**Conceptual model for climate change induced wind pattern alteration on seagrass meadow stability**

This model uses field flume derived critical orbital velocity thresholds for sediment resuspension to calculate how often these are exceeded under certain wind and fetch conditions. The effect of changing storminess (i.e., storm magnitude and frequency) and typical wind conditions (i.e,. increasing mean winds) is explored for

1) a range of seagrass blade areas (i.e., a proxy for density and biomass)

2) different sediment types, in this case a coarser sand (250 mu) vs a finer sand (150 mu) with > 5 % mud fraction, making it unfold cohesive properties

3) a sheltered (low exceedance probability of ucrit) vs a more exposed (high exceedance probability of ucrit) seagrass meadow

close all

clear variables

cd('C:\Users\jcdes\OneDrive - NIOZ\PhD\Field work\Kristineberg jun-aug 2018');

data = load('winddata.txt');

Making a wind velocity distribution based on winds in Bokevik bay.

Wind velocitys always follow a weibull distribution (i.e., normal distribution with a long tail towards higher wind velocitys). The Weibull distribution has a parameter a, which is proportional to the mean, and a parameter b, which determines the shape of the distribution. We can caculate the shape parameters from the wind velocity timeseries.

speed = data(129551:end-6,2);

speed = speed.\*(10/15).^(1/7); % correcting wind speed to 10 m above ground

speed(isnan(speed)) = 0.1;

speed(speed == 0) = 0.1;

[wb,~] = wblfit(speed);

wind\_baseline = wblrnd(wb(1),wb(2),100000,1); % baseline wind distribution

bins = [0:0.25:30]; % bins from 0 to 30 m/s for histogram plot

[n,e] = histcounts(data(:,2),bins);

figure;

plot(e(2:end),movmean(n,5)./length(data(:,2)),'-r')

hold on

[n,e] = histcounts(wind\_baseline,bins);

p(1) = plot(e(2:end),movmean(n,5)./100000,'-k');

xlabel('wind velocity (m s^{-1})')

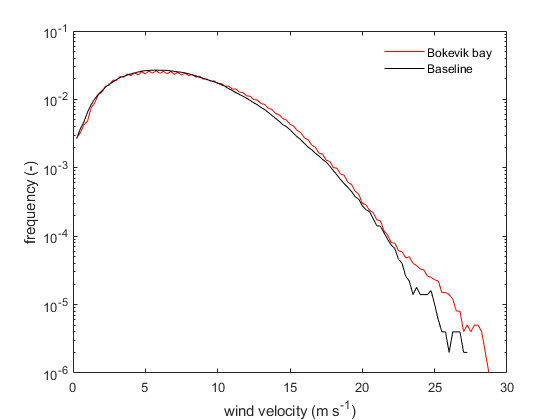
ylabel('frequency (-)')

legend('Bokevik bay','Baseline')

legend BOXOFF

set(gca,'YScale','log')

axis([0 30 1e-6 1e-1])



mean(wind\_baseline)

ans = 7.0899

This wind distribution has a mean of 7.2 m/s, which is typical for coastal areas in e.g. the North Sea, Baltic Sea, and Wadden Sea.

stromfreq\_baseline = 100 - invprctile(wind\_baseline,13.9)

stromfreq\_baseline = 4.6198

figure;

p(1) = plot(e(2:end),movmean(n,5)./100000,'-k','linewidth',2);

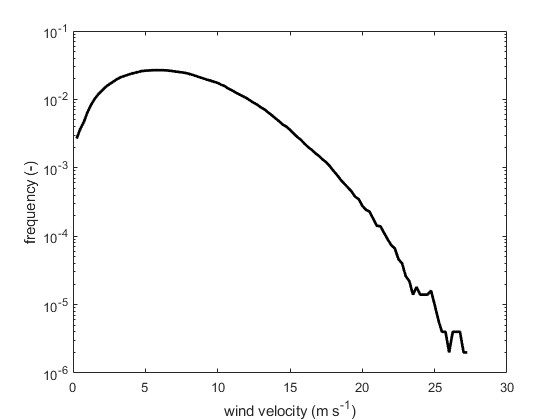
xlabel('wind velocity (m s^{-1})')

ylabel('frequency (-)')

set(gca,'Yscale','log')

axis([0 30 1e-6 1e-1])

hold on



And about 6 % of the time the winds can be classified as stormy (above 13.9 m/s, i.e., wind force 7 or higher)

**Appending climate change scenarios to baseline wind distribution -- mean winds**

Increase in mean wind velocity can be applied a change in the a parameter:

wind\_medincr = wblrnd(wb(1)\*1.1,2.5,100000,1); % 10 % increase in mean wind velocity

mean(wind\_medincr)

ans = 7.8126

100 - invprctile(wind\_medincr,13.9)

ans = 4.3470

Changing the a parameter only results in a simultaenous increase in the storminess, as the distribution between typical winds and storms remains roughly equal. Hence, the shape parameter b needs to be adapted as well. We do this iteratively

Now we make a range of median wind increase scenarios:

