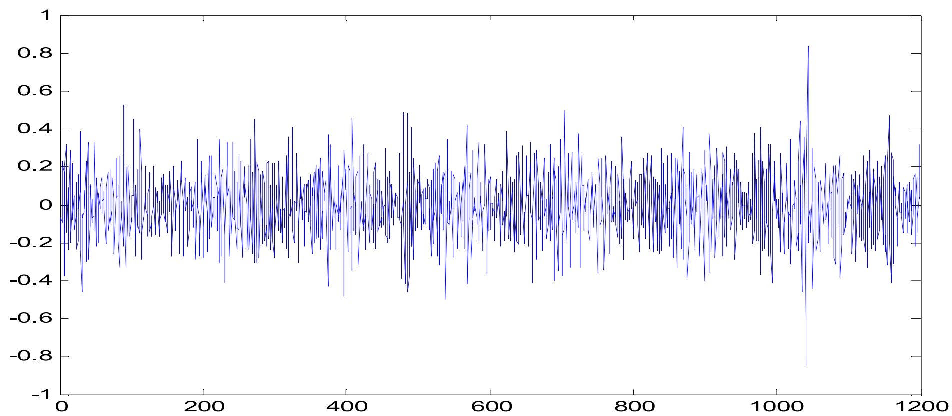


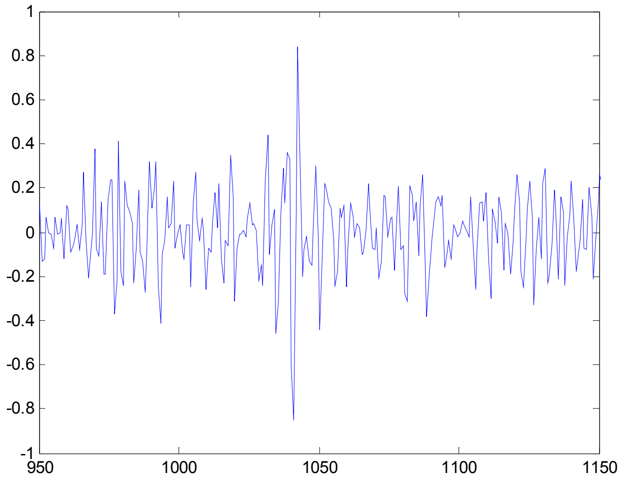
Roses: 13/07/03 18:20h





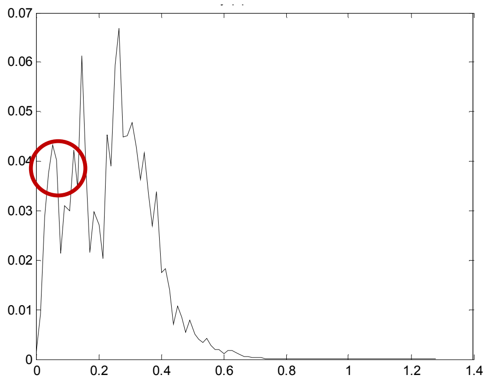
Tortosa: 30/12/05 08:00h

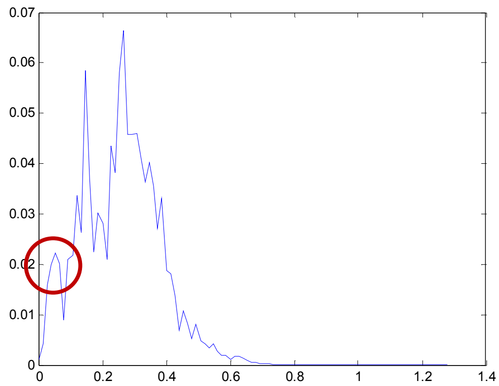




At first sight, the last two are more similar to the academic shape of a freak wave: a single wave which is extremely high compared to the ones around it. In the first case it is not clear. Instead of a freak wave it seems to be a non stationary wave record in which a constant standard deviation cannot 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 substracting 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
         ncolum=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;
                 ncolum=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
%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';
         rcolumH=r(:,colH)/100;%units m
         rtt=diff(rcolumH,2)/(dt^2);%second derivative
         rtt_ind=find(abs(rtt)<10^(-4));
         if length(rcolumH)==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;
                             ll=l;
                             l=2*length(rtt);
                             l2=ll+3;
                             %er3='Yes';
                         end
                     end
                     l=l+1;
                 end
%                  l2=ll+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;
```

