

Wind to Coil Transfer Functions
at Ligo Hanford
T030294-00-D

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v0.2

Motivation

I was curious as to how the high winds we sometimes see at Ligo Hanford effect the optics.

Methods

For LSC driven optics, only times when the LSC was on were considered. While this isn't optimal, it is the best option for the data that was available. Reasons: especially during a science run, there isn't much time with the LSC off; the little time that is available is probably corrupted due to the harsh changes being made (switching dewhites, etc.).

Data

A large data set was collected, with the following channels: for each optic the max ul, ll and sd watchdog readback, wind max speed for each building, mean wind direction for each building in minute trends. The period of data ended 03-11-19-18-4-23 utc and looked back 5 days.

Findings

Wind noise becomes prominent in the watchdog readback channels (`_VAR`) at 40 mph in undriven optics. Driven optics are much more susceptible to wind driven agitation. All optics show increased response to winds at 20 mph, though this is most prominent in small optics.

Several optics (4k: mmt1, mmt2, itmx, itmy, bs, etmx; 2k: sm1, mmt1, mmt2, etmx) showed interesting behaviour, with one or more coils displaying different behaviour from the rest. One in particular appeared broken (2k mmt2 ul coil). Two optics on the 2k displayed much noisier behaviour on the face coils, which appears real (mmt2 and etmx).

Questions

- Why is there a special response to wind speeds of 20 mph?
- What is the maximum tolerable wind speed, and which optic is limiting us? How many mV can we live with?
- Why the excess noise in 2k etmx (among others)?

Acknowledgements

Many thanks are due to Stan Whitcomb, Vern Sandberg, and Josh Meyers for helping me with this simple and all too rudimentary report.

Figures

Individual Optics pretty self explanatory

Comparison Plots ul and ll channels were averaged for these plots.

LHO Comparison Plots ETMs, RMs, and IFO locking durability.

Additional Plots wind gust distribution during 5 day period, direction of wind over speed over 10 mph, normalized wind gust distribution for all of S2 and S3 to Nov26.

MATlab scripts

durability.m measured the percent locked versus wind speed.

tketmxwind2coil.m special case of wind2coil, used explicitly for 2k etmx (which was missing a couple of data points).

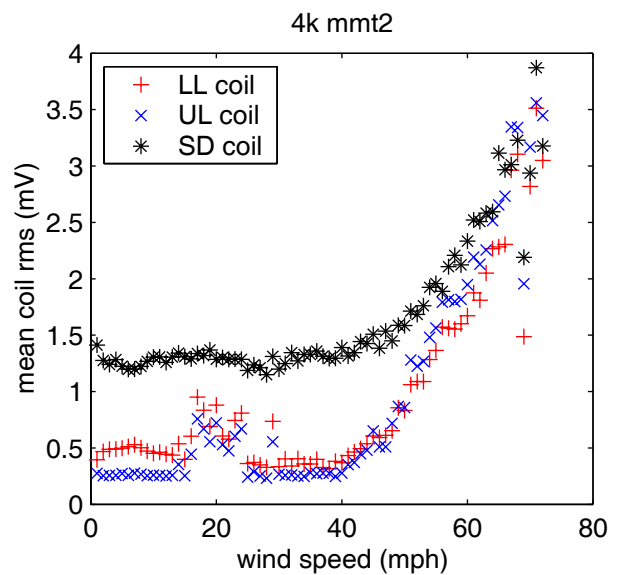
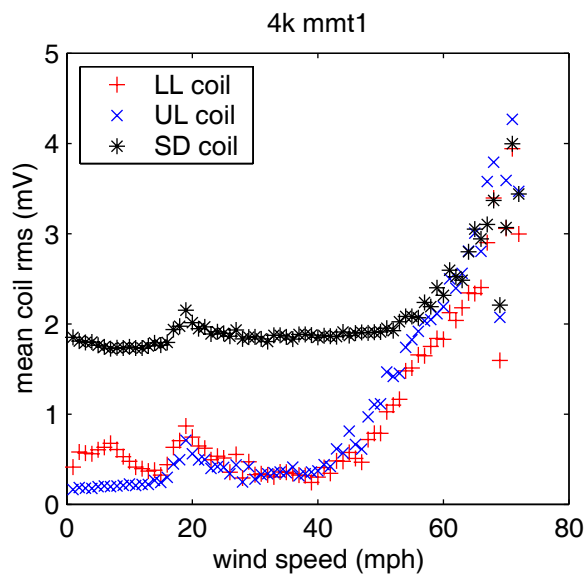
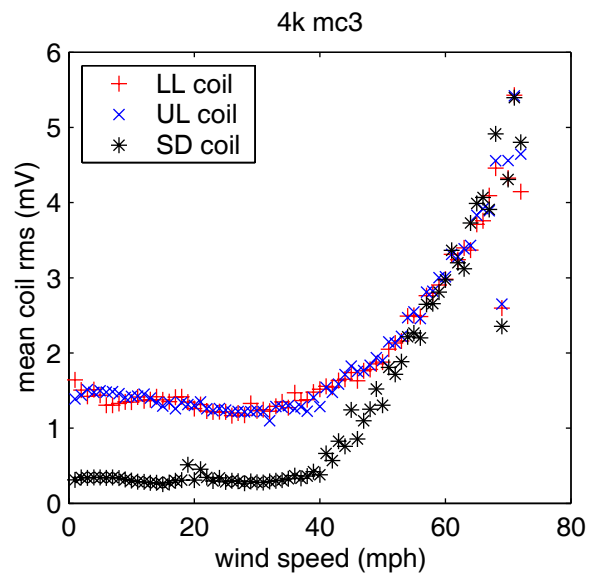
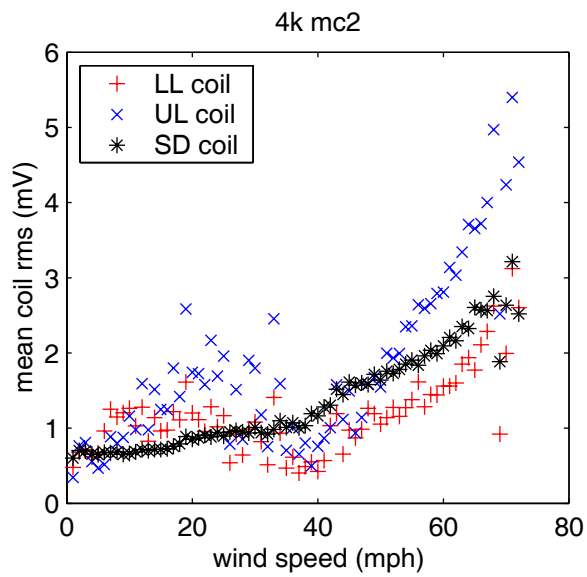
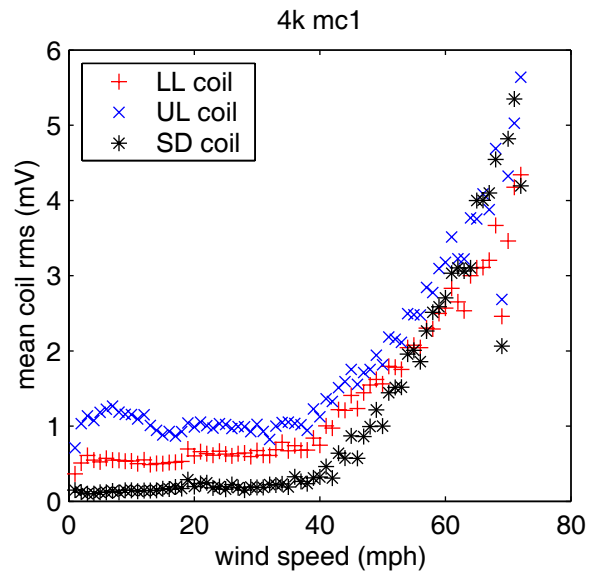
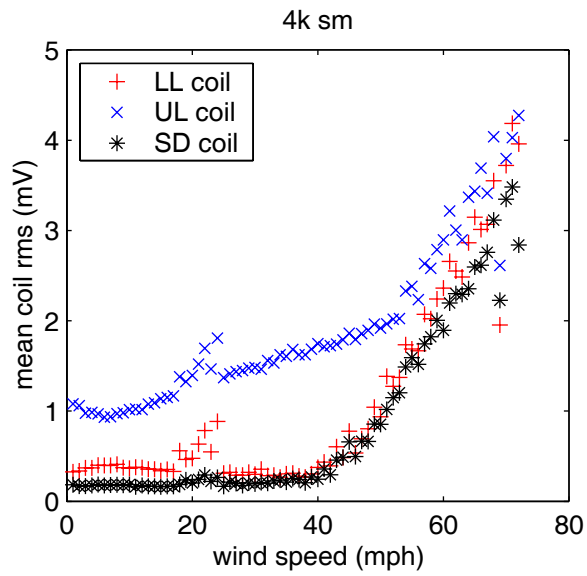
wind2coil.m actually processes the wind speed and coil data.

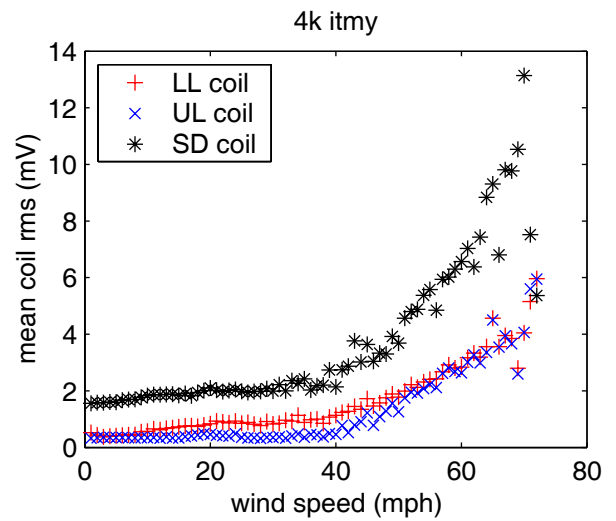
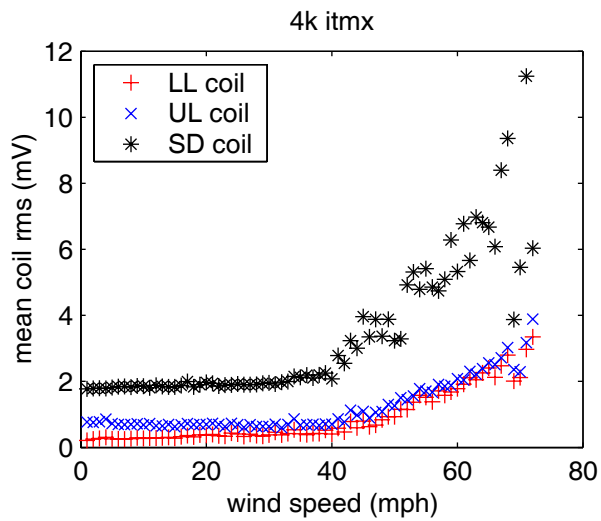
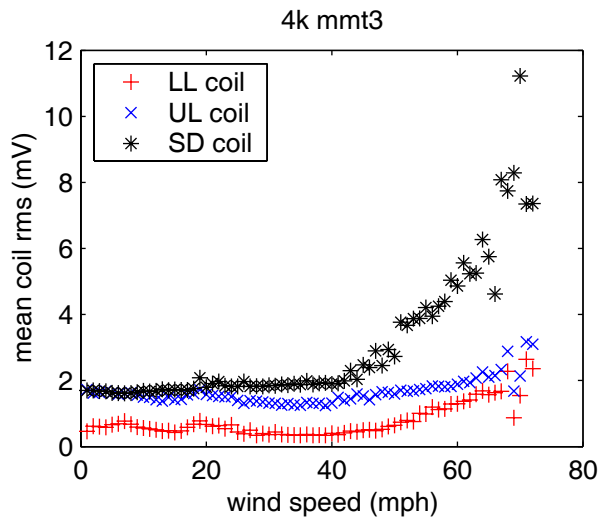
winddir.m processes wind direction and wind speed data for given station.

