Pixeldrift_analysis

March 5, 2020

1 Correction of the wavelength dependent pixel drift - SWIR

Abstract – *This document gives an analysis of the observed wavelength dependent pixel drift, and shows a way correction methed. This correction method is then analysed.*

The document is made in Jupyter Notebook with MATLAB 2019b
(note - this script is run in linux, in windows '/' might need to be changed to '\')

[1]:
```
format compact
%plot inline
addpath(genpath(pwd))

% this box is just for some settings. inline vs native2unicode
```

1.1 Analysing the pixel drift

The pixel drift can be observed by looking at the image in different wavelengts. For the SWIR is visible here This movement is bad when the samples move because it creates a spectal frankenstein from all pixels on the path

1.1.1 Estimeating the pixel drift with a checker board

Method: use a black and white checkerboard that black and white in all used wavelengths. The take one reference chanel and see what vector should be added to x and y coordinate in order to restore the shape. This obviously reaquires a continous value from the vecter which can be done in matlab using `interp2()`.

$$\text{HSI\_corrected}(i, j, \lambda) = \text{HSI}(i + \delta_i(\lambda), j\delta_j(\lambda), \lambda) \tag{1}$$

For better statistics I used a couple of measurements for each camera. First, select the files by there name. There were 6 samples made with the a side of 0.25 cm and 6 samples with a side of 0.5 cm. Always 3 straight and 3 at an angle.

[2]:
```
do_calculation = true;
do_calculation = false  % calculation may take a while, comment this line to do␣
 ↪calculation

if do_calculation
    for interp_method = ["linear","cubic"]
        interp_method
```

```
        tic
        total_path = './metingen/project pixelmovement/SWIR/SWIR_BW_*_corrected.
 ↪raw';
        names = find_files(total_path);
        [~,n] = size(names);
        all_paths = {};
        for i = 1:n
%             i
           r = HSI_pathfinder(names{i}, 50, interp_method, 5);
           all_paths{end+1} = r;
        end
        toc
        if interp_method == "linear"
            save all_paths_SWIR_linear.mat all_paths
        else
            save all_paths_SWIR_cubic.mat all_paths
        end
    end
else
    load all_paths_SWIR_linear.mat
    load all_paths_SWIR_cubic.mat
end
```

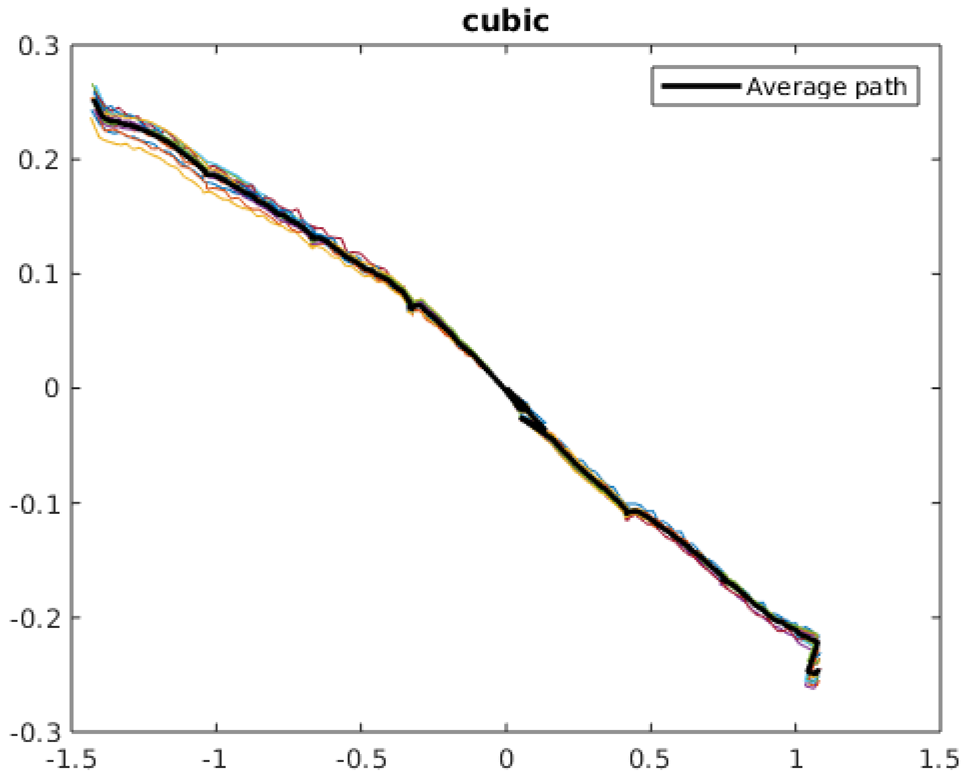
```
do_calculation =
  logical
   0
```

In time we have * Linear: 353 seconds * Cubic: 417 seconds
All paths plotted gives

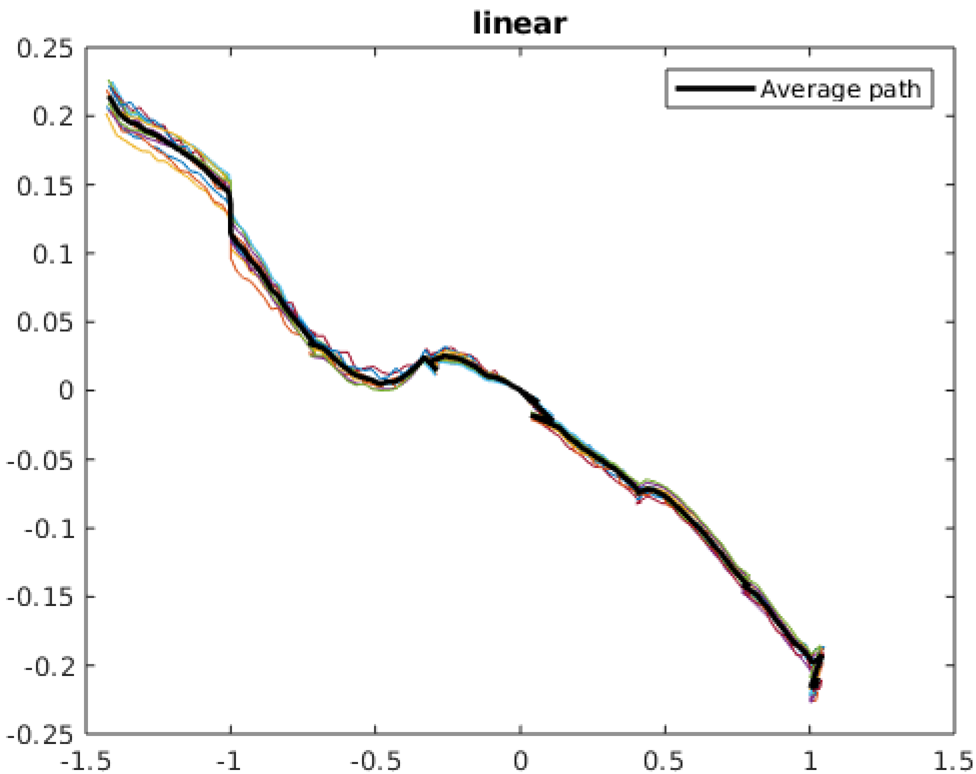
[4]:
```
for interp_method = ["linear","cubic"]
    if interp_method == "linear"
        load all_paths_SWIR_linear.mat
    else
        load all_paths_SWIR_cubic.mat
    end

    [~,n] = size(all_paths);
    average_path = zeros(size(all_paths{1}));
    figure
    for i = 1:n
        r = all_paths{i};
        plot(r(1,:),r(2,:),'HandleVisibility','off')
        hold on
        average_path = average_path +r;
    end
    average_path =  average_path/n;
    plot(average_path(1,:),average_path(2,:),'k','linewidth',2)
```

```
    [~, nb] = size(average_path);
    legend('Average path')
    title(interp_method)
    maximum_deviation = 0;
    for i = 1:n
        r = all_paths{i};
        deviation = r-average_path;
        for j = 1:nb
            if norm(deviation(:,j)) > maximum_deviation
                maximum_deviation = norm(deviation(:,j));
            end
        end
    end
    interp_method
    maximum_deviation

    if interp_method == "linear"
        save average_path_SWIR_linear average_path
    else
        save average_path_SWIR_cubic average_path
    end
end


% viscircles(average_path',maximum_deviation*ones(nb,1)) % run this if you want
 ↪to check
% (requires image processing toolbox)
```

```
interp_method =
    "linear"
maximum_deviation =
    0.0221
interp_method =
    "cubic"
maximum_deviation =
    0.0223
```



cubic
Average path
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-1.5
-1
-0.5
0
0.5
1
1.5



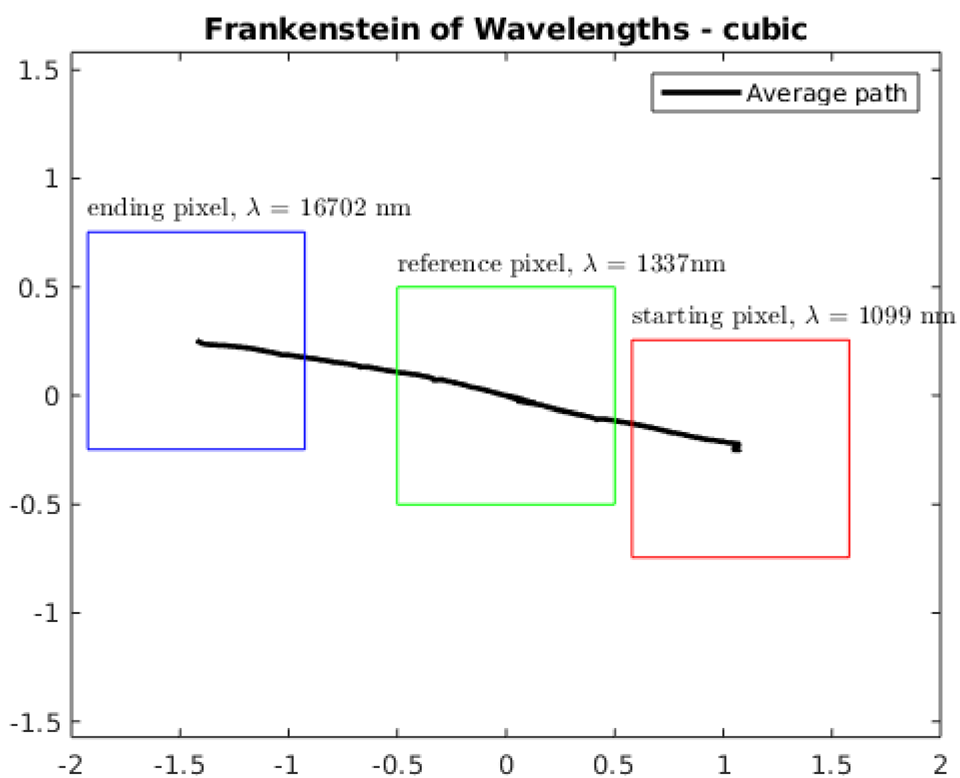
The thick line is the average path. The maximum devation frome this path for all lines is about 0.022 pixels (uncomment the last line if you want to dubble check it). This suggest the average is a reasonable pixelpath; we'll save the path.

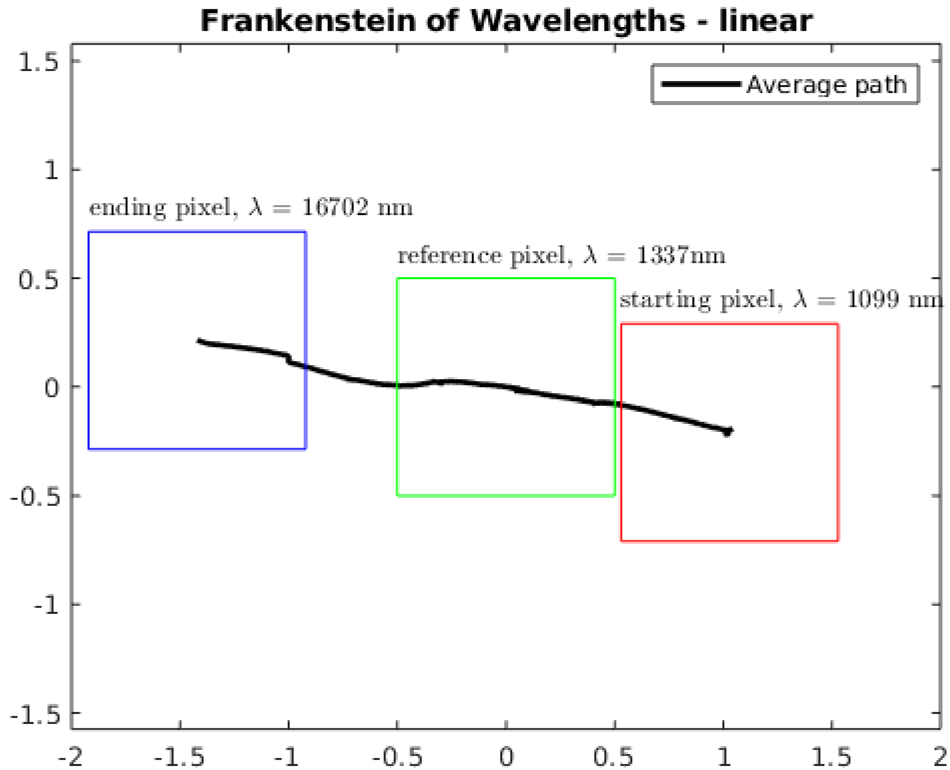
Visualy this means

[5]:
```
for interp_method = ["linear","cubic"]
    if interp_method == "linear"
        load average_path_SWIR_linear.mat
    else
        load average_path_SWIR_cubic.mat
    end
    figure
    plot(average_path(1,:),average_path(2,:),'k','linewidth',2)
    [~, nb] = size(average_path);
    title("Frankenstein of Wavelengths - " + interp_method), axis([-2,2,-1.5, 1.
 ↪5])
    legend('Average path')
    axis equal, hold on

    draw_pixel(0,0,'g')
    text(-.5,.6,'reference pixel, $\lambda$  = 1337nm','interpreter', 'latex')
```

```
    draw_pixel(average_path(1,1),average_path(2,1),'r')
    text(average_path(1,1)-.5,average_path(2,1) + .6,'starting pixel, $\lambda$ ␣
 ↪= 1099 nm','interpreter', 'latex')

    draw_pixel(average_path(1,end),average_path(2,end),'b')
    text(average_path(1,end)-.5,average_path(2,end) + .6,'ending pixel,␣
 ↪$\lambda$  = 16702 nm','interpreter', 'latex')
    length_path_pixel = norm(average_path(:,1)-average_path(:,end))
length_path_cm = length_path_pixel *  0.0340
end
```

```
length_path_pixel =
    2.4860
length_path_cm =
    0.0845
length_path_pixel =
    2.5530
length_path_cm =
    0.0868
```





[6]:
```
length_path_pixel = norm(average_path(:,1)-average_path(:,end))
length_path_cm = length_path_pixel *  0.0340
```

```
length_path_pixel =
    2.5530
length_path_cm =
    0.0868
```

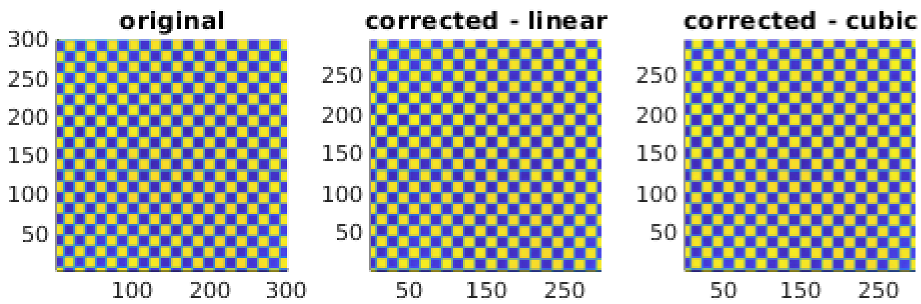
To total distance traveled is short of a milimeter.