```
                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=[];
    chi1third=[];
    chi1third_trough=[];
    chi1third_H=[];
    chi1third_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)))];
        chi1third=[chi1third,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*(chi1third(length(chi1third)))%&(max(abs(y(:,
     length(Hmax)))))<3*chi1third;%%%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))];
            chi1third=[chi1third,mean(chicrest_sort((length(H)-
            num_1third(length(num_1third))):length(H)))];
            chi1third_trough=[chi1third_trough,abs(mean(chitrough_s
            ort((1:num_1third(length(num_1third))))))];
            chi1third_H=[chi1third_H,mean(chicrest(indexH_sort((len
            gth(H)-num_1third(length(num_1third))):length(H))))];
            chi1third_trough_H=[chi1third_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*(chi1third(length(chi1third)))&abs(y
       (indmax3,i))>2.83*(chi1third(length(chi1third)))
                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))];
```

```
        chi1third=[chi1third,mean(chicrest_sort((length(H)-
        num_1third(length(num_1third))):length(H)))];
        chi1third_trough=[chi1third_trough,abs(mean(chitrough_s
        ort((1:num_1third(length(num_1third))))))];
        chi1third_H=[chi1third_H,mean(chicrest(indexH_sort((len
        gth(H)-num_1third(length(num_1third))):length(H))))];
        chi1third_trough_H=[chi1third_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=chi1third;
        jeje=max(chicrest);
        jojo=max(abs(chitrough));
        chi1third(length(chi1third))=[];
        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))=[];
        chi1third(length(chi1third))=[];
        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))=[];
            chi1third(length(chi1third))=[];
            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,l)
         normplot(y(:,i(l)))
```

```
        title(['kurt:        ',num2str(kurt(i(l))),',        skew:
',num2str(ske(i(l))),''])
    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,l)
        [bincounts binpositions]=hist(y(:,i(l)),20);
        delta=abs(binpositions(1)-binpositions(2));
        area_hist=delta*len;
        y_norm=normpdf(sort(y(:,i(l))),0,dev(i(l)));
        hist(y(:,i(l)),20)
        hold on
        plot(sort(y(:,i(l))),area_hist*y_norm,'r','LineWidth',2);
        title(['kurt:        ',num2str(kurt(i(l))),',        skew:
',num2str(ske(i(l))),''])
    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)=[];
     chi1third(ind_aliasing)=[];
     relHchicrest(ind_aliasing)=[];
     Hmax(ind_aliasing)=[];
     num_1third(ind_aliasing)=[];
     relHchitrough(ind_aliasing)=[];
     relHchicrest2(ind_aliasing)=[];
     relHchitrough2(ind_aliasing)=[];
     chi1third_trough(ind_aliasing)=[];
     chi1third_H(ind_aliasing)=[];
     chi1third_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)=[];
     T1third(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)))

     H1third(ind_bump)=[];
     chi1third(ind_bump)=[];
     relHchicrest(ind_bump)=[];
     Hmax(ind_bump)=[];
     num_1third(ind_bump)=[];
     relHchitrough(ind_bump)=[];
     relHchicrest2(ind_bump)=[];
     relHchitrough2(ind_bump)=[];
     chi1third_trough(ind_bump)=[];
     chi1third_H(ind_bump)=[];
     chi1third_trough_H(ind_bump)=[];
     H1third_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)=[];
     T1third(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);


     H1third(ind_shallow)=[];
     chi1third(ind_shallow)=[];
     relHchicrest(ind_shallow)=[];
     Hmax(ind_shallow)=[];
     num_1third(ind_shallow)=[];
     relHchitrough(ind_shallow)=[];
     relHchicrest2(ind_shallow)=[];
     relHchitrough2(ind_shallow)=[];
     chi1third_trough(ind_shallow)=[];
     chi1third_H(ind_shallow)=[];
     chi1third_trough_H(ind_shallow)=[];
     H1third_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)=[];
    T1third(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 directlu 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','chi1third','chi1third_trough','eps_2');
        eps_tot=[eps_tot,eps_2];
        m0_all=[m0_all,m0];
        H1third_all=[H1third_all,H1third];
        crest1third_all=[crest1third_all,chi1third];
        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','chi1third','chi1third_trough','eps_2');
        eps_tot=[eps_tot,eps_2];
        m0_all=[m0_all,m0];
        H1third_all=[H1third_all,H1third];
        crest1third_all=[crest1third_all,chi1third];
        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','chi1third','chi1third_trough','eps_2');
        eps_tot=[eps_tot,eps_2];
        m0_all=[m0_all,m0];
```

```
        H1third_all=[H1third_all,H1third];
        crest1third_all=[crest1third_all,chi1third];
        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','chi1third','chi1third_trough','eps_2');
        eps_tot=[eps_tot,eps_2];
        m0_all=[m0_all,m0];
        H1third_all=[H1third_all,H1third];
        crest1third_all=[crest1third_all,chi1third];
        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');
```

REFERENCES

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