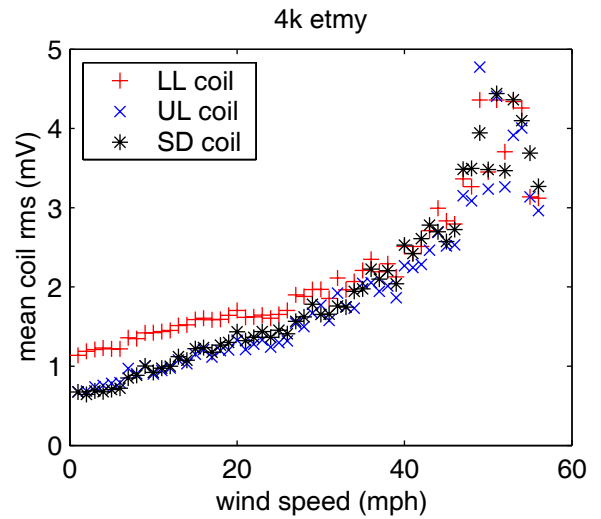
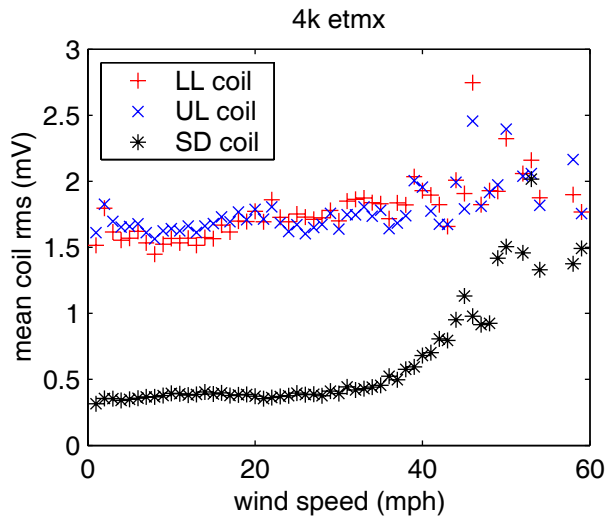
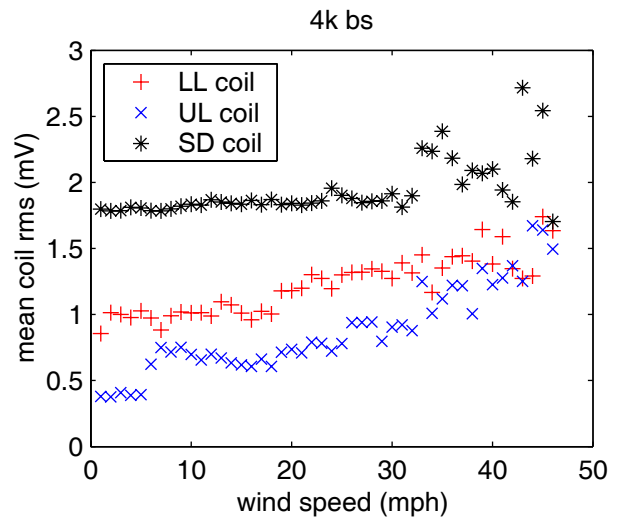
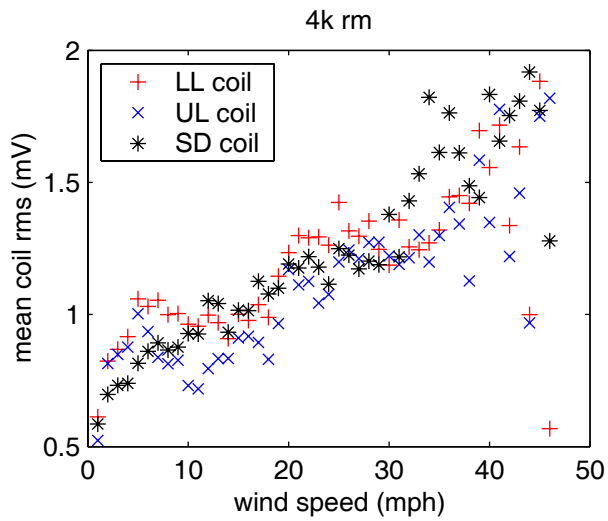
windplots.m generates all coil vs wind plots by calling wind2coil.m.

windspd.m produces wind gust distribution plot for all buildings.