1.1.2 Correcting the pixeldrift

I wrote a code which tries to correct this pixel drift by interpolationg from the right pixels, taking the motion into account.

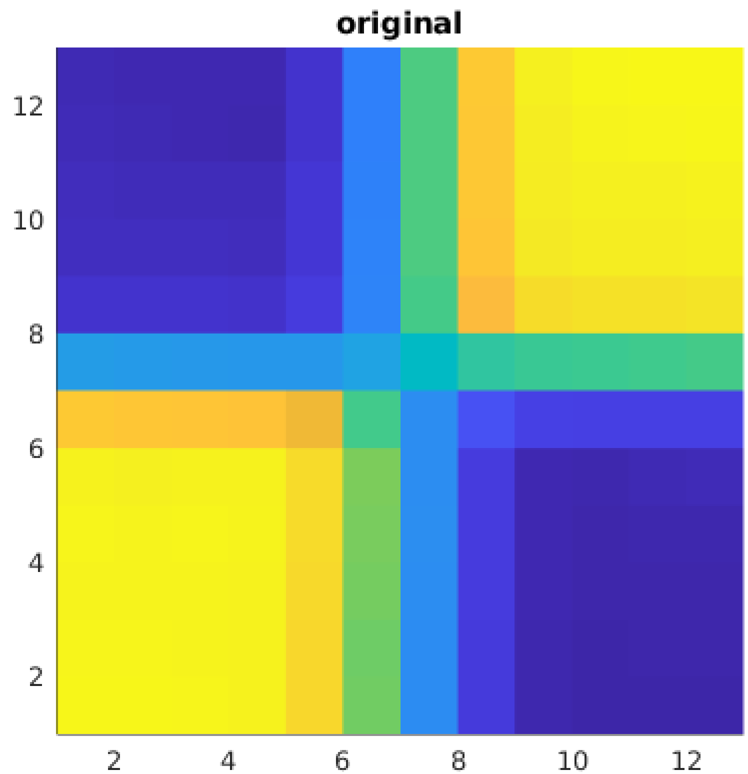
[7]:
```
%plot inline
%plot native
%plot inline

[HSI, lambda, nx, ny, nb] = HSI_reader('SWIR_BW_p5cm-1_corrected');


subplot(131)
```

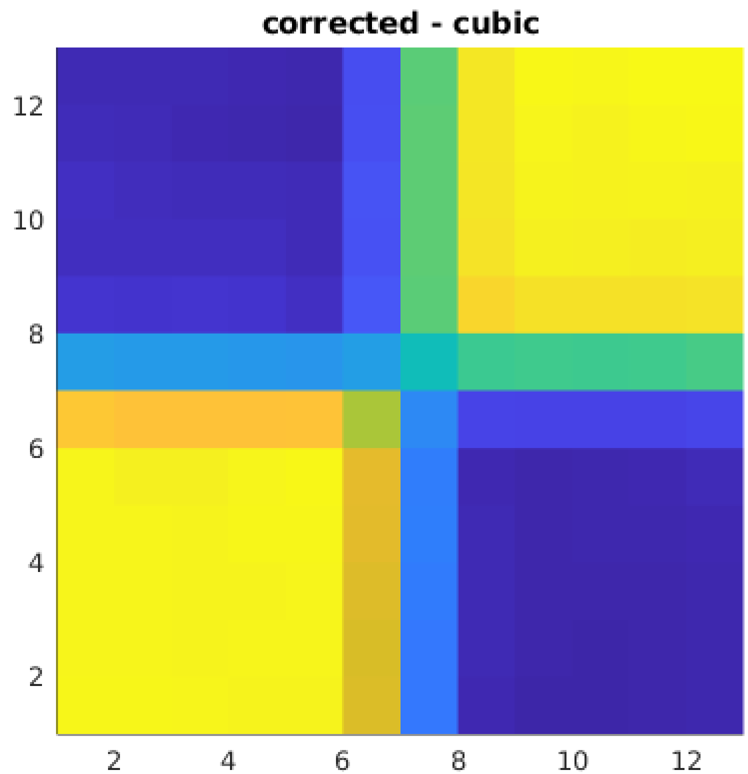
```
average_HSI = HSI_wavelength_average(HSI);
surf(average_HSI,'EdgeColor','none')
view([0 0 1]), axis('equal',[1,nx,1,ny])
title('original')

% linear
load average_path_SWIR_linear.mat
HSI_corr_linear = HSI_apply_pixelcorrection('SWIR_BW_p5cm-1_corrected', 50,␣
↪'linear', average_path);
subplot(132)
average_corrected_HSI_linear = HSI_wavelength_average(HSI_corr_linear);
surf(average_corrected_HSI_linear,'EdgeColor','none')
axis('equal'), view([0 0 1.1])
title('corrected - linear')
% sum(isnan(HSI_corr_linear(:)))

% cubic
load average_path_SWIR_cubic.mat
HSI_corr_cubic = HSI_apply_pixelcorrection('SWIR_BW_p5cm-1_corrected', 50,␣
↪'cubic', average_path);
subplot(133)
average_corrected_HSI_cubic = HSI_wavelength_average(HSI_corr_cubic);
surf(average_corrected_HSI_cubic,'EdgeColor','none')
axis('equal'), view([0 0 1.1])
title('corrected - cubic')
% sum(isnan(HSI_corr_cubic(:)))

% Three pixel rows are lost in the battle of reconstruction
```



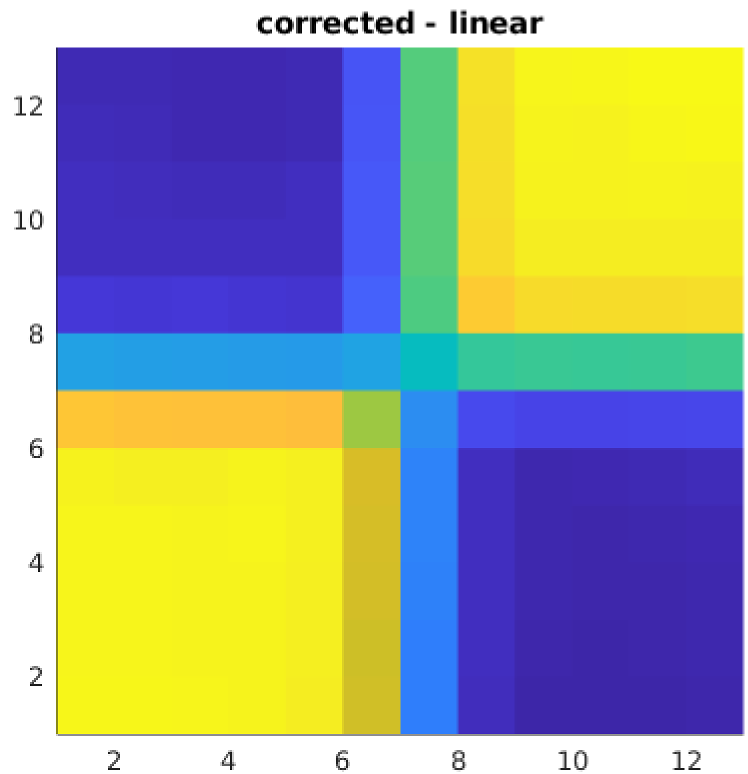
When we compare two the same regions we get

[8]:
```
index_OG_x = 97:109 ;
index_OG_y = 101:113;

index_corr_x = index_OG_x - 2;
index_corr_y = index_OG_x + 2;

surf(average_corrected_HSI_linear(index_corr_x,index_corr_y),'EdgeColor','none')
axis('equal'), view([0 0 1]),title('corrected - linear')
figure
surf(average_corrected_HSI_cubic(index_corr_x,index_corr_y),'EdgeColor','none')
axis('equal'), view([0 0 1]),title('corrected - cubic')
figure
surf(average_HSI(index_OG_x,index_OG_y),'EdgeColor','none')
axis('equal'), view([0 0 1]),title('original')
```


original
12
10
8
6
4
2
2
4
6
8
10
12



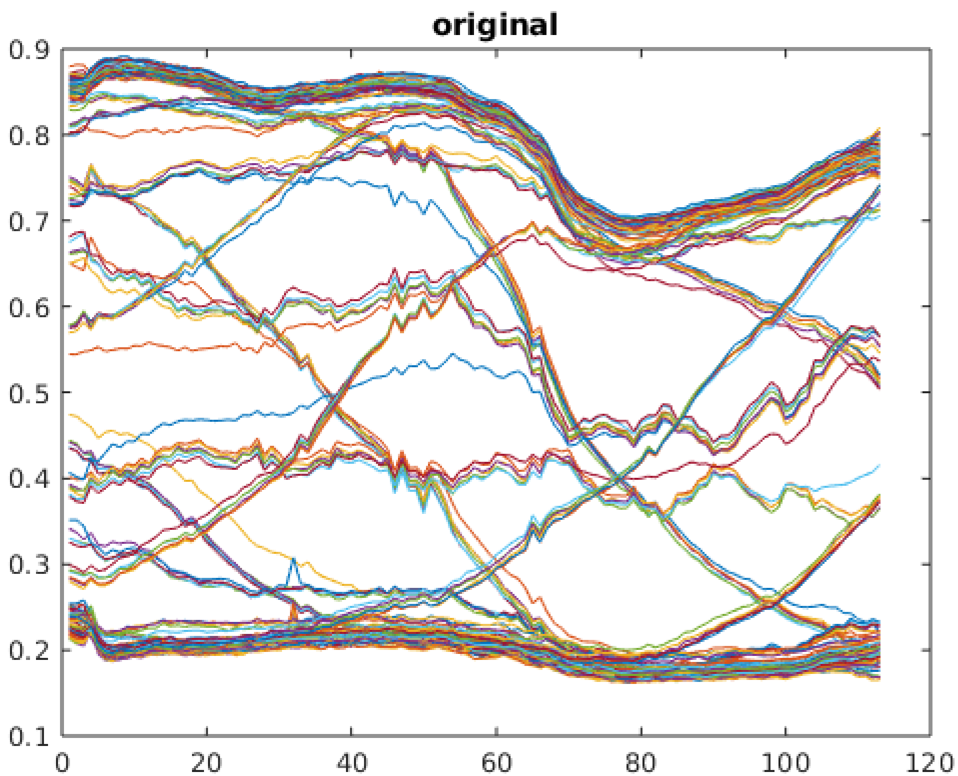
corrected - cubic
12
10
8
6
4
2
2
4
6
8
10
12