Weibull\_A = wb(1).\*[1.05 1.1 1.15]; % 5-10-15 % increase in mean wind velocity

Weibull\_B = [wb(2) wb(2) wb(2)];

for i = 1:length(Weibull\_A)

wind\_medincr(:,i) = wblrnd(Weibull\_A(i),Weibull\_B(i),100000,1);

stormfreq\_medincr(:,i) = (100-invprctile(wind\_medincr(:,i),13.9))./stromfreq\_baseline;

while abs(1-stormfreq\_medincr(:,i)) > 0.05

if stormfreq\_medincr(:,i) < 1

Weibull\_B(i) = Weibull\_B(i) - 0.001;

elseif stormfreq\_medincr > 1

Weibull\_B(i) = Weibull\_B(i) + 0.001;

end

wind\_medincr(:,i) = wblrnd(Weibull\_A(i),Weibull\_B(i),100000,1);

stormfreq\_medincr(:,i) = (100-invprctile(wind\_medincr(:,i),13.9))./stromfreq\_baseline;

end

[n,e] = histcounts(wind\_medincr(:,i),bins);

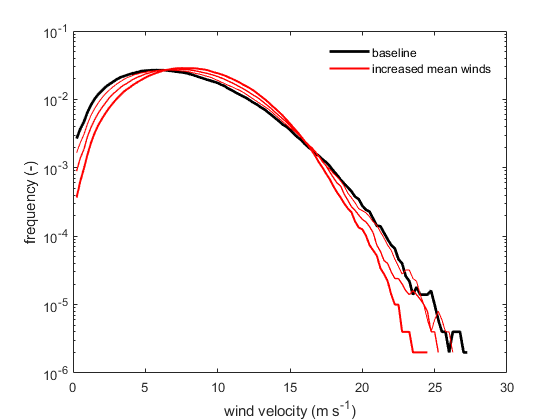
plot(e(2:end),movmean(n,5)./100000,'-r','linewidth',i/2)

end

p(2) = plot(NaN,NaN,'-r','linewidth',1.5);

legend([p(1) p(2)],{'baseline','increased mean winds'})

legend BOXOFF



mean(wind\_medincr)

ans = 1×3

7.4259 7.7882 8.1677

100 - invprctile(wind\_medincr,13.9)

ans = 1×3

4.8049 4.8148 4.8474

So, the mean wind velocity is increased by 5, 10 and 15 %, but the storminess remains constant.

**Appending climate change scenarios to baseline wind distribtution -- stormy winds**

Similar to changing the mean wind velocity and keeping the storm frequency constant, we can increase the storm frequency while keeping the mean winds constant:

Weibull\_A = [wb(1) wb(1) wb(1)];

Weibull\_B = [wb(2) wb(2) wb(2)];

incr = [1.05 1.1 1.15];

for i = 1:length(Weibull\_A)

wind\_stormincr(:,i) = wblrnd(Weibull\_A(i),Weibull\_B(i),100000,1);

stormfreq\_stormincr(:,i) = (100-invprctile(wind\_stormincr(:,i),13.9))./stromfreq\_baseline;

while stormfreq\_stormincr(:,i) < incr(i)

Weibull\_B(i) = Weibull\_B(i) - 0.01;

wind\_stormincr(:,i) = wblrnd(Weibull\_A(i),Weibull\_B(i),100000,1);

stormfreq\_stormincr(:,i) = (100-invprctile(wind\_stormincr(:,i),13.9))./stromfreq\_baseline;

end

[n,e] = histcounts(wind\_stormincr(:,i),bins);

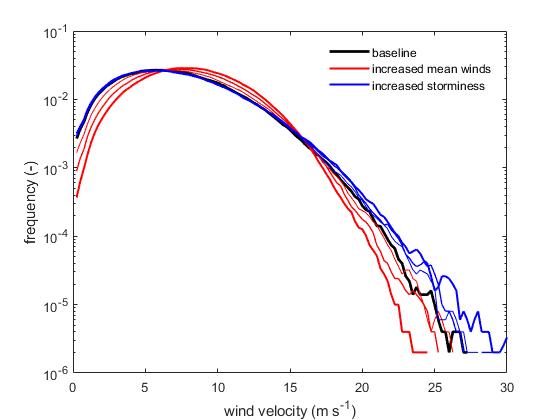
plot(e(2:end),movmean(n,5)./100000,'-b','linewidth',i/2)

end

p(3) = plot(NaN,NaN,'-b','linewidth',1.5);

legend([p(1) p(2) p(3)],{'baseline','increased mean winds','increased storminess'})

legend BOXOFF



mean(wind\_stormincr)

ans = 1×3

7.0995 7.0839 7.1039

100 - invprctile(wind\_stormincr,13.9)

ans = 1×3

4.8823 5.1987 5.4303

So, the mean wind velocity remains constant, but the storm frequency is increased by 3.3, 6.6 and 10 %.

**Calculating turbidity pressure**

Turbidity pressure is here defined as the duration for which the critical orbital velocity for the onset of sediment resuspension, as measured in the field flume experiments, is exceeded. The turbidity pressure hence is determined by the wind conditions, i.e., climate change scenarios, but also by the seagrass density and sediment type.