4k: Individual Optics

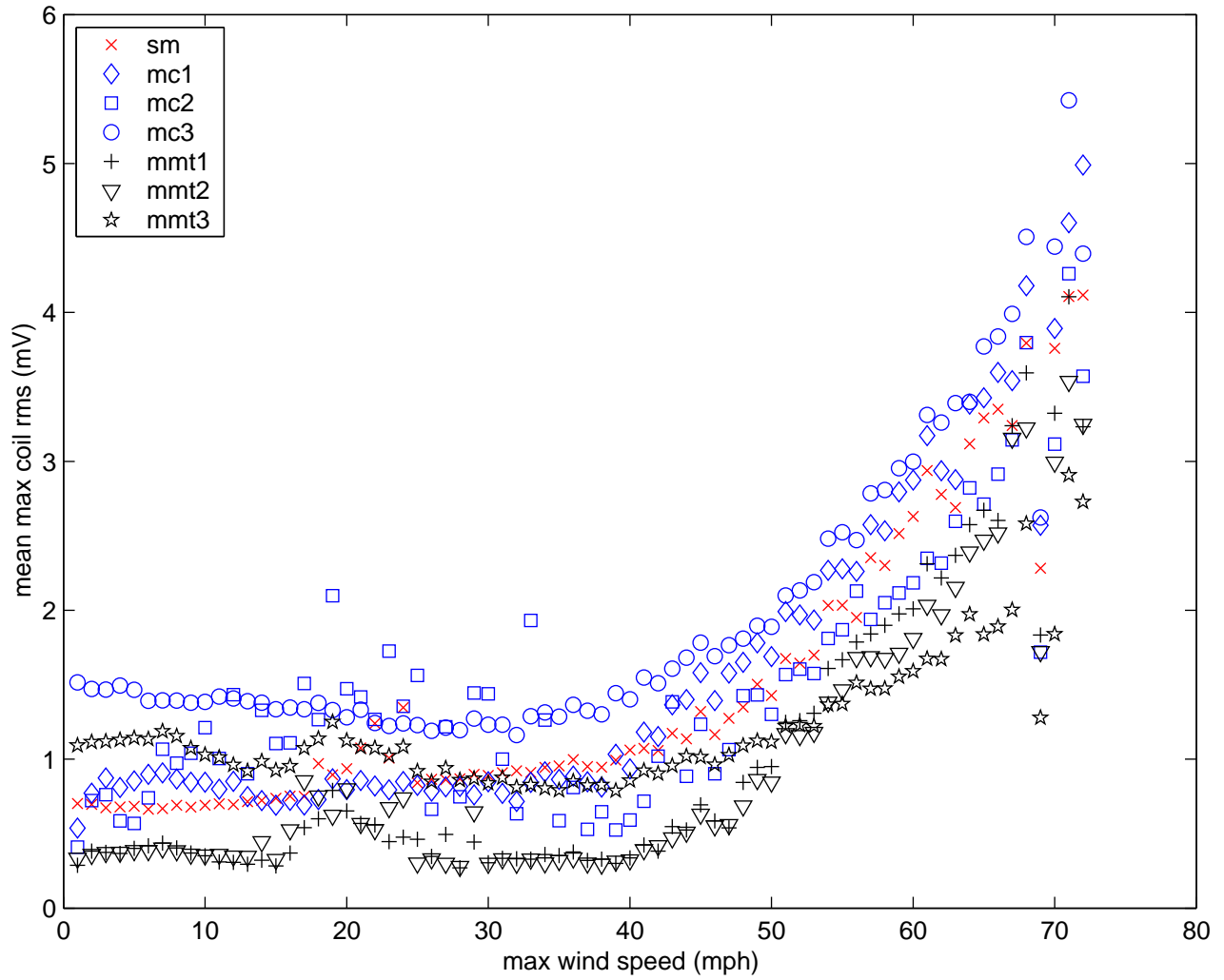




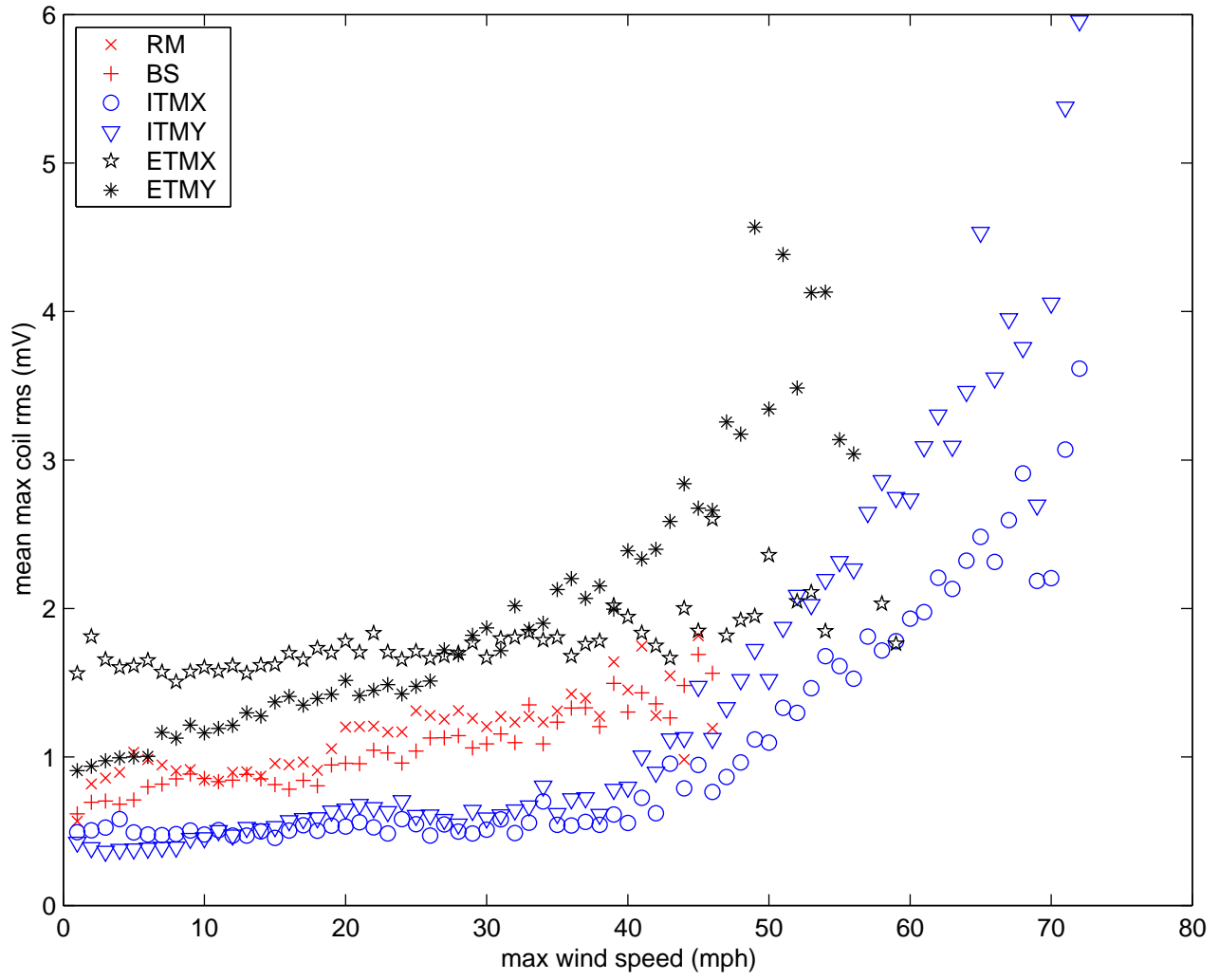


4k: Comparison Plots

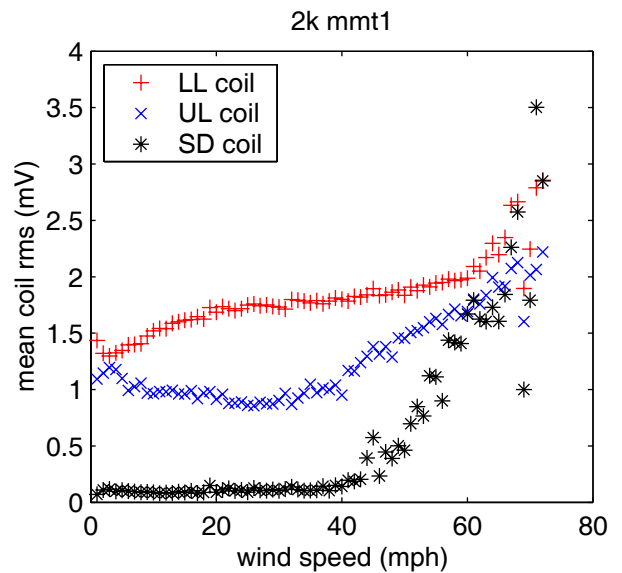
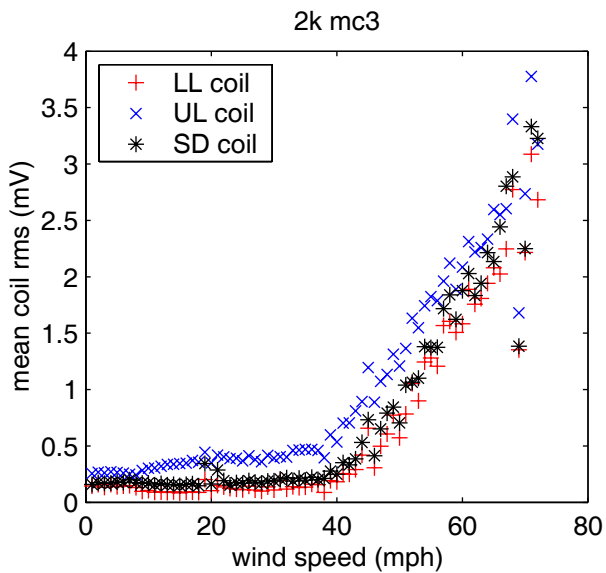
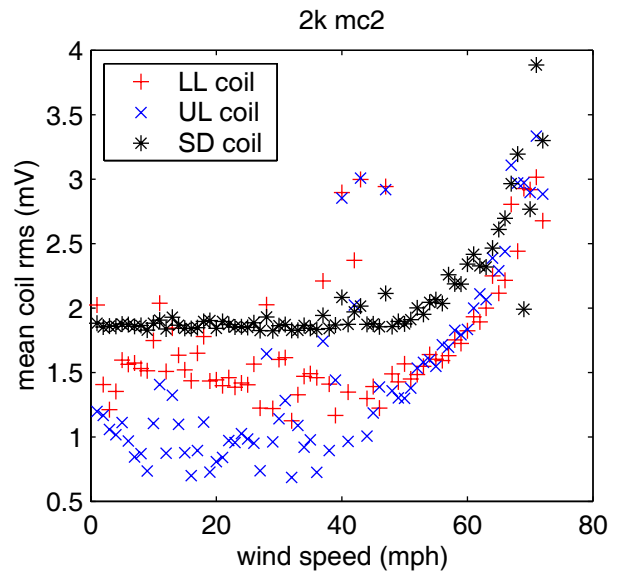
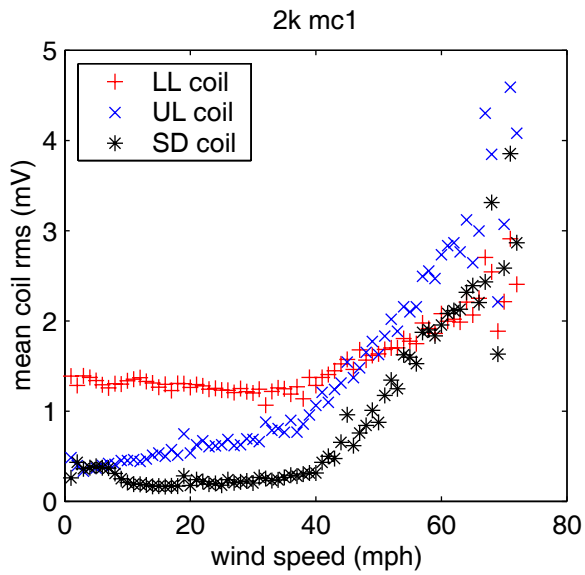
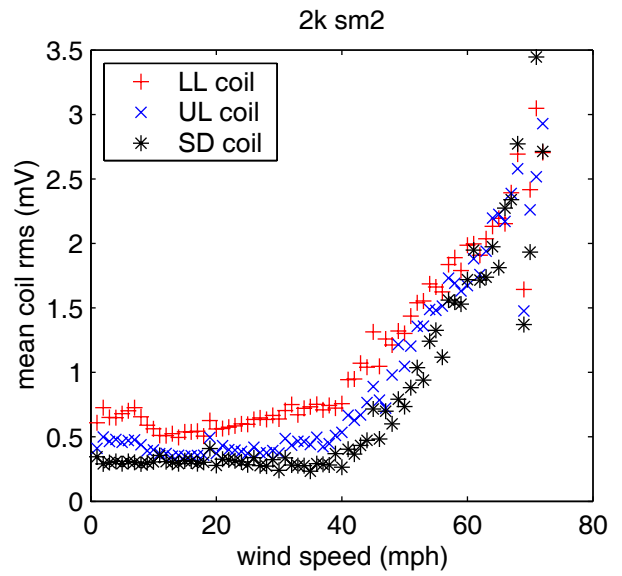
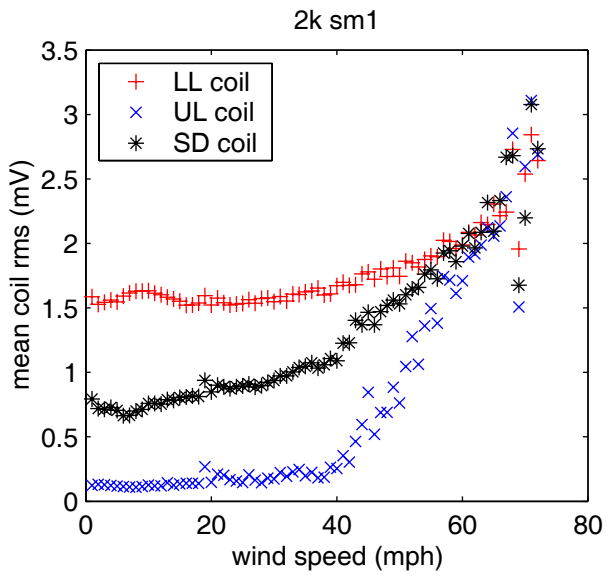
4k small optics