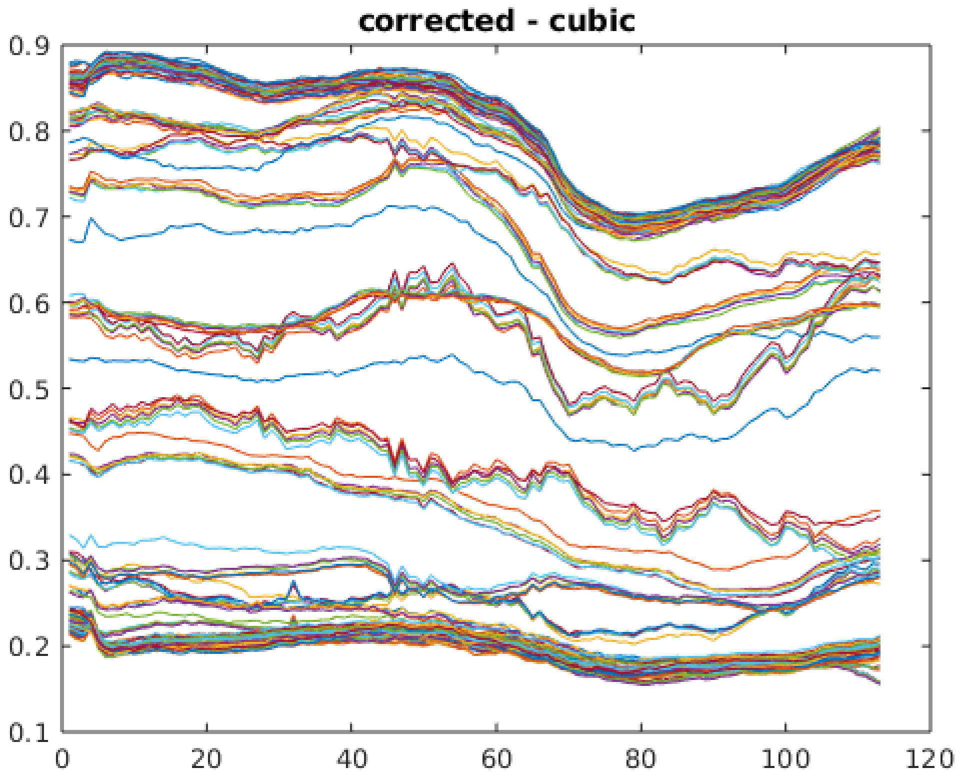


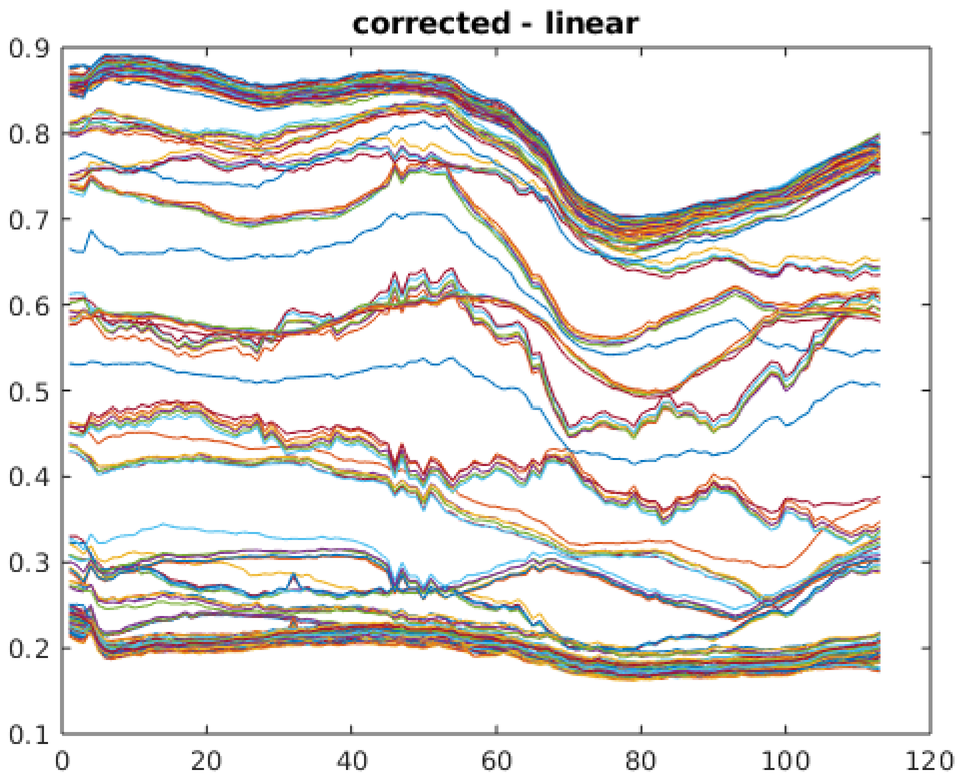
It's less blurry.

[9]:
```
for i = index_corr_x
    for j = index_corr_y
        spectrum = HSI_corr_linear(i,j,:);
        plot(spectrum(:))
        hold on
    end
end
title('corrected - linear')
figure
for i = index_corr_x
    for j = index_corr_y
        spectrum = HSI_corr_cubic(i,j,:);
        plot(spectrum(:))
        hold on
    end
end
title('corrected - cubic')
figure
for i = index_OG_x
    for j = index_OG_y
```

```
        spectrum = HSI(i,j,:);
        plot(spectrum(:))
        hold on
    end
end
title('original')
```



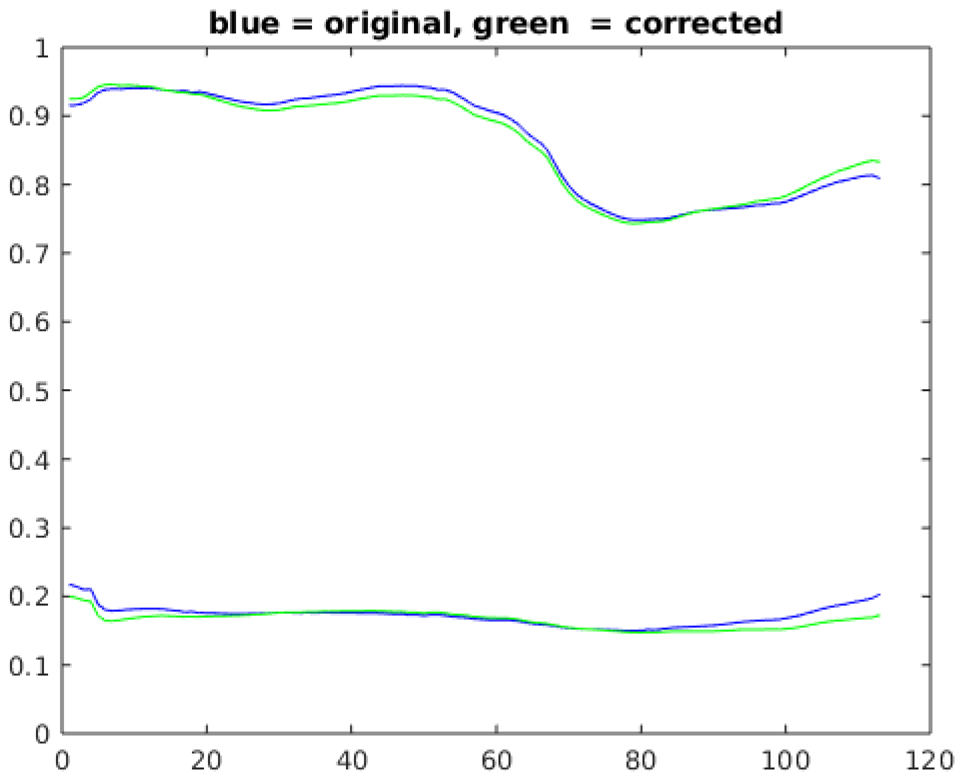

corrected - cubic
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
20
40
60
80
100
120



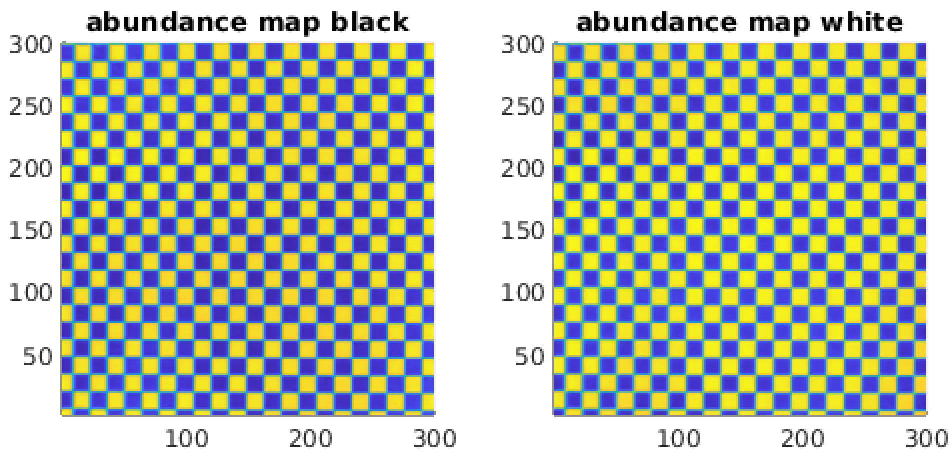
1.2 Classification and reconstruction error

The classification uses VCA, with code from J. Bioucas-Dias, et al. “Hyperspectral unmixing overview: geometrical, statistical, and sparse regression-based approaches”.

[10]:
```
[HSI, lambda, nx, ny, nb] = HSI_reader('SWIR_BW_p5cm-1_corrected');

load average_path_SWIR_cubic.mat
HSI_corr = HSI_apply_pixelcorrection('SWIR_BW_p5cm-1_corrected', 50, 'cubic',␣
 ↪average_path);

[endm_OG abund_OG] = HSI_linear_unmixing(HSI,2,300*300);
[endm_corr abund_corr] = HSI_linear_unmixing(HSI_corr,2,295*295);

plot(endm_OG,'b'), ylim([0,1])
hold on
plot(endm_corr,'g'), ylim([0,1])
title('blue = original, green  = corrected')
% sum(abund_OG) % gives ones, as it should.
```

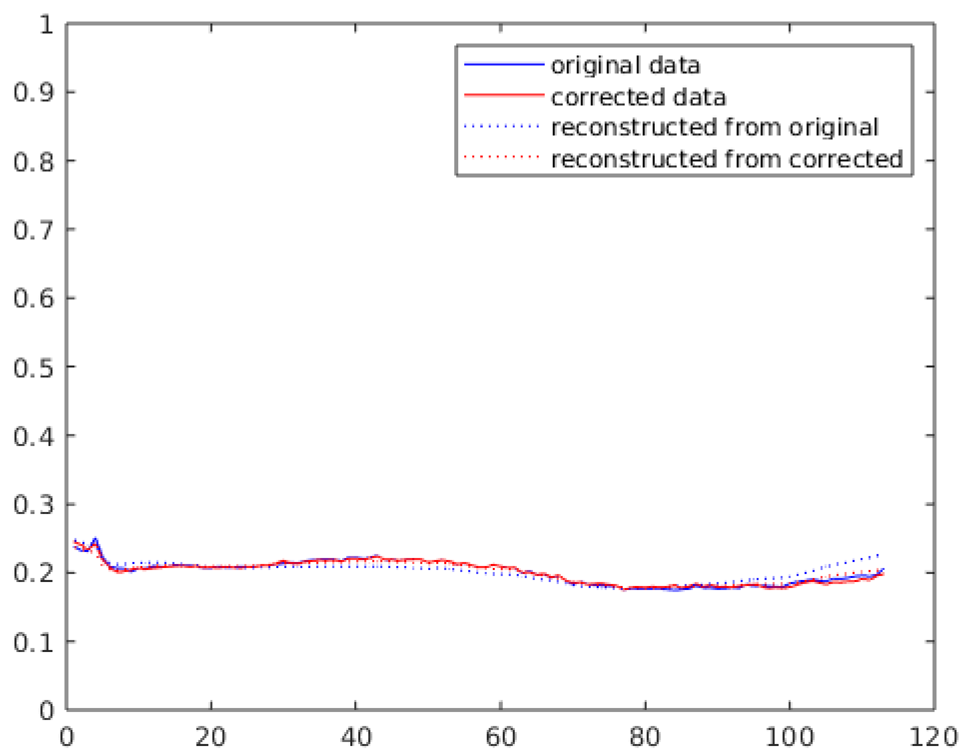


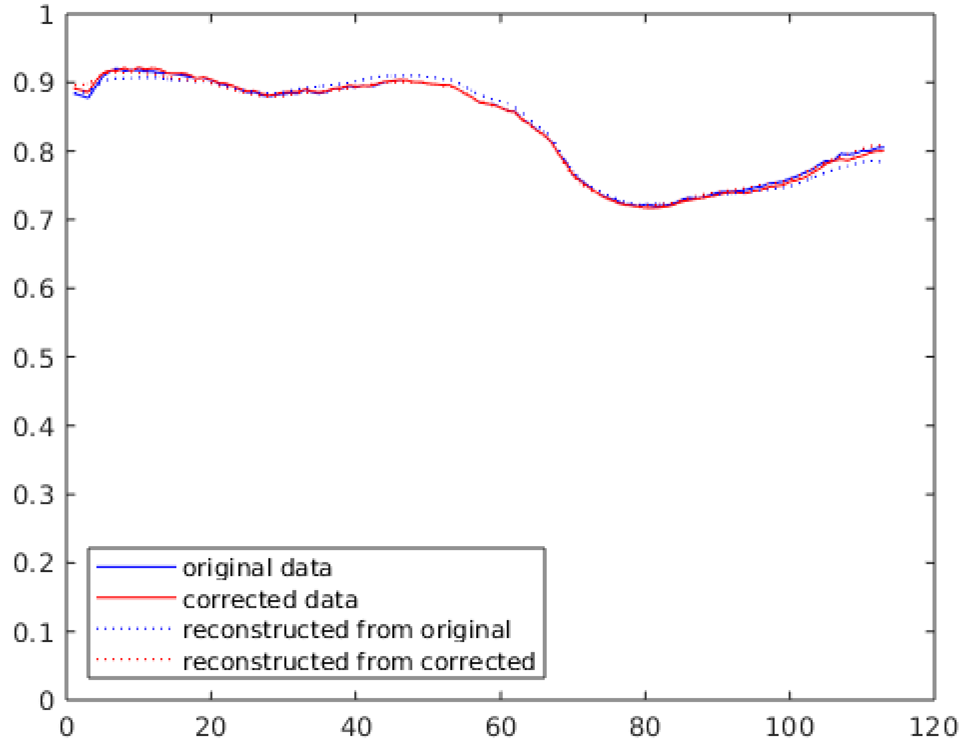
[11]:
```
abundance_black = reshape(abund_OG(1,:),[300 300]);
abundance_white = reshape(abund_OG(2,:),[300 300]);
figure
subplot(121)
HSI_plot_frame(abundance_black)
title('abundance map black')
subplot(122)
HSI_plot_frame(abundance_white)
title('abundance map white')
```



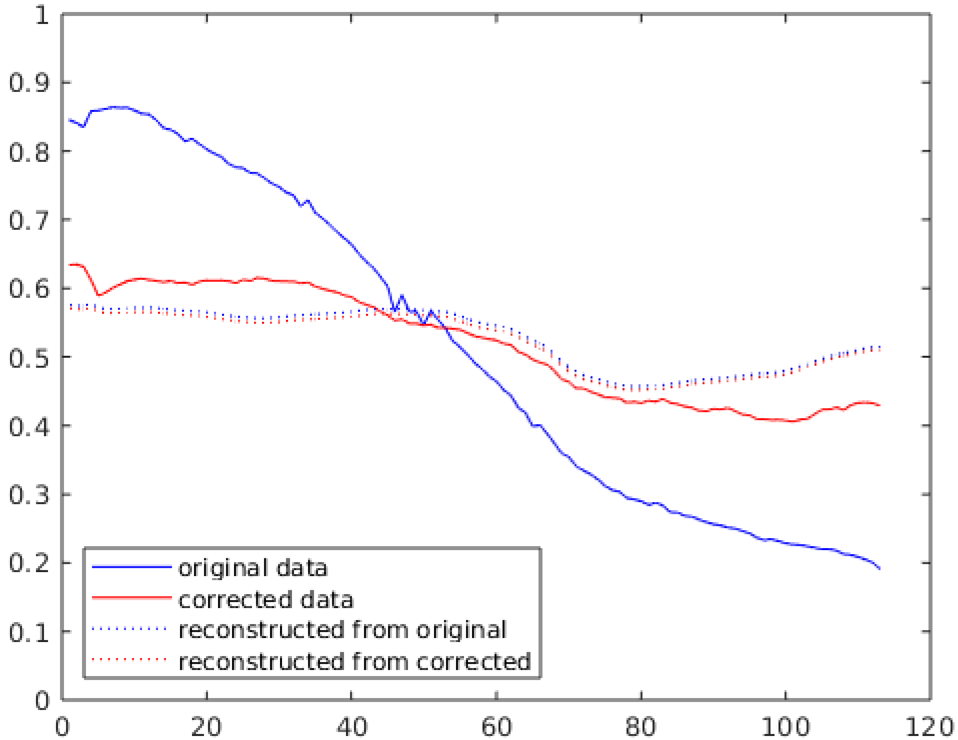
[12]:
```
for i = 1:4
figure
    switch i
        case 1
            i = 11;
            j = 11;
            location = 'southeast';
        case 2
            i = 14;
            j = 23;
            location = 'southwest';
        case 3 % white
            i = 10;
            j = 18;
            location = 'southwest';
        case 4 % black
            i = 16;
            j = 3;
            location = 'northeast';
    end
    k_OG = i+300*(j-1);
```