First, we explore the stability of a seagrass meadow at 1m depth in a system with a short fetch, of 2 km. We assess for both coarse sand and fine sand how the exceedance duration of ucrit changes over a seagrass density range from bare sediment to a full length, dense canopy based on the measured blade areas of the field flume experiments.

First, we merge the baseline and climate change scenarios into a single matrix:

wind = [wind\_baseline wind\_medincr wind\_stormincr];

We use the JONSWAP equations to calculate the wave heights and periods from the wind velocity timeseries.

h = 1; % water depth in m

fetch = 6000; % fetch in m

g = 9.81; % gravitation acceleration

F\_star = g.\*fetch./wind.^2;

H\_star = 0.0016.\*sqrt(F\_star);

Tp\_star = 0.286.\*F\_star.^0.333;

H = wind.^2.\*H\_star./g;

Tp = wind.\*Tp\_star./g;

w = (2\*pi)./Tp;

And we use linear wave theory to calculate the corresponding near-bed orbital velocities

for i = 1:length(wind(1,:))

for j = 1:length(wind)

count = 1;

l{count} = 0;

l{count+1} = (g/(2\*pi))\*Tp(j,i)^2;

while abs(l{count+1} - l{count}) > 0.0001

l{count+2} = ((9.81\*Tp(j,i)^2)/(2\*pi))\*tanh((2\*pi\*h)/l{count+1});

count = count+1;

end

L(j,i) = l{count};

k(j,i) = (2\*pi)/L(j,i);

clear l

end

end

U = H.\*w./(2.\*sinh(k.\*h));

Based on the linear regressions from Figure 4 in the paper, we can derive ucrit - blade area relations, so that we can translate ucrit into blade area for the different sediment types.

Ucrit\_line = [0:0.01:0.5];

Ablade\_coarse = (Ucrit\_line-0.19)./0.17;

Ablade\_fine = (Ucrit\_line-0.15)./0.12;

Now we calculate the exceedance probability of a given ucrit, which yields the turbidity pressure over the range of typical ucrits.

for i = 1:length(Ucrit\_line)

Ucrit\_exc(i,:) = 100 - invprctile(U,Ucrit\_line(i));

for j = 1:length(wind(1,:))

stormfreq\_U(i,j) = 100 - invprctile(wind(U(:,j) > Ucrit\_line(i),j),13.9);

end

end

**Assessment**

figure;

axis([0 1.5 0 100])

hold on

for i = 2:4

plot(Ablade\_fine,Ucrit\_exc(:,i),'-r');

plot(Ablade\_coarse,Ucrit\_exc(:,i),'--r');

end

for i = 5:7

plot(Ablade\_fine,Ucrit\_exc(:,i),'-b');

plot(Ablade\_coarse,Ucrit\_exc(:,i),'--b');

end

plot(Ablade\_fine,Ucrit\_exc(:,1),'-k','linewidth',2);

plot(Ablade\_coarse,Ucrit\_exc(:,1),'--k','linewidth',2);

xlabel('Blade area per m^2 seabed surface (-)')

ylabel('P(u > u\_{cr})')

p(1) = plot(NaN,NaN,'-k');

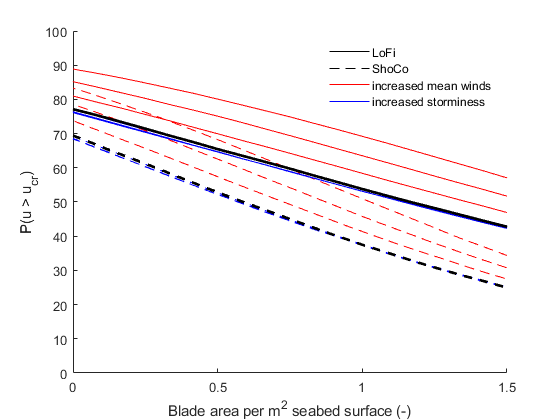
p(2) = plot(NaN,NaN,'--k');

p(3) = plot(NaN,NaN,'-r');

p(4) = plot(NaN,NaN,'-b');

legend([p(1) p(2) p(3) p(4)],{'LoFi','ShoCo','increased mean winds','increased storminess'})

legend BOXOFF



figure;

axis([0 1.5 0 100])

hold on

plot(Ablade\_fine,stormfreq\_U(:,1),'-r');

plot(Ablade\_coarse,stormfreq\_U(:,1),'--r');

xlabel('Blade area per m^2 seabed surface (-)')

ylabel('P\_{storm}(u > u\_{cr})')

p(1) = plot(NaN,NaN,'-k');

p(2) = plot(NaN,NaN,'--k');

p(5) = plot(NaN,NaN,'-k');

p(3) = plot(NaN,NaN,'-b');

p(4) = plot(NaN,NaN,'-r');

legend([p(1) p(2) p(5) p(3) p(4)],{'LoFi','ShoCo','Bokevik bay','Fully exposed, low','Fully exposed, high'})

legend BOXOFF