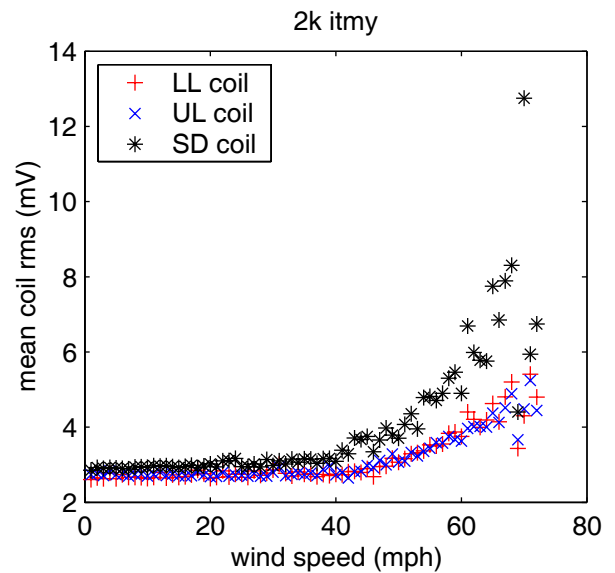
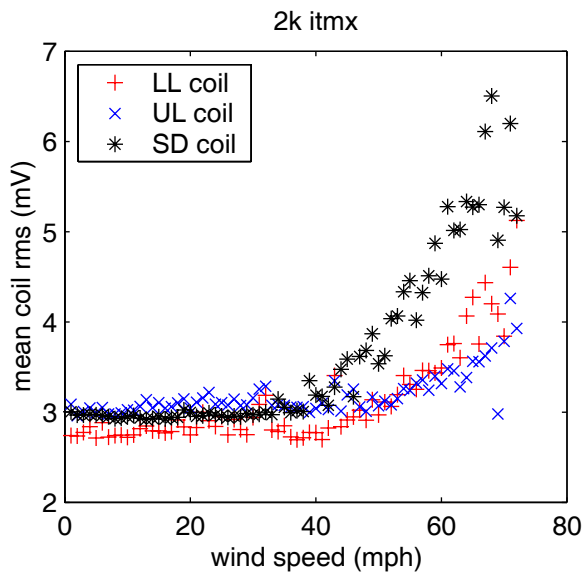
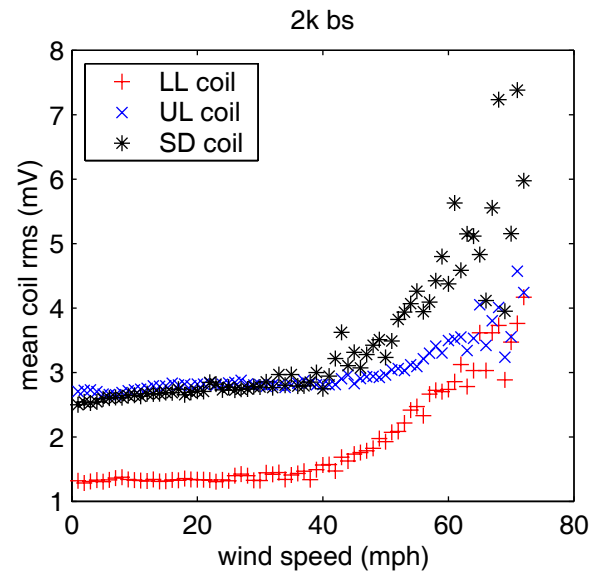
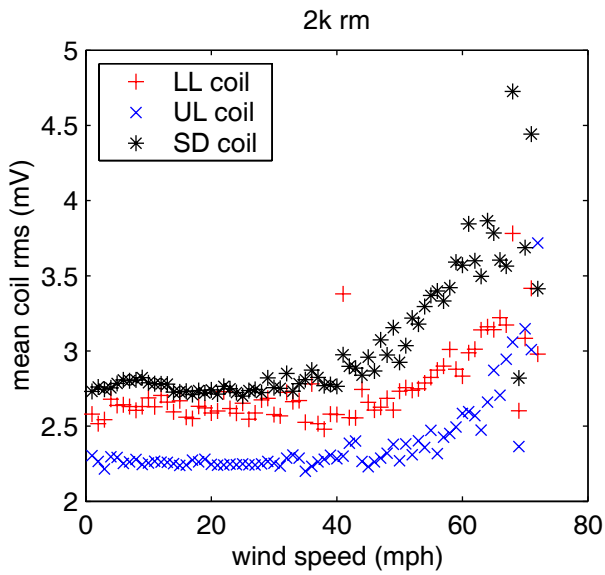
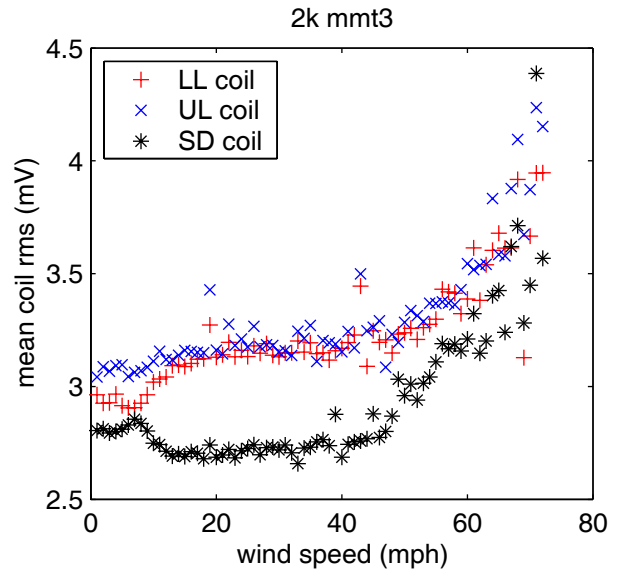
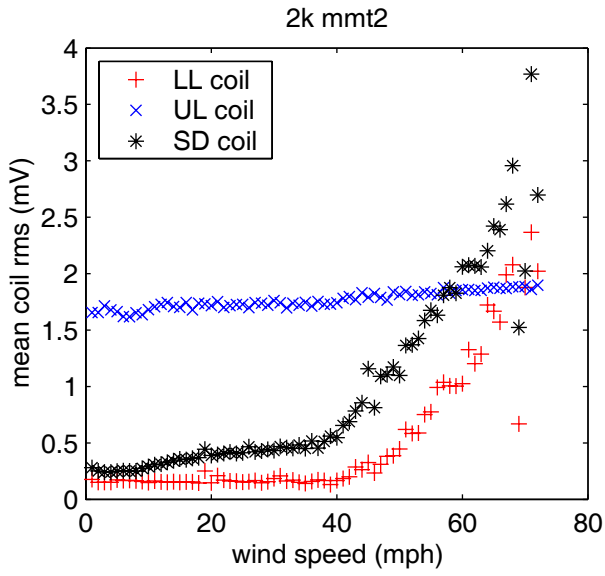


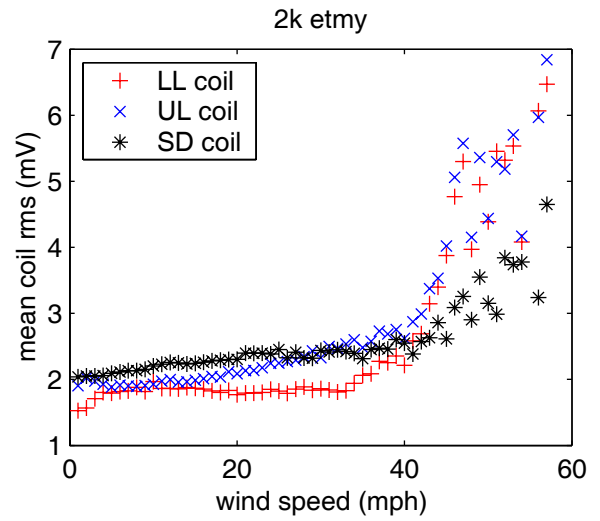
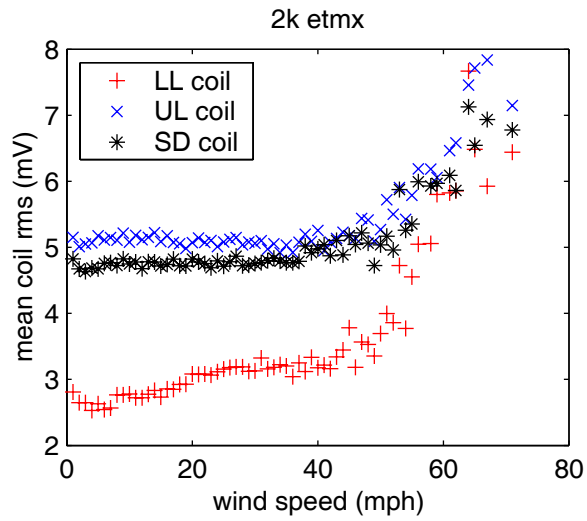
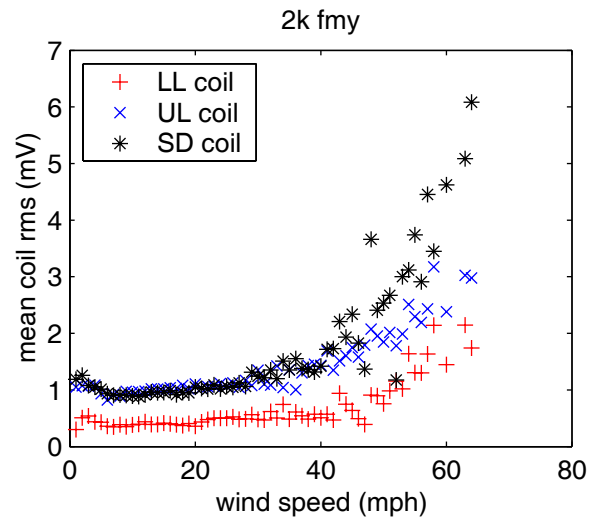
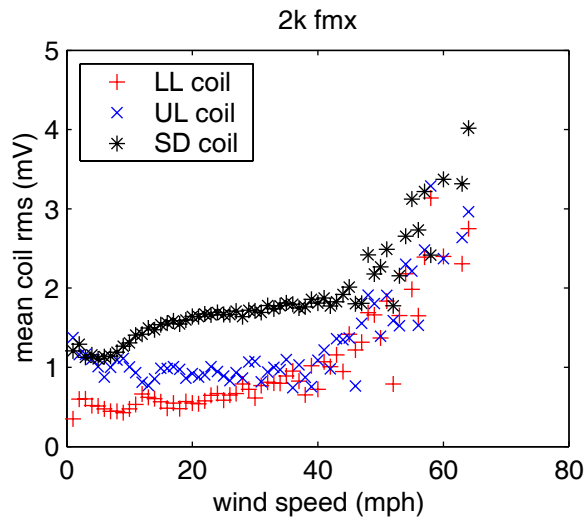
4k large optics