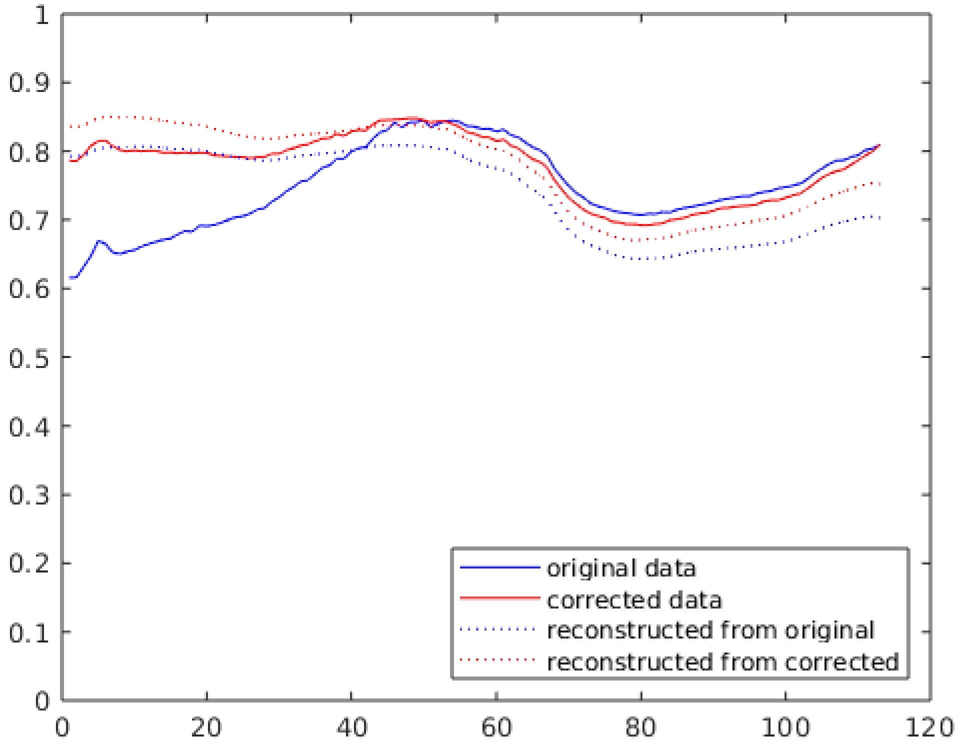
```
    k_corr = i-2+295*(j-3); % HSI(i,j,50) == HSI+corr(i-2,j-2,50)
    datapoint = HSI(i,j,:);
    plot(datapoint(:),'b')
    hold on
    datapoint = HSI_corr(i-2,j-2,:);
    plot(datapoint(:),'r')

    reconstruction = abund_OG(1,k_OG)*endm_OG(:,1) + abund_OG(2,k_OG)*endm_OG(:
 ↪,2);
    plot(reconstruction,'b:'),
    reconstruction = abund_corr(1,k_corr)*endm_corr(:,1) +␣
 ↪abund_corr(2,k_corr)*endm_corr(:,2);
    plot(reconstruction,'r:'), ylim([0,1])

    legend('original data','corrected data','reconstructed from␣
 ↪original','reconstructed from corrected','location',location)
%     plot([50 50],[0 1])
    hold off
end
```





1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
20
40
60
80
100
120
original data
corrected data
reconstructed from original
reconstructed from corrected


original data
corrected data
reconstructed from original
reconstructed from corrected
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
20
40
60
80
100
120



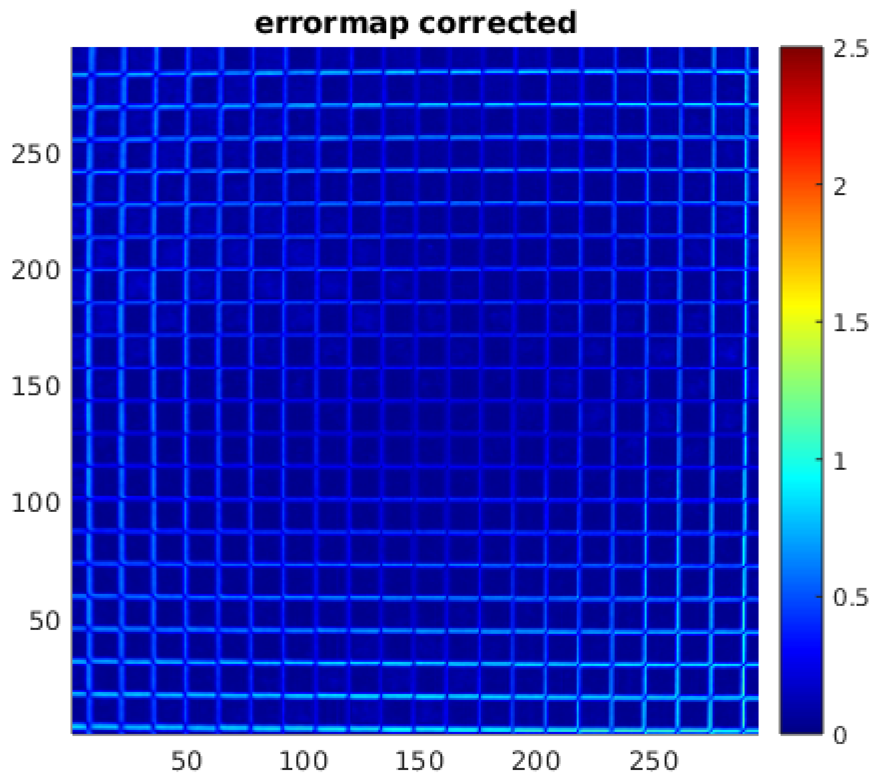
Error map

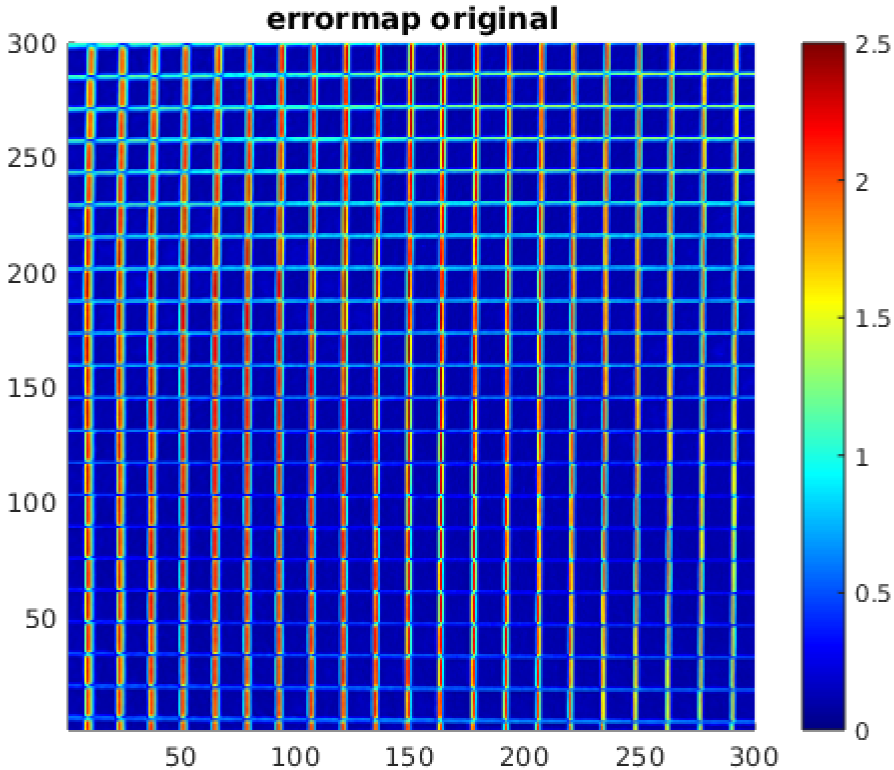
Reconstruction error map and (weighted) reconstruction error sum

[13]:
```
%plot inline

err = endm_OG*abund_OG - reshape(HSI, [300*300 113])';
error_map = vecnorm(err);
HSI_plot_frame(reshape(error_map,[300, 300]))
colormap jet
caxis([0 2.5])
colorbar
average_error_original = mean(error_map);
title('errormap original')

figure

err = endm_corr*abund_corr - reshape(HSI_corr, [295*295 113])';
error_map = vecnorm(err);
HSI_plot_frame(reshape(error_map,[295, 295]))
colormap jet
caxis([0 2.5])
colorbar
```

```
title('errormap corrected')

average_error_corrected = mean(error_map)
average_error_original
ratio = average_error_original/average_error_corrected
```

```
average_error_corrected =
    0.1638
average_error_original =
    0.4712
ratio =
    2.8757
```





Note thate the error in the original is bigger on the right side. The ratio of 2.9 might seem lower as expected, the border is only a fraction of the image. * Only black ink works in infrared – manual:

2 Correction of the wavelength dependent pixel drift - VNIR

We'll do the same thing with the VNIR; and actualy do some unmixing (cyan-magenta-yellow are invisible in IR, so unmixing couldn't be done on printed paper).

2.1 Analysing the pixel drift

2.1.1 Estimeating the pixel drift with a checker board

[14]:
```
do_calculation = true;
do_calculation = false  % calculation may take a while, comment this line to do
 ↪calculation



if do_calculation
    for interp_method = ["linear","cubic"]
        interp_method
```

```
        tic
        total_path = './metingen/project pixelmovement/VNIR/VNIR_BW_*_corrected.
 ↪raw';
        names = find_files(total_path);
        [~,n] = size(names);
        all_paths = {};
        for i = 1:n
           i
           r = HSI_pathfinder(names{i}, 75, interp_method, 2); %todo: reference␣
 ↪pixel and wavelength in file
           all_paths{end+1} = r;
        end
        toc
        if interp_method == "linear"
            save all_paths_VNIR_linear.mat all_paths
        else
            save all_paths_VNIR_cubic.mat all_paths
        end
    end
else
    load all_paths_VNIR_linear.mat
    load all_paths_VNIR_cubic.mat
end
```

```
do_calculation =
  logical
   0
```

In time we took

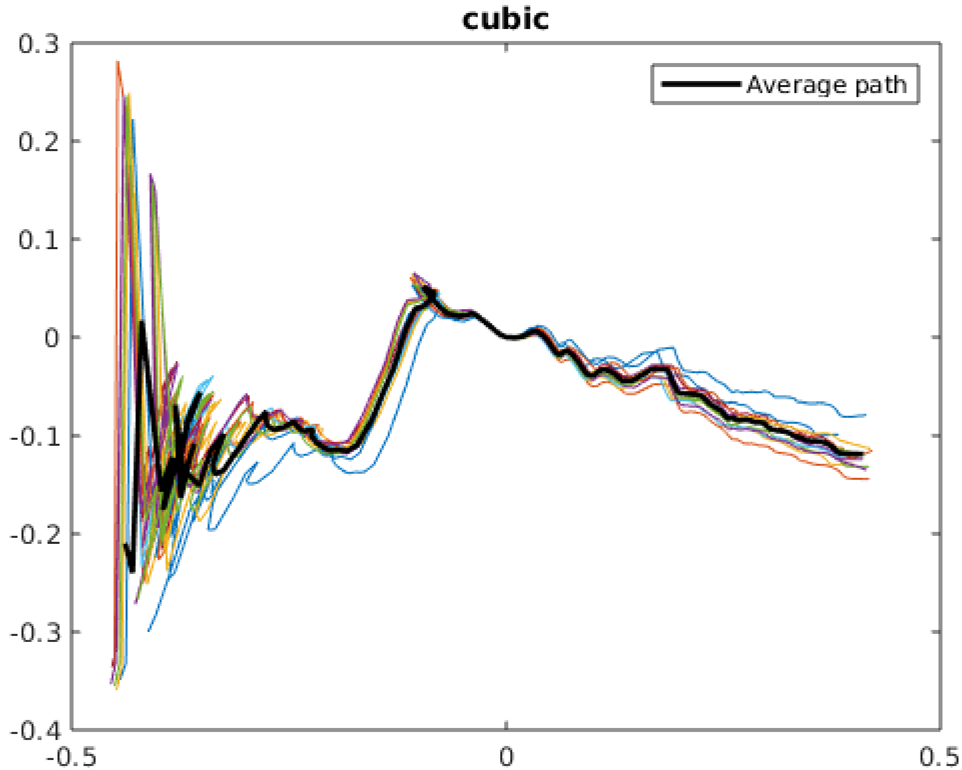
- Linear: 2491 seconds. (40 min)
- Cubic: 3263 seconds (54 min)

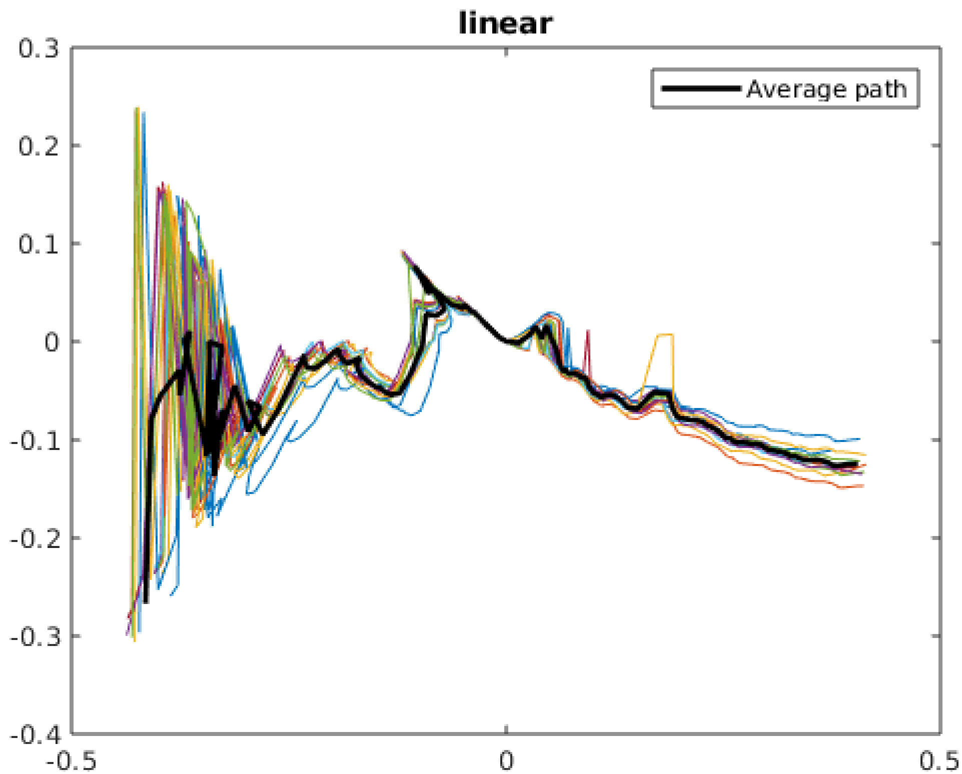
All paths plotted gives

[15]:
```
for interp_method = ["linear","cubic"]
    if interp_method == "linear"
        load all_paths_VNIR_linear.mat
    else
        load all_paths_VNIR_cubic.mat
    end

    [~,n] = size(all_paths);
    average_path = zeros(size(all_paths{1}));
    figure
    for i = 1:n
        r = all_paths{i};
        plot(r(1,:),r(2,:),'HandleVisibility','off')
```

```
        hold on
        average_path = average_path +r;
    end
    average_path =  average_path/n;
    plot(average_path(1,:),average_path(2,:),'k','linewidth',2)
    [~, nb] = size(average_path);
    legend('Average path')
    title(interp_method)
    maximum_deviation = 0;
    for i = 1:n
        r = all_paths{i};
        deviation = r-average_path;
        for j = 1:nb
            if norm(deviation(:,j)) > maximum_deviation
                maximum_deviation = norm(deviation(:,j));
            end
        end
    end
    interp_method
    maximum_deviation

    if interp_method == "linear"
        save average_path_VNIR_linear average_path
    else
        save average_path_VNIR_cubic average_path
    end
end

% maximum_deviation_in_pixels = maximum_deviation
% maximum_deviation_in_cm = maximum_deviation_in_pixels *0.0087
```

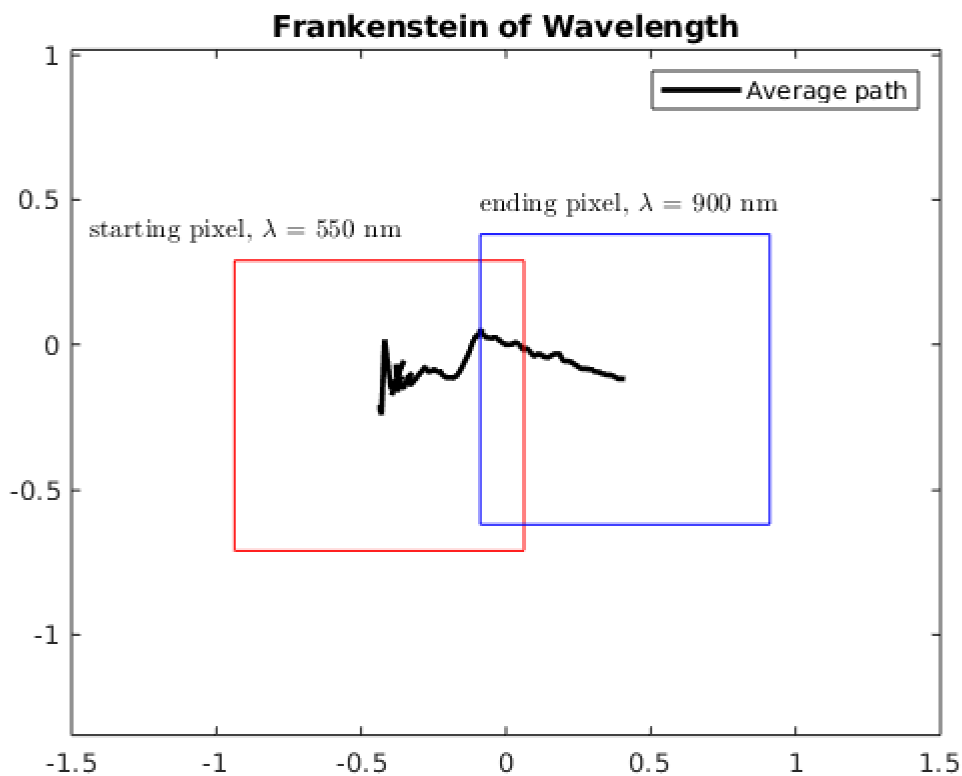
```
interp_method =
    "linear"
maximum_deviation =
    0.3186
interp_method =
    "cubic"
maximum_deviation =
    0.5220
```


cubic
Average path
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
0.5



[16]:
```
[HSI, lambda, nx, ny, nb] = HSI_reader('VNIR_BW_p5cm-1_corrected');



load average_path_VNIR_linear.mat

HSI_corr_linear = HSI_apply_pixelcorrection('VNIR_BW_p5cm-1_corrected', 50,␣
↪'linear', average_path);
subplot(132)
average_corrected_HSI_linear = HSI_wavelength_average(HSI_corr_linear);
surf(average_corrected_HSI_linear,'EdgeColor','none')
axis('equal'), view([0 0 1.1])
title('corrected - linear')
sum(isnan(HSI_corr_linear(:)))

% cubic
load average_path_SWIR_cubic.mat
HSI_corr_cubic = HSI_apply_pixelcorrection('SWIR_BW_p5cm-1_corrected', 50,␣
↪'linear', average_path);
subplot(133)
average_corrected_HSI_cubic = HSI_wavelength_average(HSI_corr_cubic);
surf(average_corrected_HSI_cubic,'EdgeColor','none')
```

```
axis('equal'), view([0 0 1.1])
title('corrected - cubic')
sum(isnan(HSI_corr_cubic(:)))
plot(average_path(1,:),average_path(2,:),'k','linewidth',2)
[~, nb] = size(average_path);
title('Frankenstein of Wavelength'), axis([-1.5,1.5,-1, 1])
legend('Average path')
axis equal, hold on

% draw_pixel(0,0,'g')
% text(-.5,.6,'reference pixel, $\lambda$  = 1337nm','interpreter', 'latex')

draw_pixel(average_path(1,1),average_path(2,1),'r')
text(average_path(1,1)-1,average_path(2,1) + .6,'starting pixel, $\lambda$  =␣
 ↪550 nm','interpreter', 'latex')

draw_pixel(average_path(1,end),average_path(2,end),'b')
text(average_path(1,end)-.5,average_path(2,end) + .6,'ending pixel, $\lambda$  =␣
 ↪900 nm','interpreter', 'latex')
```

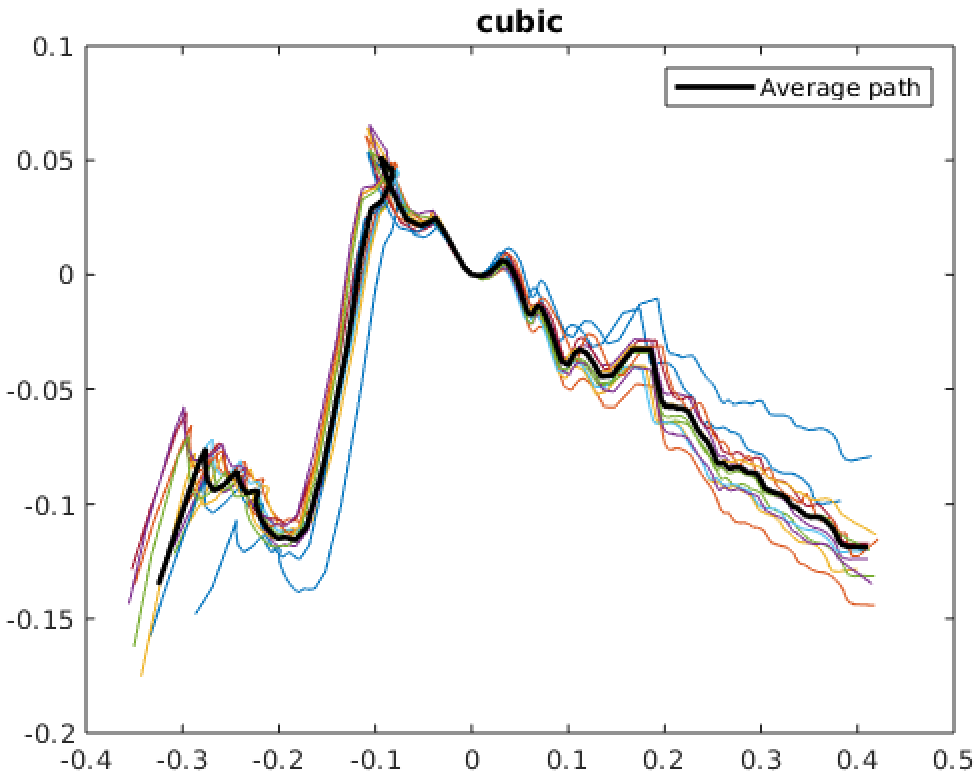


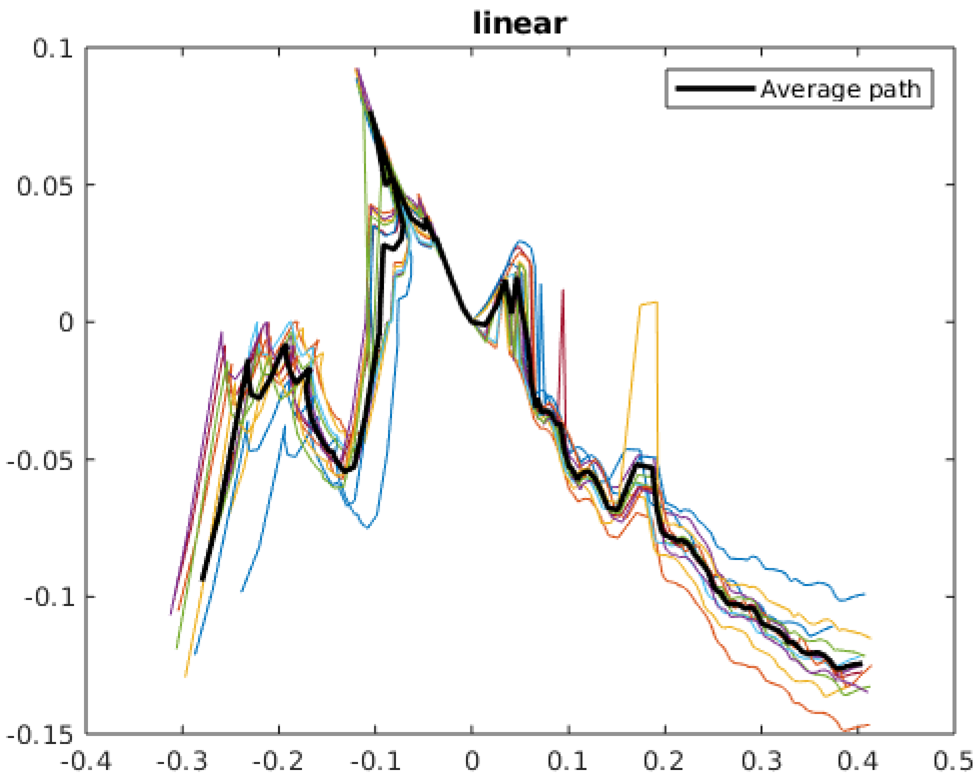
The starting bands seem realy noisy so we will take fewer bands to do the unmixing.