2k: Individual Optics

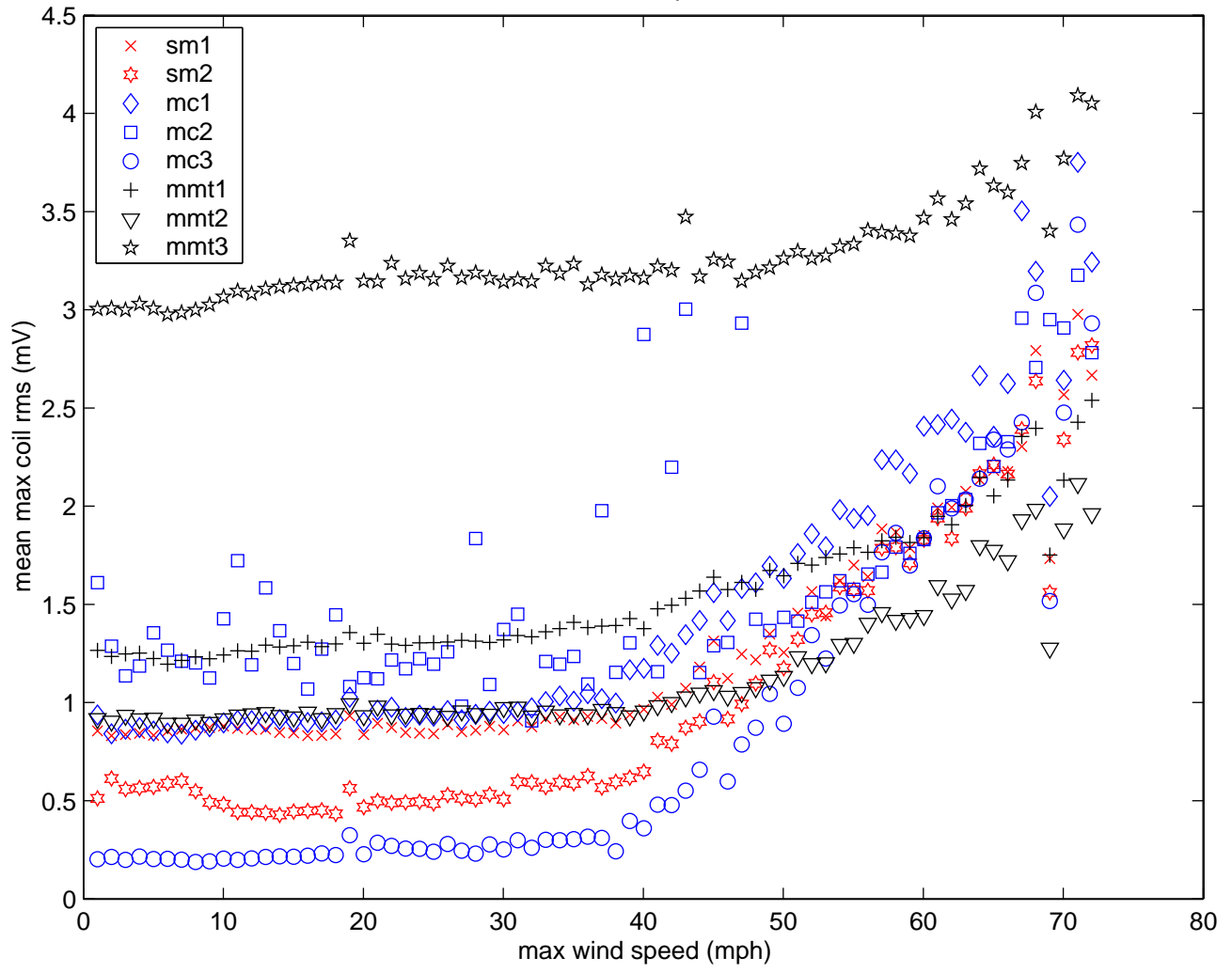




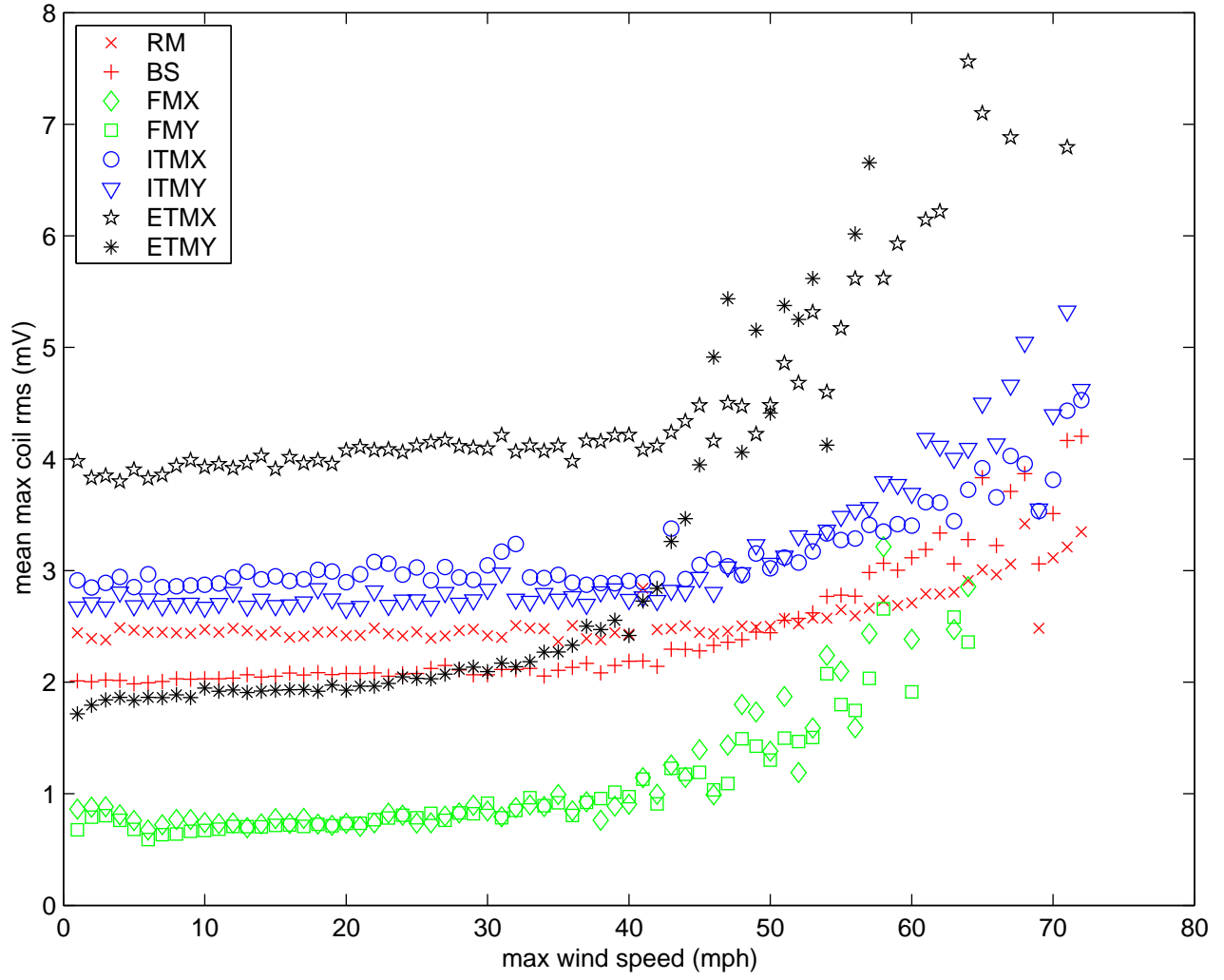


2k: Comparison Plots

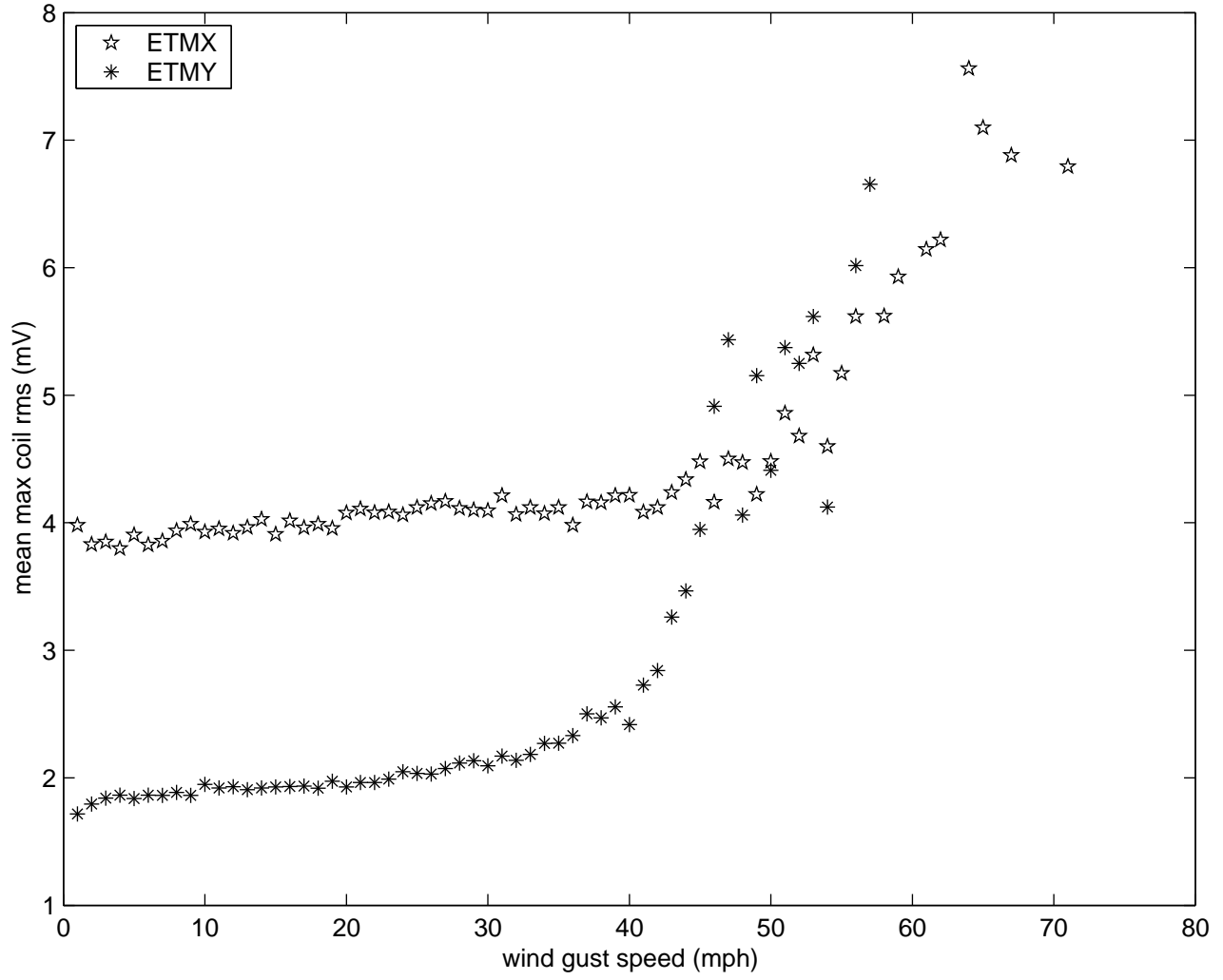