[17]:
```
start_band = 28

and store in dark conditions.
for interp_method = ["linear","cubic"]
    figure
    if interp_method == "linear"
        load all_paths_VNIR_linear.mat
        load average_path_VNIR_linear average_path
    else
        load all_paths_VNIR_cubic.mat
        load average_path_VNIR_cubic average_path
    end

    for i = 1:n
        r = all_paths{i};
        plot(r(1,start_band:end),r(2,start_band:end),'HandleVisibility','off')
        hold on
    end

    plot(average_path(1,start_band:end),average_path(2,start_band:
↪end),'k','linewidth',2)
    [~, nb] = size(average_path);
    legend('Average path')
    title(interp_method)

    maximum_deviation = 0;
    for i = 1:n
        r = all_paths{i};
        deviation = r-average_path;
        for j = start_band:nb
            if norm(deviation(:,j)) > maximum_deviation
                maximum_deviation = norm(deviation(:,j));
            end
        end
    end
    interp_method
    maximum_deviation
end

% maximum_deviation_in_pixels = maximum_deviation
% maximum_deviation_in_cm = maximum_deviation_in_pixels *0.0087
```

```
start_band =
    28
interp_method =
    "linear"
maximum_deviation =
```

```
    0.0797
interp_method =
    "cubic"
maximum_deviation =
    0.0460
```





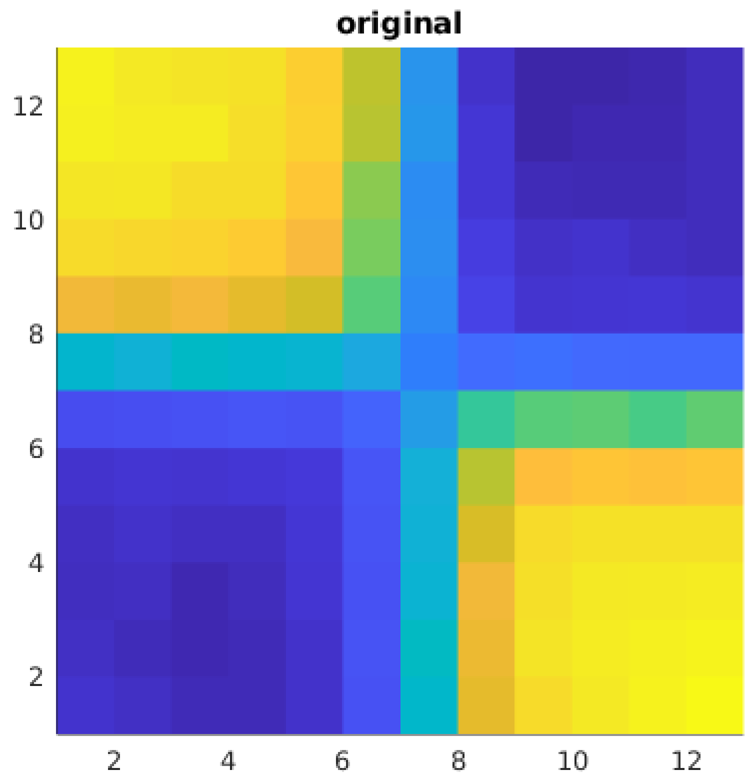
the maximum deviation changed from 0.52 to 0.04 pixel for cubic interpolation if we start at the 28 band

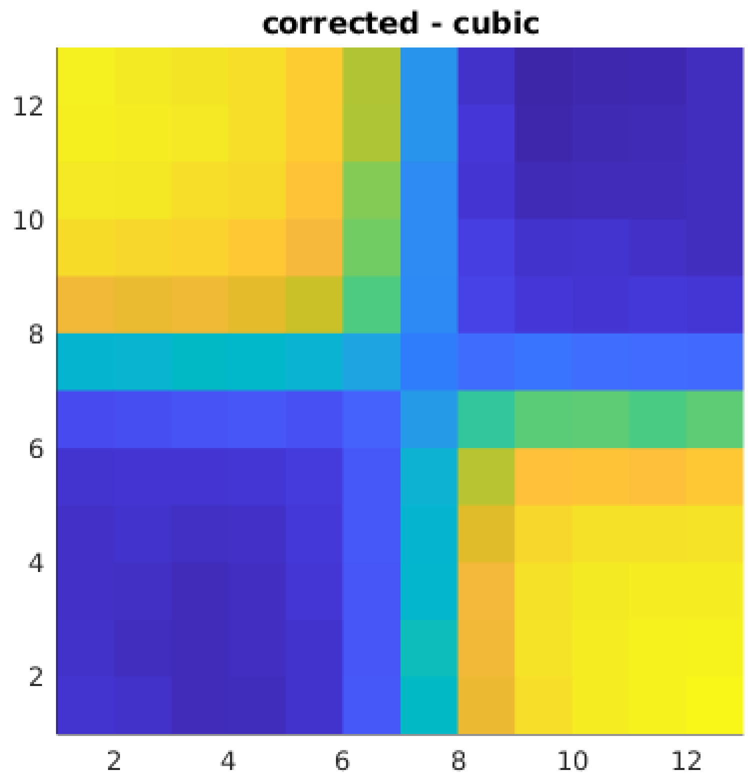
[18]:
```
length_path_pixel = norm(average_path(:,1)-average_path(:,end))
length_path_cm = length_path_pixel *  0.0087
```

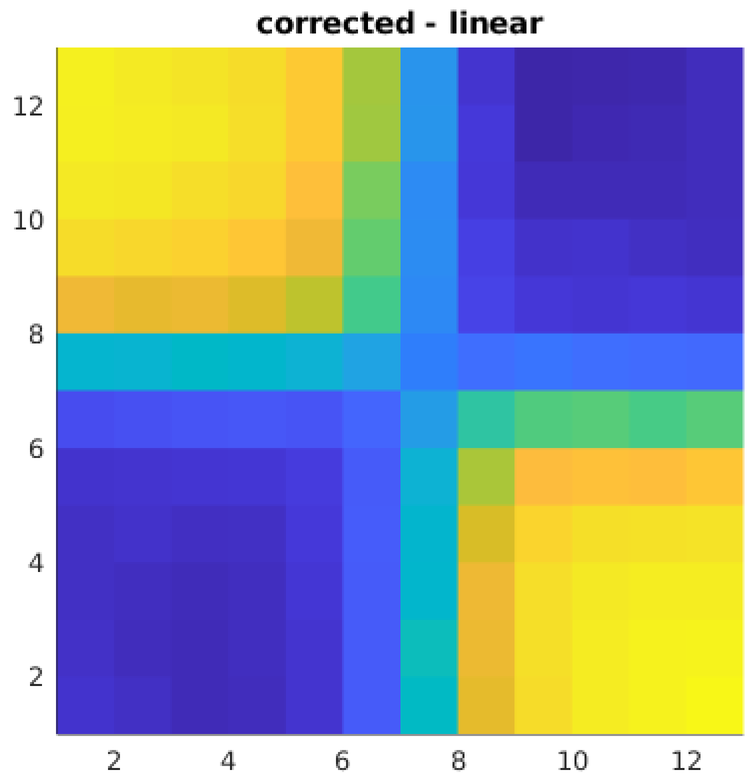
```
length_path_pixel =
    0.8535
length_path_cm =
    0.0074
```

[69]:
```
[HSI, lambda, nx, ny, nb] = HSI_reader('VNIR_BW_p25cm-1_corrected');

% % % correct

load average_path_VNIR_linear.mat
HSI_corr_linear = HSI_apply_pixelcorrection('VNIR_BW_p25cm-1_corrected', 75,␣
 ↪'linear', average_path);

load average_path_VNIR_cubic.mat
HSI_corr_cubic = HSI_apply_pixelcorrection('VNIR_BW_p25cm-1_corrected', 75,␣
 ↪'cubic', average_path);
```

```
% % reduce

HSI_corr_linear(:,:,1:27) = [];
HSI_corr_cubic(:,:,1:27) = [];

% % find pixel difference
% % di = -1
% % dj = -1
% % HSI(i,j,75)-HSI_corr_cubic(i+di,j+dj,75-27);

index_OG_x = 118:130;
index_OG_y = 107:119;

index_corr_x = index_OG_x - 1;
index_corr_y = index_OG_y - 1;


average_HSI = HSI_wavelength_average(HSI_corr_linear);
HSI_plot_frame(average_HSI(index_corr_x,index_corr_y))
title('corrected - linear')

figure

average_HSI = HSI_wavelength_average(HSI_corr_cubic);
HSI_plot_frame(average_HSI(index_corr_x,index_corr_y))
title('corrected - cubic')

figure

average_HSI = HSI_wavelength_average(HSI);
HSI_plot_frame(average_HSI(index_OG_x,index_OG_y))
title('original')
```


original
12
10
8
6
4
2
2
4
6
8
10
12

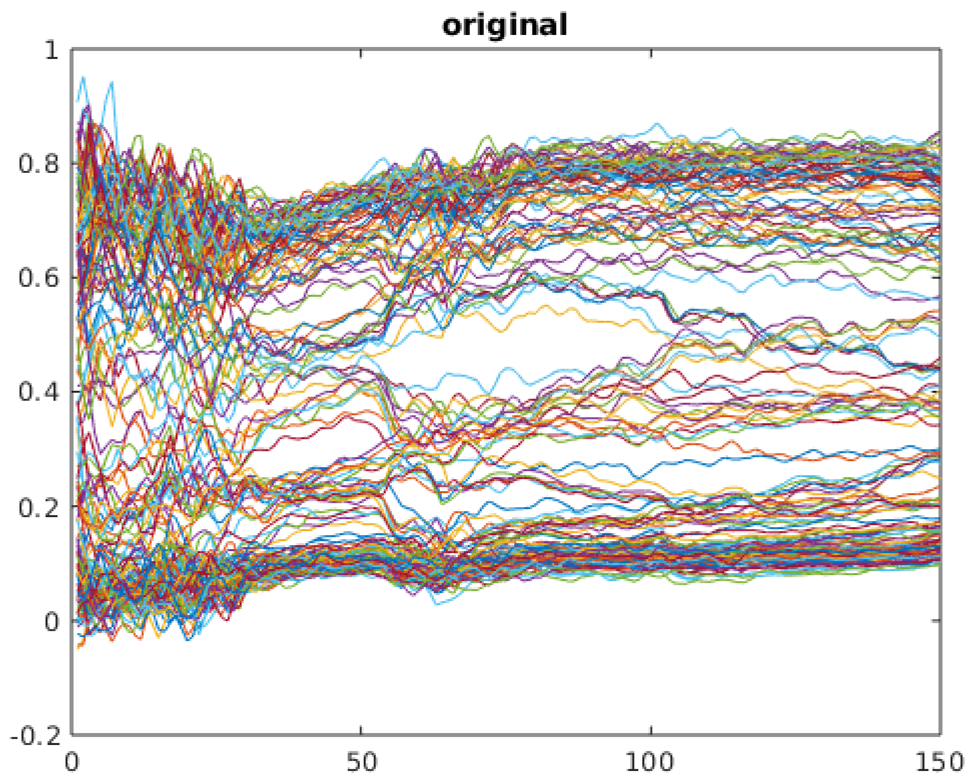

corrected - cubic
12
10
8
6
4
2
2
4
6
8
10
12

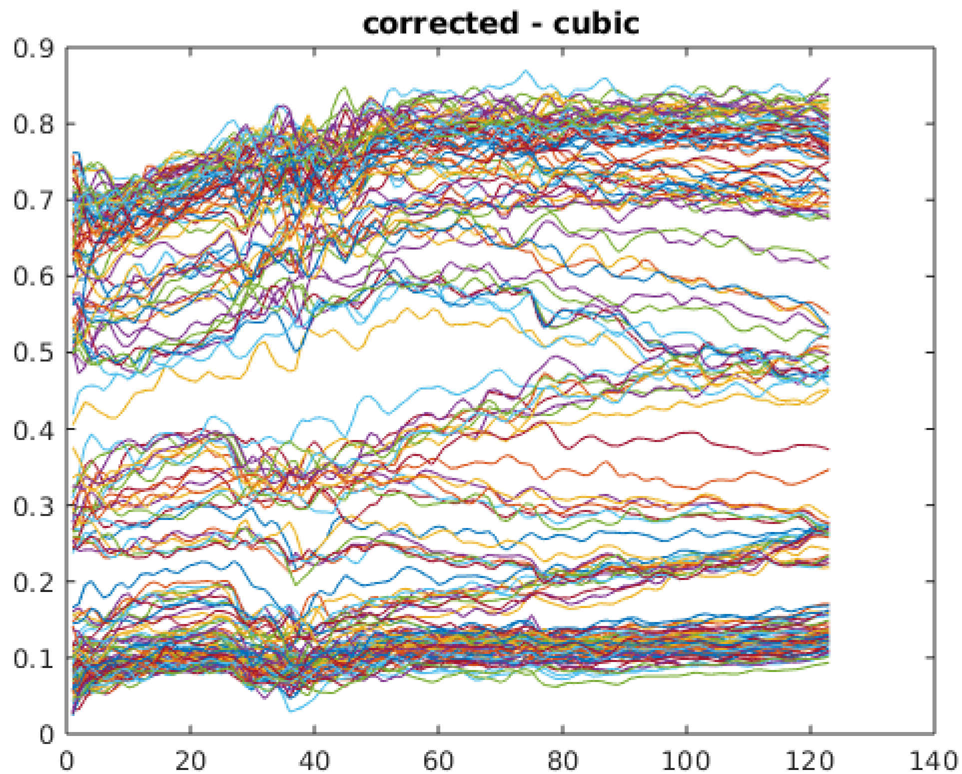


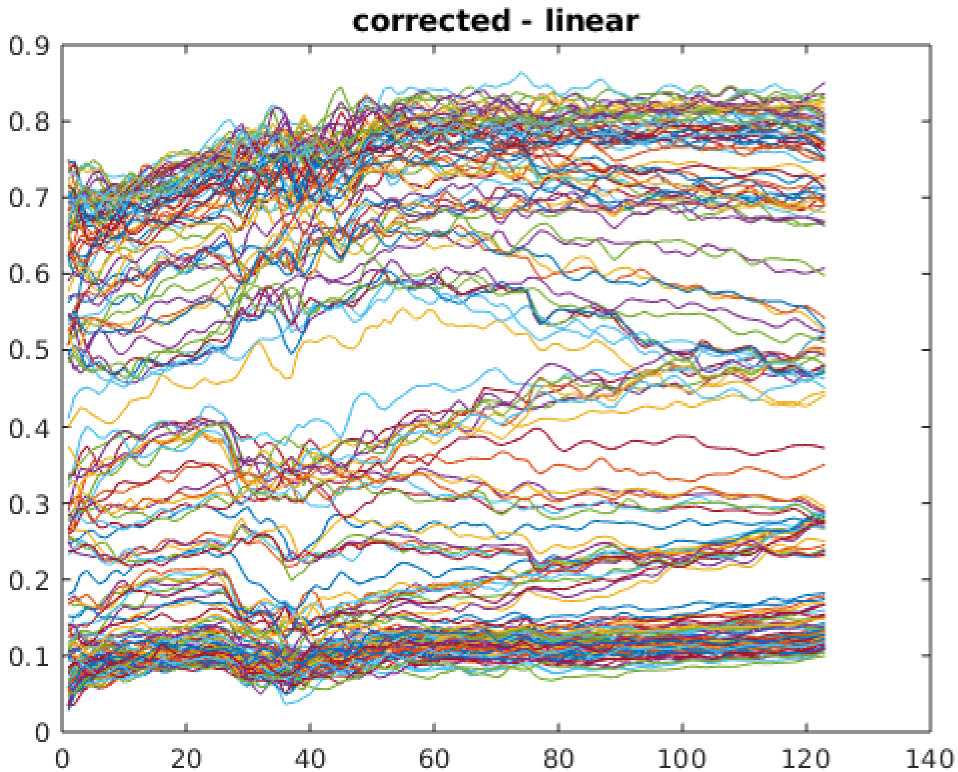
No significant difference

[70]:
```
for i = index_corr_x
    for j = index_corr_y
        spectrum = HSI_corr_linear(i,j,:);
        plot(spectrum(:))
        hold on
    end
end
title('corrected - linear')
figure
for i = index_corr_x
    for j = index_corr_y
        spectrum = HSI_corr_cubic(i,j,:);
        plot(spectrum(:))
        hold on
    end
end
title('corrected - cubic')
figure
for i = index_OG_x
    for j = index_OG_y
```

```
        spectrum = HSI(i,j,:);
        plot(spectrum(:))
        hold on
    end
end
title('original')
```




corrected - cubic
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
20
40
60
80
100
120
140



2.2 Unmixing 5 endmember checkerboard

We now try to unmix a checkerboard which looks like with endmembers black white, cyan, mangenta, yellow (and gray, as a linear combination of black and white)

white	magenta	yellow	gray
cyan	black	magenta	white

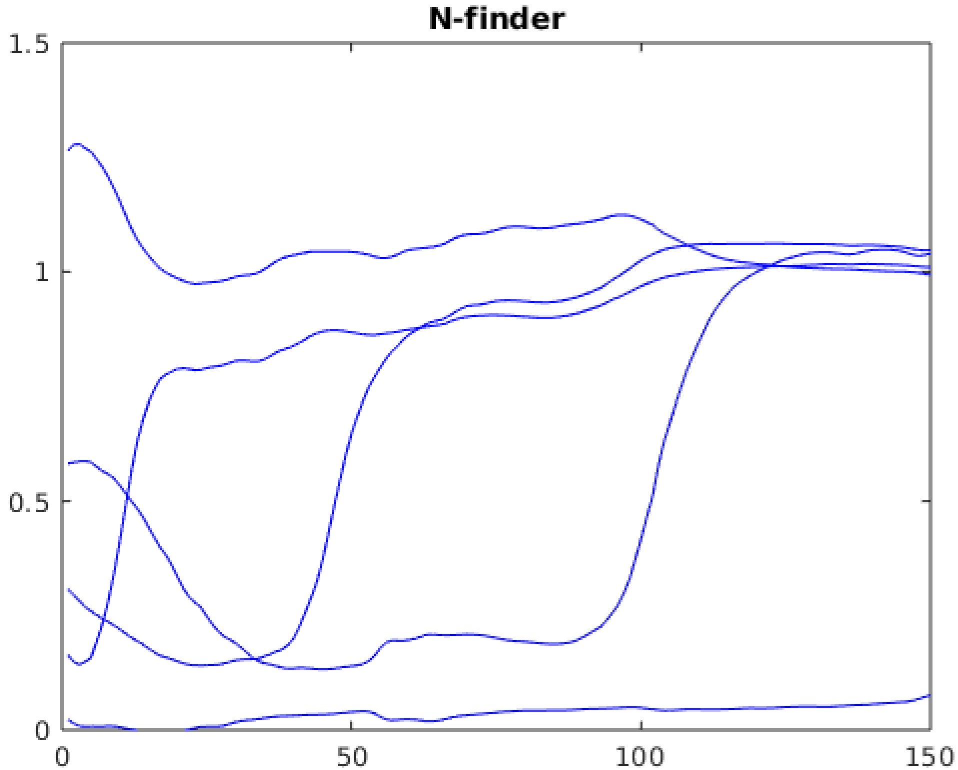
This been done with a sidelength of both 0.25 and 0.125 cm.

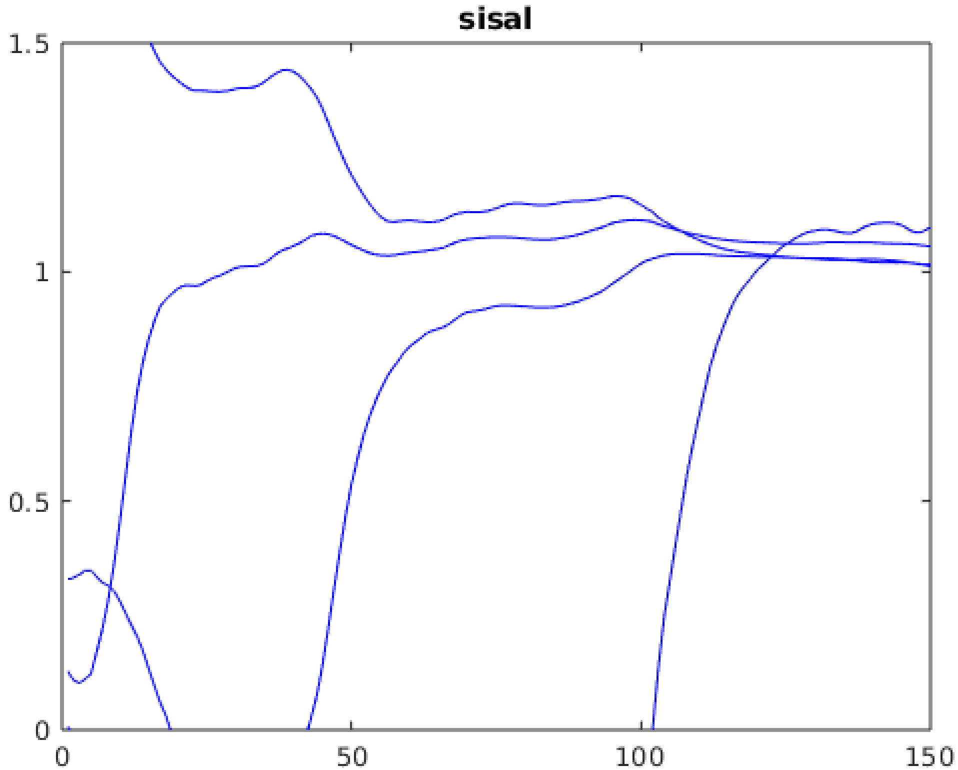
2.2.1 Unmixing a multicolor checkerboard

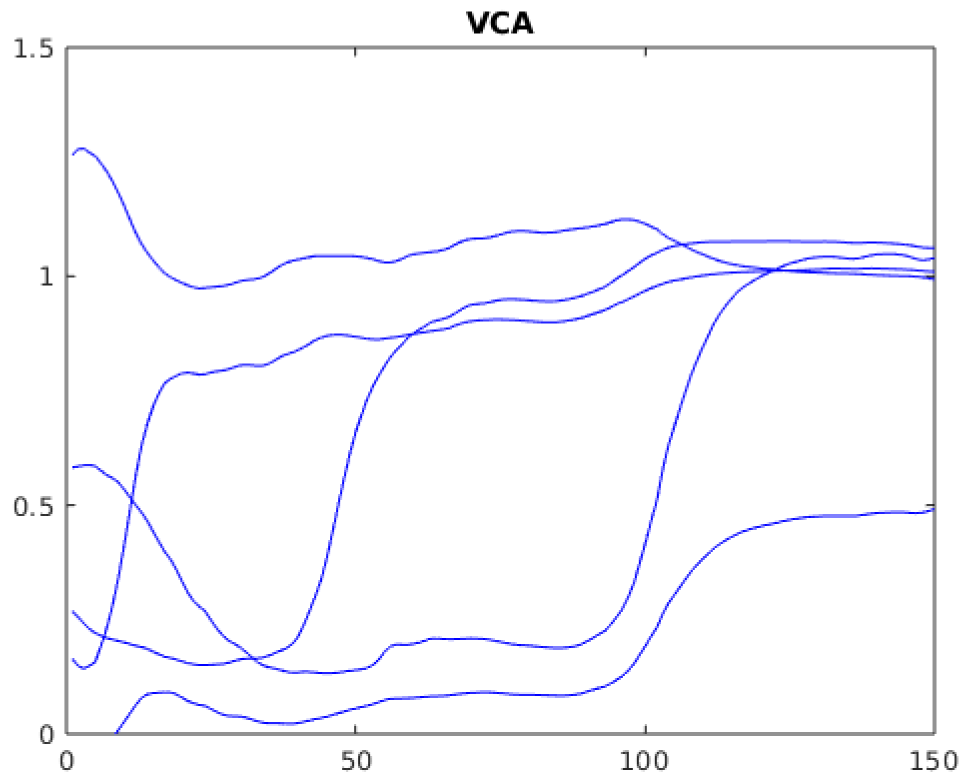
[140]:
```
[HSI, lambda, nx, ny, nb] = HSI_reader('VNIR_color2_p25-1_corrected.raw');

[E_VCA_OG, A_VCA_OG, E_sisal_OG, A_sisal_OG, E_NF_OG, A_NF_OG] =␣
↪HSI_linear_unmixing(HSI,5,'all');

% VCA
plot(E_VCA_OG,'b'), ylim([0,1.5])
title('VCA')
```

```
err = E_VCA_OG*A_VCA_OG - reshape(HSI, [nx*ny nb])';

error_map = vecnorm(err);
average_error_VCA = mean(error_map);

% sisal
figure
plot(E_sisal_OG,'b'), ylim([0,1.5])
title('sisal')
err = E_sisal_OG*A_sisal_OG - reshape(HSI, [nx*ny nb])';
error_map = vecnorm(err);
average_error_sisal = mean(error_map);

% N-finder
figure
plot(E_NF_OG,'b'), ylim([0,1.5])
title('N-finder')
err = E_NF_OG*A_NF_OG - reshape(HSI, [nx*ny nb])';
error_map = vecnorm(err);
average_error_NF = mean(error_map);

[average_error_VCA average_error_sisal average_error_NF]
```

```
ans =
    0.7739    0.2219    0.3133
```


N-finder
1.5
1
0.5
0
0
50
100
150


sisal
1.5
1
0.5
0
0
50
100
150



Please note that the endmembers are verry different and exceed 1 (maximum value of the HSI is 1.5). Sisal has negative

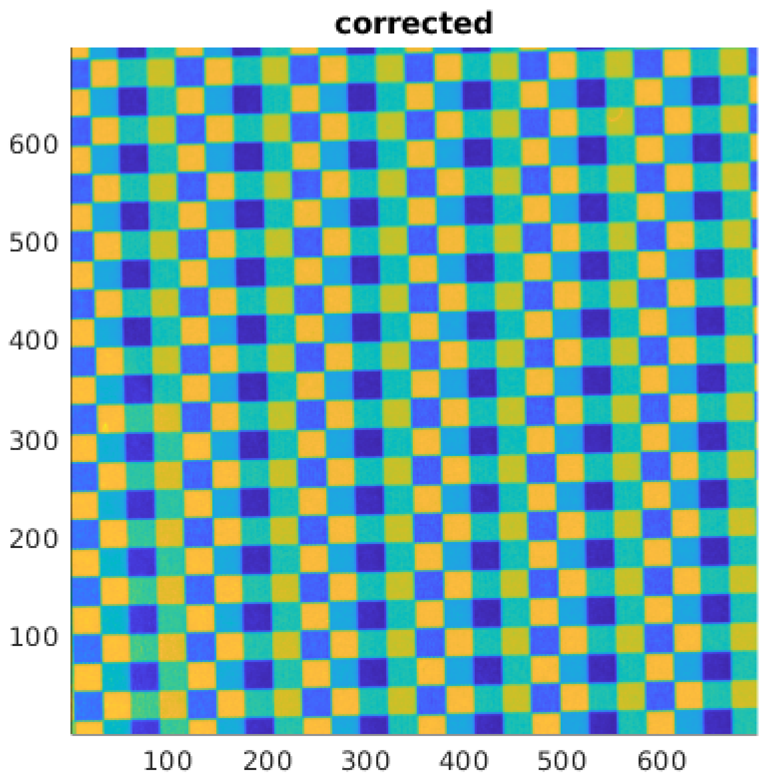
why?

Now let's work with the *reduced bandwith data*, and the *reduced and corrected data*.

correcting the data

[141]:
```
load average_path_VNIR_cubic.mat
HSI_corr = HSI_apply_pixelcorrection('VNIR_color2_p25-1_corrected.raw', 75,␣
  ↪'cubic', average_path);
% subplot(133)
average_corrected_HSI = HSI_wavelength_average(HSI_corr);
surf(average_corrected_HSI','EdgeColor','none')
axis('equal'), view([0 0 1.1])
title('corrected')
sum(isnan(HSI_corr(:)))
```

```
ans =
     0
```



reduce the data – take away band `1:27` and leave `28:end`.

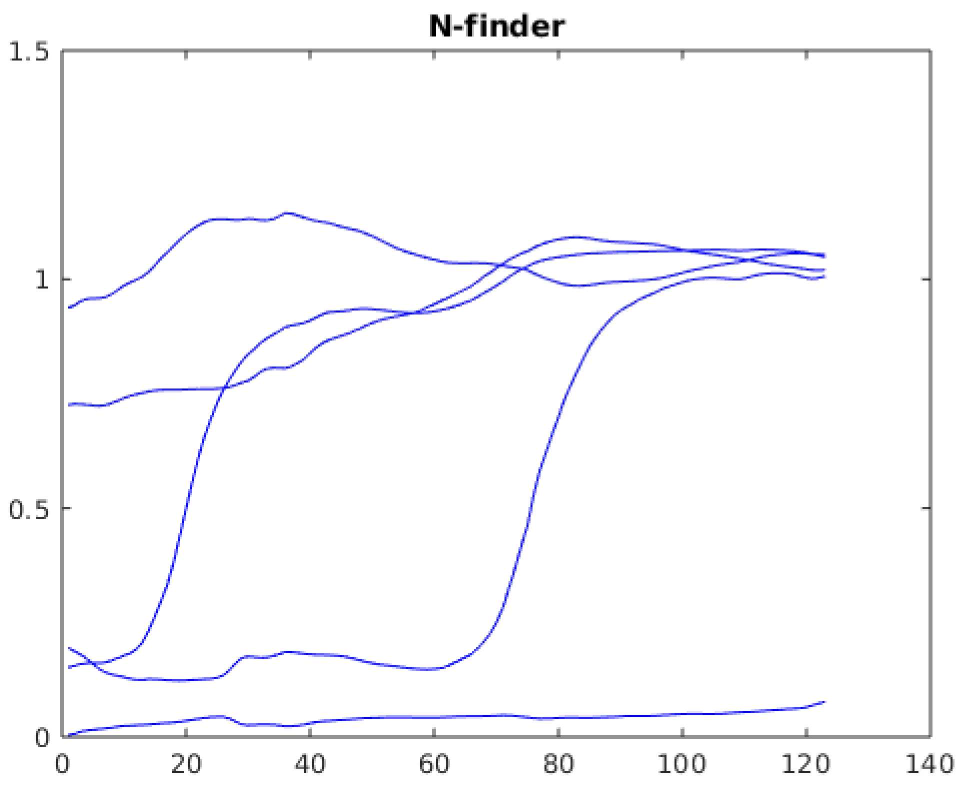
[142]:
```
hsi = HSI;
hsi(:,:,1:27) = [];

hsi_corr = HSI_corr;
hsi_corr(:,:,1:27) = [];
```