2k small optics



2k large optics

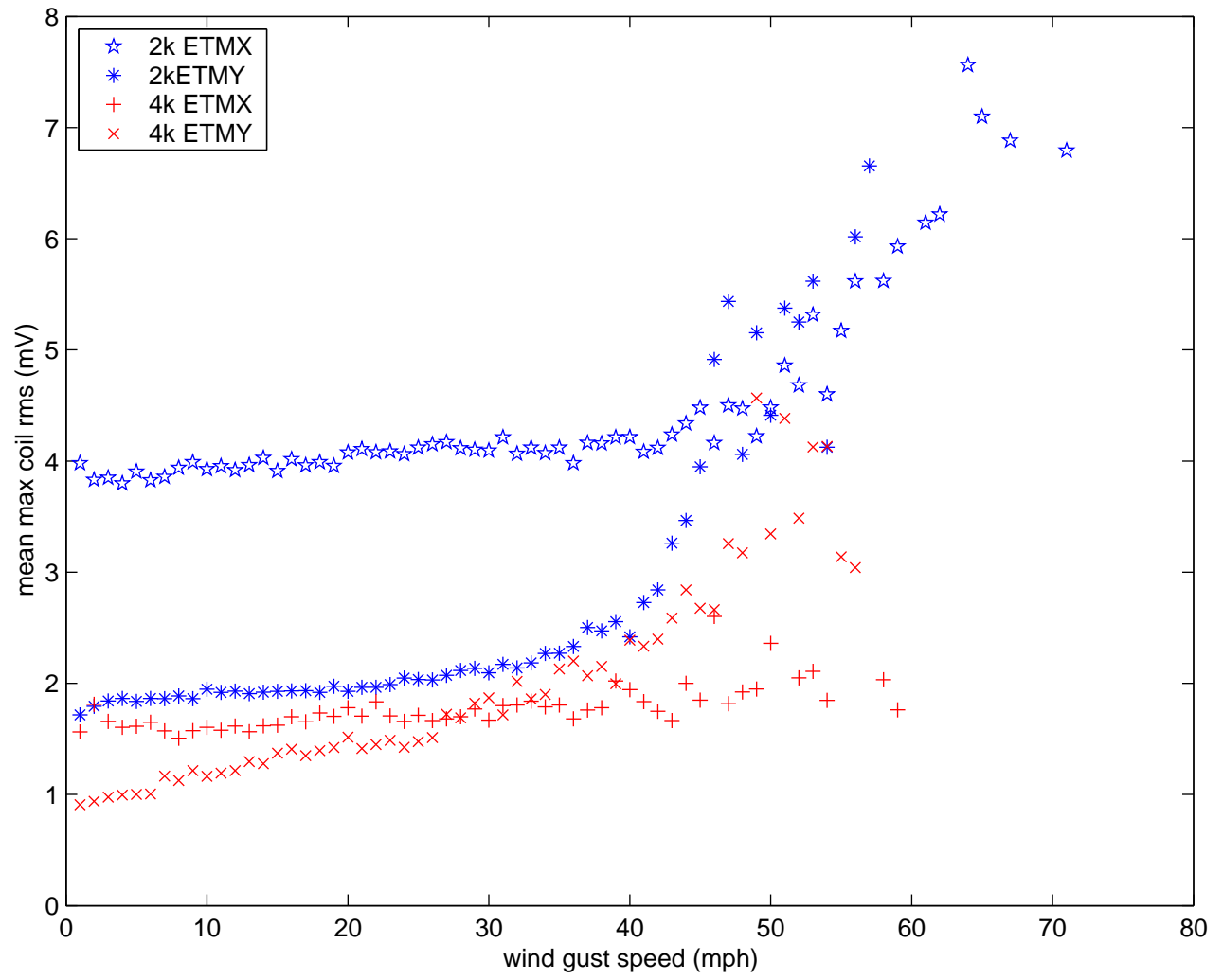


2k ETMs

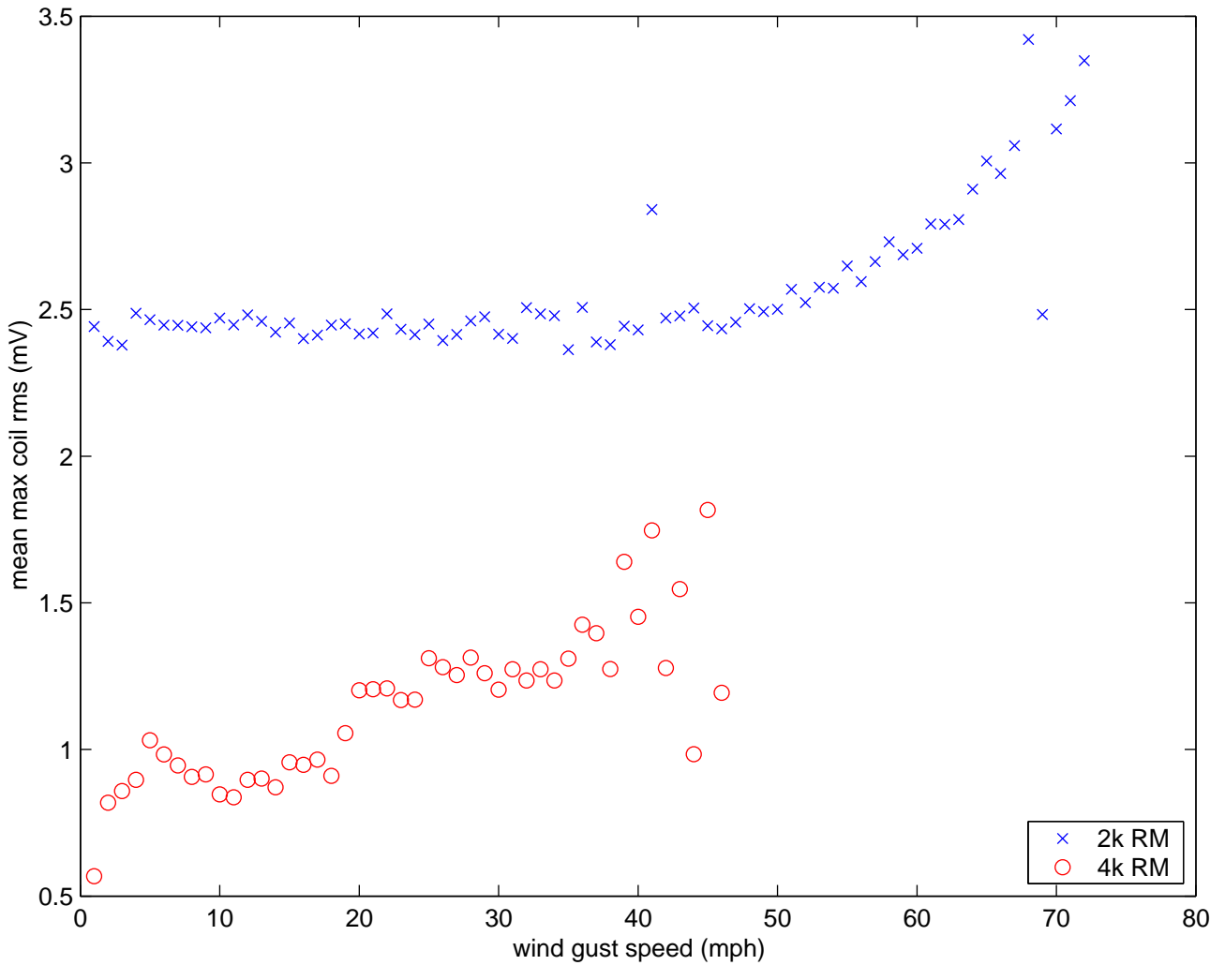


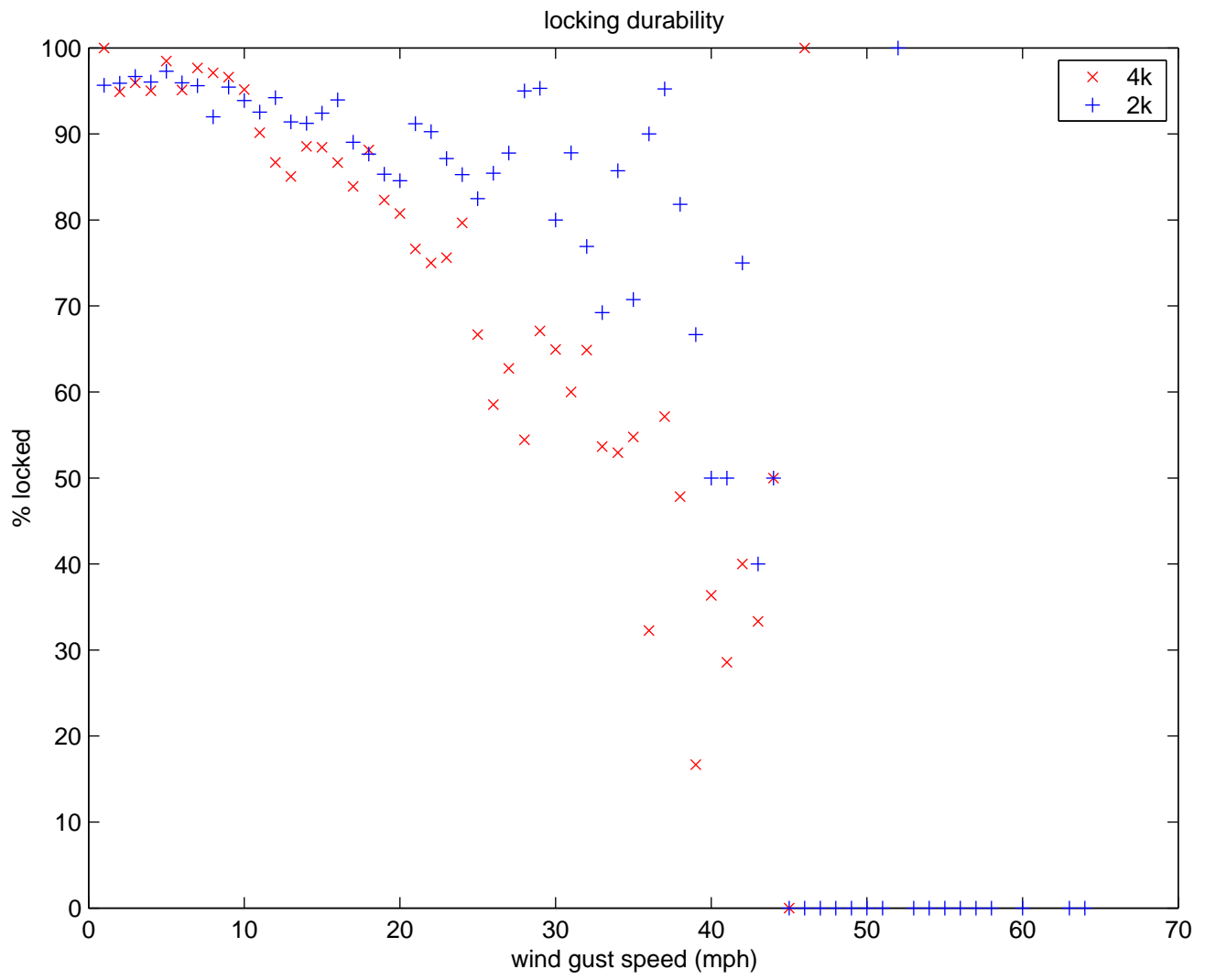
LHO Comparison Plots

LHO ETMs



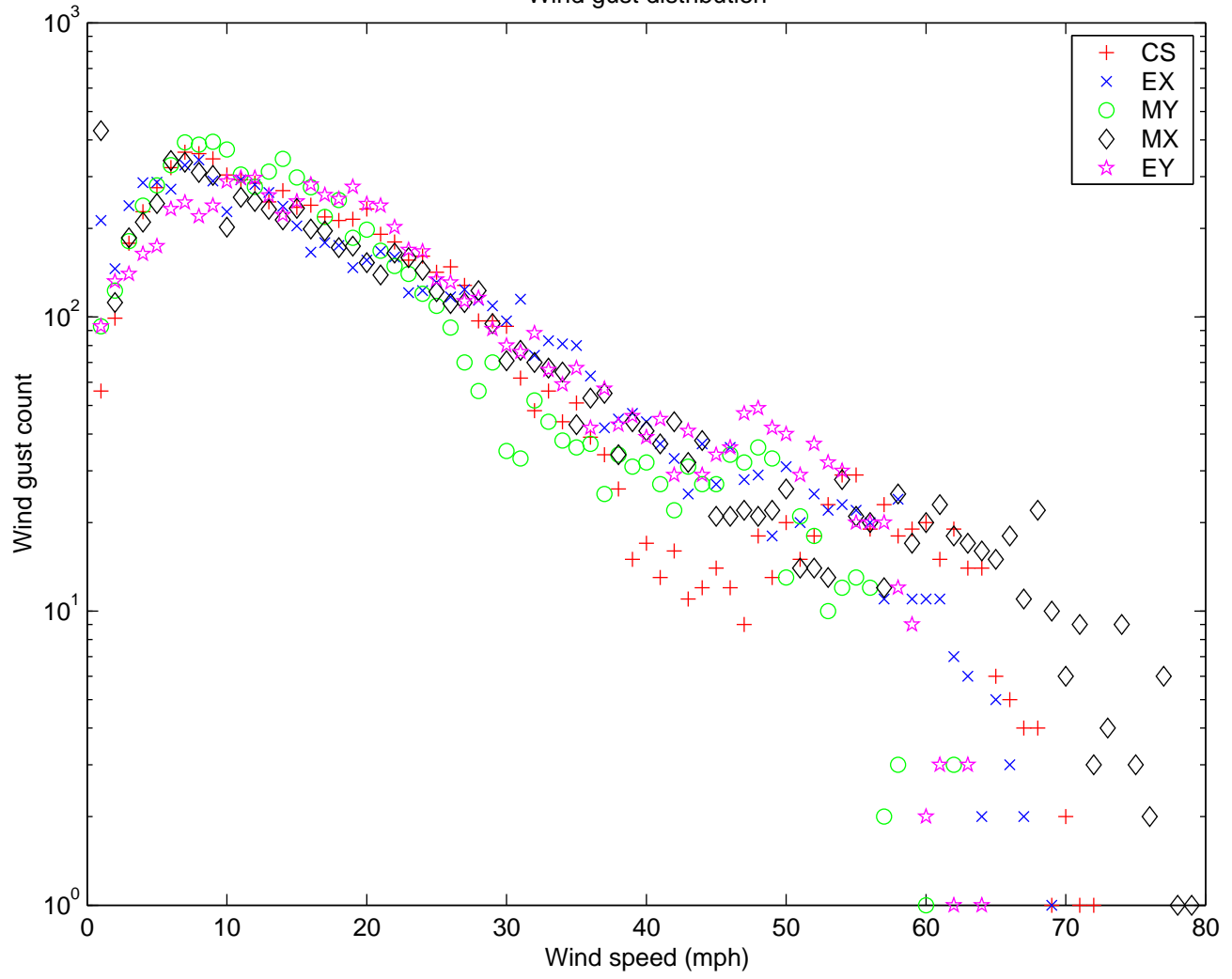
LHO RMs

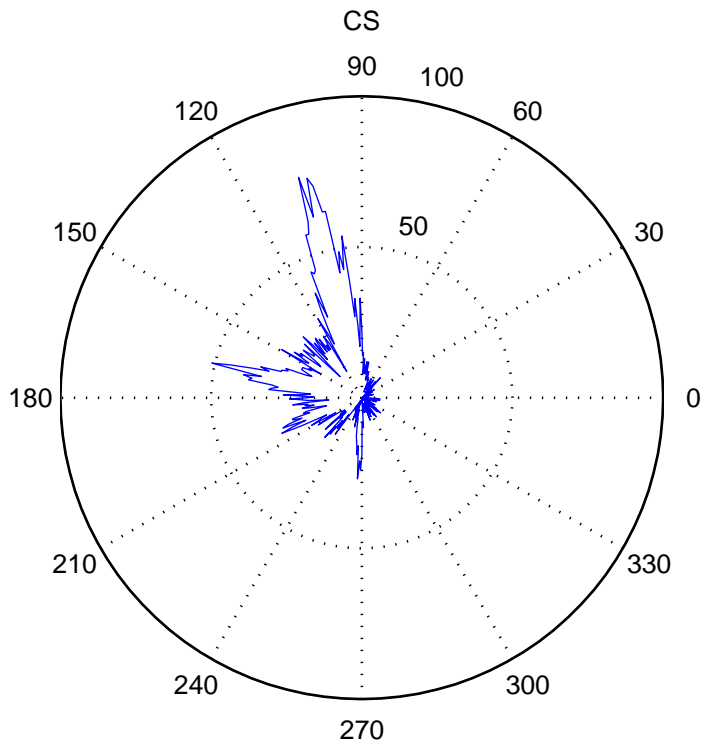
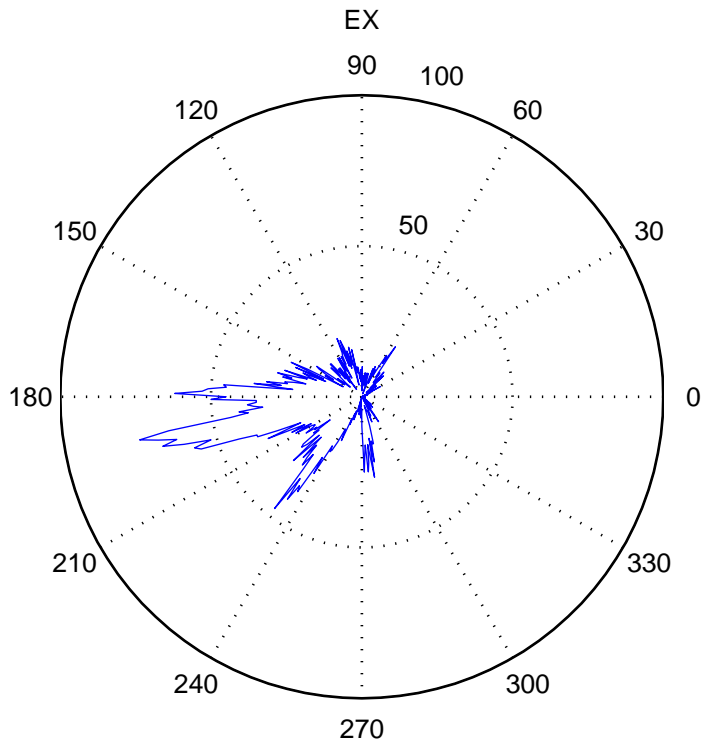




Additional Wind Plots

Wind gust distribution





m files

```
%function(IFO,BLDG)
% IFO is which IFO, ie '2k' or '4k'.
% BLDG is which building to check against, ie 'cs','mx', etc.
% function returns a plot of the percentage that the
% ifo was locked for a particular wind speed.

lock = load('4k/ifo-locked.dat');
lock = lock(:,2);
for i = 1:length(lock);
    if lock(i)>0
        lock(i) = 1;
    else
        lock(i) = 0;
    end
end

css = load('W-data/cs-s.dat');
css = ceil(css(:,2));

lsc = load('4k/lsc.dat');
lsc = lsc(:,2);

goodind = find(lsc>0);

data = [[lock],[ceil(css)]];
data = data(goodind,:);

maxwind = max(data(:,2));

for i=1:maxwind,
    windi = find(data(:,2)==i);
    locked(i) = 100 * mean(data(windi,1));
end

plot(locked,'r+')
ylabel('% locked')
xlabel('wind gust speed (mph)')
title('4k Locked vs. CS wind speed data')
```

```
ws = load('W-data/mx-s.dat');
texul = load('2k/etmx-ul.dat');
texll = load('2k/etmx-ll.dat');
texsd = load('2k/etmx-sd.dat');
lsc = load('2k/lsc.dat');

for i=1:length(texll)
    index = find(ws(:,1) == texll(i,1));
    goodind(i) = index;
end

texlla = texll(:,2);
texula = texul(:,2);
texsda = texsd(:,2);

spd = ws(goodind,:);
lsca = lsc(goodind,:);
dir = spd;

data = [[texll(:,2)],[texul(:,2)],[texsd(:,2)],[lsca(:,2)],[dir(:,2)],ceil([spd(:,2)])];

clear goodind;

%use only data for which the lsc fe is on for the lsc driven optics...
OPTIC = 'etmx';
IFO = '2k';
if IFO == '2k'
    if strcmp(OPTIC, strcat('fmx', 'fmy', 'etmx', 'etmy'))
        goodind = find(data(:,4)>0);
        data = data(goodind,:);
    end
elseif IFO == '4k'
    if strcmp(OPTIC, strcat('bs', 'rm', 'etmx', 'etmy'))
        goodind = find(data(:,4)>0);
        data = data(goodind,:);
    end
end

DISC = 50;

%use only data for which the ul, ll and sd coils were less than 50.
for i = 1:3,
    goodind = find(data(:,i)<DISC);
    data = data(goodind,:);
end;

%find the fastest wind speed...
maxwind = max(data(:,6));

%turn off that pesky divide by zero error message...
%warning off MATLAB:divideByZero;

for i=1:maxwind,
    windi = find(data(:,6)==i);
    % if ~isempty(windi),
    mc11(i) = mean(data(windi,1));
    mc12(i) = mean(data(windi,2));
    mc13(i) = mean(data(windi,3));
    % end
end

%make the reduced data array...
mcs = [mc11' mc12' mc13'];
```

```
%make the plot...
xx = length(mcs);
plot(1:xx,mcs(:,1),'r+',1:xx,mcs(:,2),'bx',1:xx,mcs(:,3),'k*')
xlabel('wind speed (mph)')
ylabel('mean coil rms (mV)')
titlestring = [IFO,' ',OPTIC];
title(titlestring)
legend('LL coil','UL coil','SD coil',2)

%send out the average of ll and ul...
aetmx = mean([mcll;mcu]);
```

```
function out = WIND2COIL(IFO,OPTIC,DISC)
%function out = WIND2COIL('IFO','OPTIC',DISC)
%IFO = which ifo, ie '2k', '4k' (not h1 or h2, etc.).
%OPTIC = which optic, ie 'mmt3'
%BUILDING = which building is the optic in ('ex','mx','cs','my','ey').
%DISC = discriminator, which coil data to be eliminated. should be
%watchdog trip value.
%
%function will plot all three coil channels vs wind speed.
%out is the mean of ll and ul coils, sd is discarded.
%
%Also, data points are discarded for when the lsc is off for the lsc driven optics.

%automatically figure the building...
if strcmp(OPTIC,strcmp('sm','sml','sm2','mc1','mc2','mc3','mmt1','mmt2','mmt3','rm','bs',
'fmx','fmy','itm','itmy'))
    BUILDING = 'cs';
elseif IFO == '2k'
    if OPTIC == 'etmx'
        BUILDING = 'mx';
    elseif OPTIC == 'etmy'
        BUILDING = 'my';
    end
elseif IFO == '4k'
    if OPTIC == 'etmx'
        BUILDING = 'ex';
    elseif OPTIC == 'etmy'
        BUILDING = 'ey';
    end
end

%load the data...
c11 = load([IFO,'/',OPTIC,'-ll.dat']);
c12 = load([IFO,'/',OPTIC,'-ul.dat']);
c13 = load([IFO,'/',OPTIC,'-sd.dat']);
lsc = load([IFO,'/','lsc.dat']);
dir = load(['W-data','/',BUILDING,'-d.dat']);
spd = load(['W-data','/',BUILDING,'-s.dat']);

data = [[c11(:,2)],[c12(:,2)],[c13(:,2)],[lsc(:,2)],[dir(:,2)],[ceil([spd(:,2)])]];

%use only data for which the lsc fe is on for the lsc driven optics...
if IFO == '2k'
    if strcmp(OPTIC,strcmp('fmx','fmy','etmx','etmy'))
        goodind = find(data(:,4)>0);
        data = data(goodind,:);
    end
elseif IFO == '4k'
    if strcmp(OPTIC,strcmp('bs','rm','etmx','etmy'))
        goodind = find(data(:,4)>0);
        data = data(goodind,:);
    end
end

%use only data for which the ul, ll and sd coils were less than 50.
for i = 1:3,
    goodind = find(data(:,i)<DISC);
    data = data(goodind,:);
end;

%find the fastest wind speed...
maxwind = max(data(:,6));

%turn off that pesky divide by zero error message...
%warning off MATLAB:divideByZero;
```

```
for i=1:maxwind,
    windi = find(data(:,6)==i);
    %   if ~isempty(windi),
        mcll(i) = mean(data(windi,1));
        mcul(i) = mean(data(windi,2));
        mcsd(i) = mean(data(windi,3));
    %   end
end

%make the reduced data array...
mcs = [mcll' mcul' mcsd'];

%make the plot...
xx = length(mcs);
plot(1:xx,mcs(:,1),'r+',1:xx,mcs(:,2),'bx',1:xx,mcs(:,3),'k*')
xlabel('wind speed (mph)')
ylabel('mean coil rms (mV)')
titlestring = [IFO,' ',OPTIC];
title(titlestring)
legend('LL coil','UL coil','SD coil',2)

%send out the average of ll and ul...
out = mean([mcll;mcul]);
```

```
function WINDDIR(SPD)
% plots cs and ex wind direction data for winds above SPD.

exd = load('W-data/ex-d.dat');
exs = load('W-data/ex-s.dat');
csd = load('W-data/cs-d.dat');
css = load('W-data/cs-s.dat');

ex = [ceil(exs(:,2)), exd(:,2)];
cs = [ceil(css(:,2)), csd(:,2)];

gia = find(ex(:,1)>SPD);
gib = find(cs(:,1)>SPD);

ex = ex(gia,2);
%giaa = find(ex(:,1)<[SPD + 10]);
%ex = ex(giaa,2);

cs = cs(gib,2);
%gibb = find(cs(:,1)>[SPD + 10]);
%cs = cs(gibb,2);

EX = hist(ex,360);
CS = hist(cs,360);

dirs = 1:360;
dirs = [2*pi*dirs]/360;

figure(3)
title(['Wind Direction Distribution above ',SPD,' mph'])
subplot(2,1,1)
polar(dirs,EX)
title('EX')

%figure(2)
subplot(2,1,2)
polar(dirs,CS)
title('CS')
```



```

figure(1)
subplot(3,2,1)
asma = wind2coil('2k','sm1',50);
subplot(3,2,2)
asmb = wind2coil('2k','sm2',50);
subplot(3,2,3)
amca = wind2coil('2k','mc1',50);
subplot(3,2,4)
amcb = wind2coil('2k','mc2',50);
subplot(3,2,5)
amcc = wind2coil('2k','mc3',50);
subplot(3,2,6)
ammta = wind2coil('2k','mmt1',50);

```

```

figure(2)
subplot(3,2,1)
ammtb = wind2coil('2k','mmt2',50);
subplot(3,2,2)
ammtc = wind2coil('2k','mmt3',50);
subplot(3,2,3)
arm = wind2coil('2k','rm',50);
subplot(3,2,4)
abs = wind2coil('2k','bs',50);
subplot(3,2,5)
aitmx = wind2coil('2k','itmx',50);
subplot(3,2,6)
aitmy = wind2coil('2k','itmy',50);

```

```

figure(3)
subplot(2,2,1)
afmx = wind2coil('2k','fmx',50);
subplot(2,2,2)
afmy = wind2coil('2k','fmy',50);
subplot(2,2,3)
tketmxwind2coil;
subplot(2,2,4)
aetmy = wind2coil('2k','etmy',50);

```

%small optics

```

figure(4)
plot(1:length(asma),asma,'rx',1:length(asmb),asmb,'rh',1:length(amca),amca,'bd',1:length(amcb),amcb,'bs',1:length(amcc),amcc,'bo',1:length(ammta),ammta,'k+',1:length(ammtb),ammtb,'kv',1:length(ammtc),ammtc,'kp')
legend('sm1','sm2','mc1','mc2','mc3','mmt1','mmt2','mmt3',2)
title('2k small optics')
ylabel('mean max coil rms (mV)')
xlabel('max wind speed (mph)')

```

%large optics

```

figure(5)
plot(1:length(arm),arm,'rx',1:length(abs),abs,'r+',1:length(afmx),afmx,'gd',1:length(afmy),afmy,'gs',1:length(aitmx),aitmx,'bo',1:length(aitmy),aitmy,'bv',1:length(aetmx),aetmx,'kp',1:length(aetmy),aetmy,'k*')
%don't forget to add etms: 1:length(aetmx),aetmx,'yv'
legend('RM','BS','FMX','FMY','ITMX','ITMY','ETMX','ETMY',2)
title('2k large optics')
ylabel('mean max coil rms (mV)')
xlabel('max wind speed (mph)')

```

%the 4k after here:

```

figure(6)
subplot(3,2,1)
bsm = wind2coil('4k','sm',50);
subplot(3,2,2)
bmca = wind2coil('4k','mc1',50);

```

```
subplot(3,2,3)
bmcb = wind2coil('4k','mc2',100);
subplot(3,2,4)
bmcc = wind2coil('4k','mc3',50);
subplot(3,2,5)
bmmta = wind2coil('4k','mmt1',50);
subplot(3,2,6)
bmmtb = wind2coil('4k','mmt2',50);

figure(7)
subplot(2,2,1)
bmmtc = wind2coil('4k','mmt3',50);
subplot(2,2,3)
bitmx = wind2coil('4k','itmx',50);
subplot(2,2,4)
bitmy = wind2coil('4k','itmy',50);

figure(8)
subplot(2,2,1)
brm = wind2coil('4k','rm',50);
subplot(2,2,2)
bbs = wind2coil('4k','bs',50);
subplot(2,2,3)
betmx = wind2coil('4k','etmx',200);
subplot(2,2,4)
betmy = wind2coil('4k','etmy',200);

%small optics
figure(9)
plot(1:length(bsm),bsm,'rx',1:length(bmca),bmca,'bd',1:length(bmcb),bmcb,'bs',1:length(bmcc),
,bmcc,'bo',1:length(bmmta),bmmta,'k+',1:length(bmmtb),bmmtb,'kv',1:length(bmmtc),bmmtc,'kp')
legend('sm','mc1','mc2','mc3','mmt1','mmt2','mmt3',2)
title('4k small optics')
ylabel('mean max coil rms (mV)')
xlabel('max wind speed (mph)')

%large optics
figure(10)
plot(1:length(brm),brm,'rx',1:length(bbs),bbs,'r+',1:length(bitmx),bitmx,'bo',1:length(bitmy),
),bitmy,'bv',1:length(betmx),betmx,'kp',1:length(betmy),betmy,'k*')
legend('RM','BS','ITMX','ITMY','ETMX','ETMY',2)
title('4k large optics')
ylabel('mean max coil rms (mV)')
xlabel('max wind speed (mph)')
```

```
clear all
csspd = load('W-data/cs-s.dat');
csspd = ceil(csspd(:,2));
csh = hist(csspd,max(csspd));

mxspd = load('W-data/mx-s.dat');
mxspd = ceil(mxspd(:,2));
mxh = hist(mxspd,max(mxspd));

myspd = load('W-data/my-s.dat');
myspd = ceil(myspd(:,2));
myh = hist(myspd,max(myspd));

exspd = load('W-data/ex-s.dat');
exspd = ceil(exspd(:,2));
exh = hist(exspd,max(exspd));

eyspd = load('W-data/ey-s.dat');
eyspd = ceil(eyspd(:,2));
eyh = hist(eyspd,max(eyspd));

semilogy(1:length(csh),csh,'r+',1:length(exh),exh,'bx',1:length(myh),myh,'go',1:length(mxh),
mxh,'kd',1:length(eyh),eyh,'mp')
title('Wind gust distribution')
legend('CS','EX','MY','MX','EY')
ylabel('Wind gust count')
xlabel('Wind speed (mph)')
```