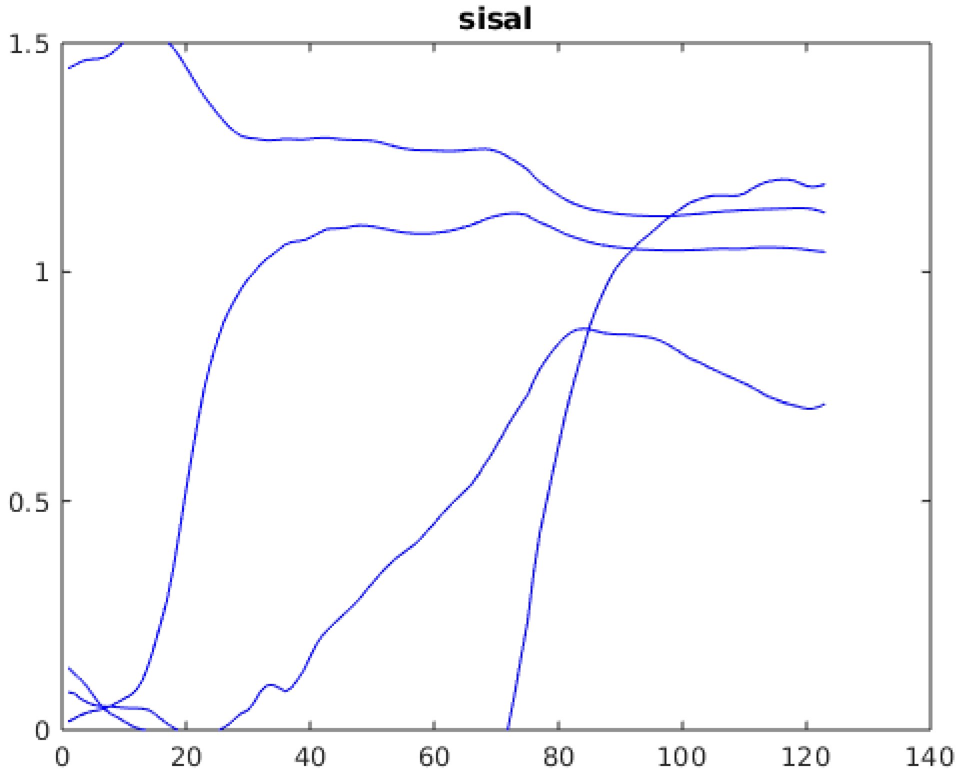
Unimix the reduced uncorreted data

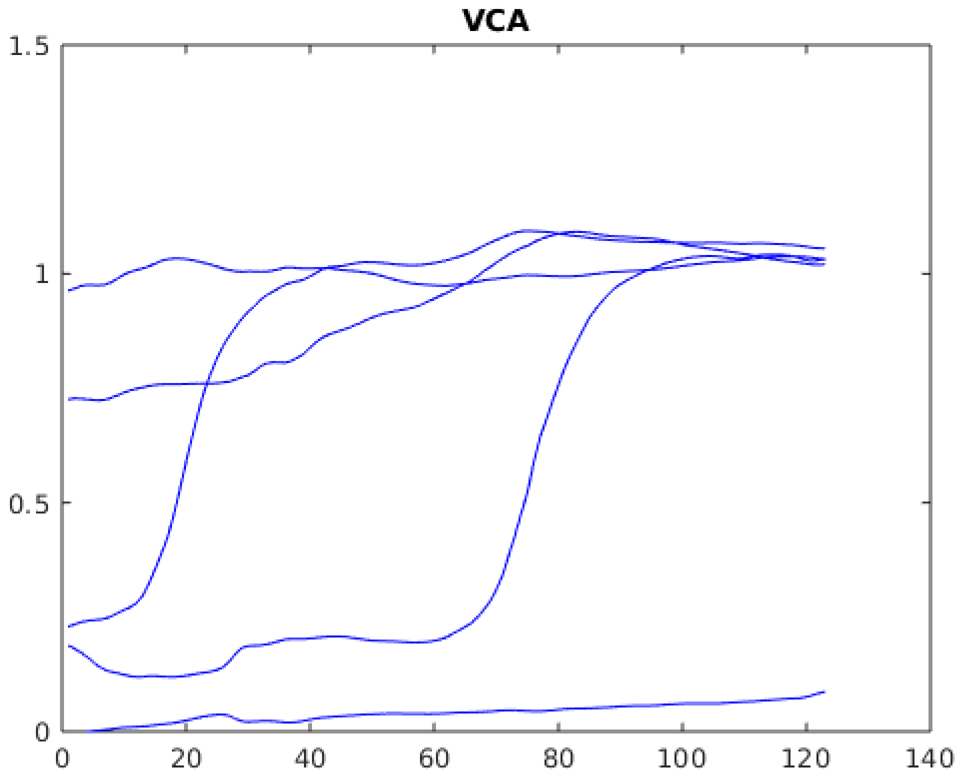
[143]:
```
[nx, ny, nb] = size(hsi);
[E_VCA_og, A_VCA_og, E_sisal_og, A_sisal_og, E_NF_og, A_NF_og] =␣
 ↪HSI_linear_unmixing(hsi,5,'all');

% VCA
plot(E_VCA_og,'b'), ylim([0,1.5])
title('VCA')
err = E_VCA_og*A_VCA_og - reshape(hsi, [nx*ny nb])';

error_map = vecnorm(err);
average_error_VCA = mean(error_map);

% sisal
```

```
figure
plot(E_sisal_og,'b'), ylim([0,1.5])
title('sisal')
err = E_sisal_og*A_sisal_og - reshape(hsi, [nx*ny nb])';
error_map = vecnorm(err);
average_error_sisal = mean(error_map);

% N-finder
figure
plot(E_NF_og,'b'), ylim([0,1.5])
title('N-finder')
err = E_NF_og*A_NF_og - reshape(hsi, [nx*ny nb])';
error_map = vecnorm(err);
average_error_NF = mean(error_map);

[average_error_VCA average_error_sisal average_error_NF]
```

```
ans =
    0.2252    0.1233    0.1956
```




sisal
1.5
1
0.5
0
0
20
40
60
80
100
120
140

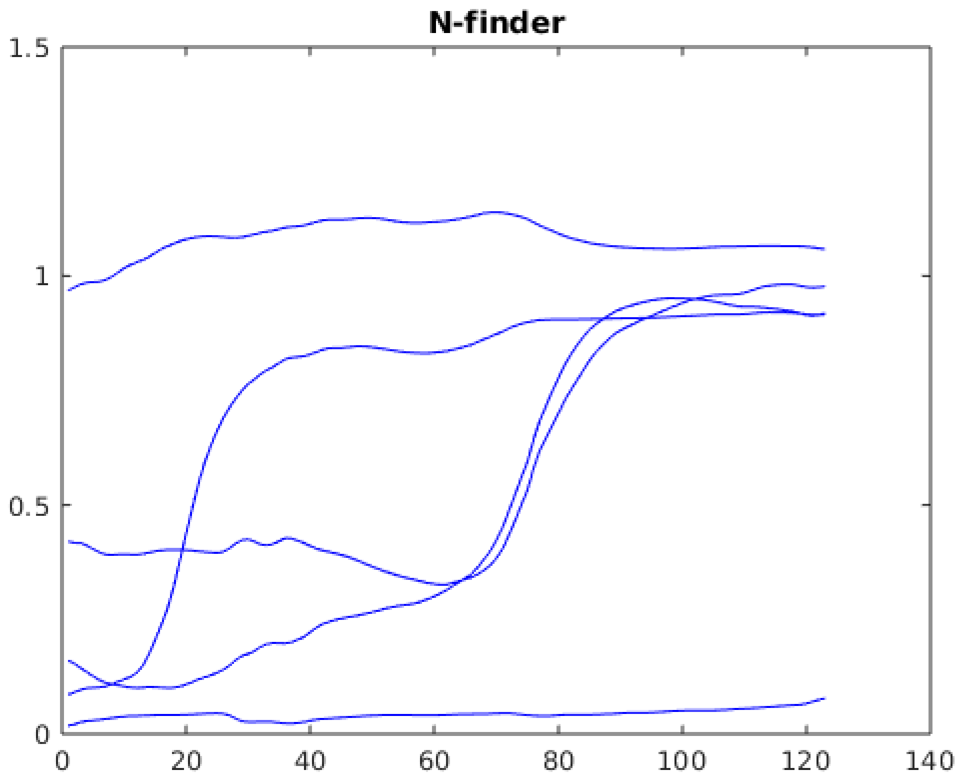


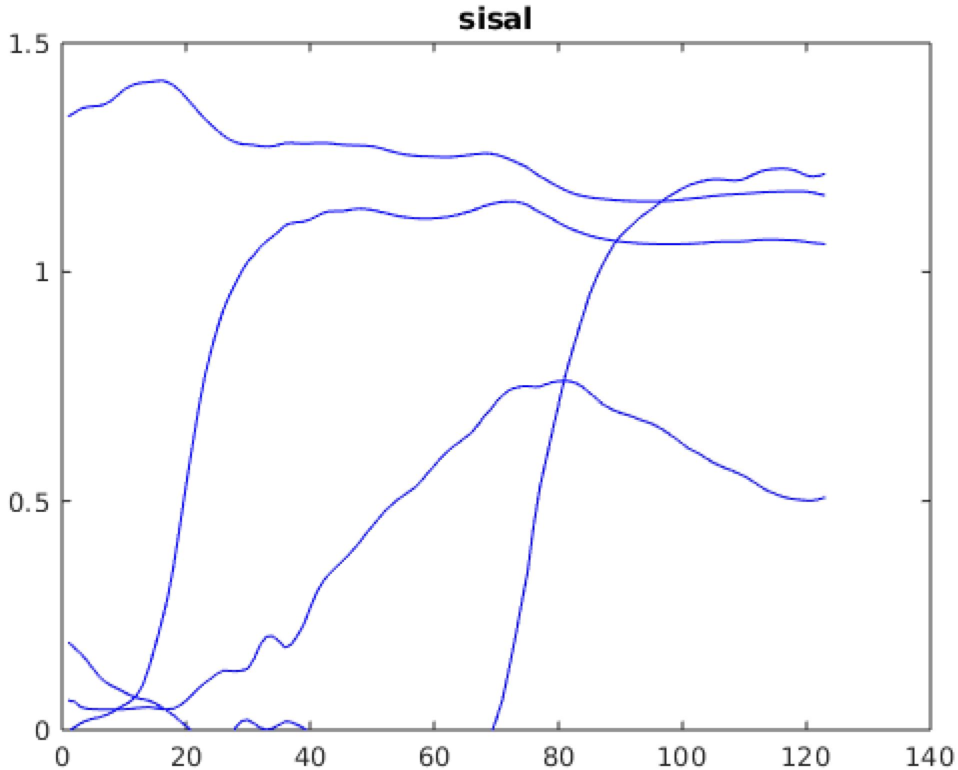
We choose VCA for not being negative. Which leads to the abundance maps:

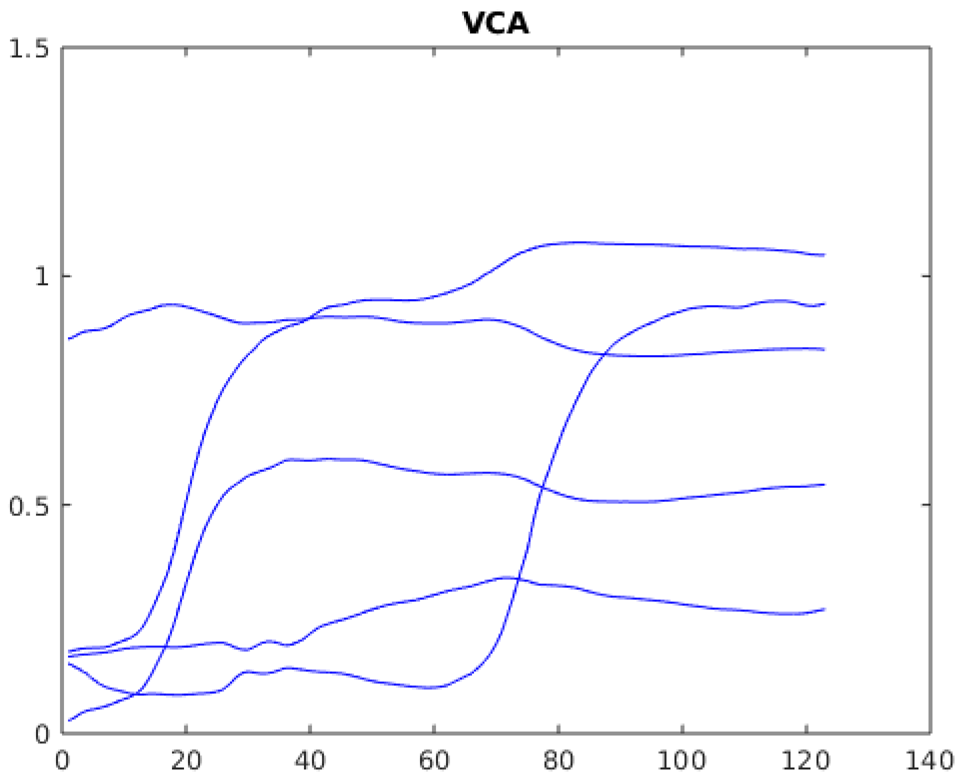
[144]:
```
[nx, ny, nb] = size(hsi_corr);
[E_VCA_corr, A_VCA_corr, E_sisal_corr, A_sisal_corr, E_NF_corr, A_NF_corr] =␣
 ↪HSI_linear_unmixing(hsi_corr,5,'all');

% VCA
plot(E_VCA_corr,'b'), ylim([0,1.5])
title('VCA')
err = E_VCA_corr*A_VCA_corr - reshape(hsi_corr, [nx*ny nb])';

error_map = vecnorm(err);
average_error_VCA = mean(error_map);

% sisal
figure
plot(E_sisal_corr,'b'), ylim([0,1.5])
title('sisal')
err = E_sisal_corr*A_sisal_corr - reshape(hsi_corr, [nx*ny nb])';
error_map = vecnorm(err);
average_error_sisal = mean(error_map);
```

```
% N-finder
figure
plot(E_NF_corr,'b'), ylim([0,1.5])
title('N-finder')
err = E_NF_corr*A_NF_corr - reshape(hsi_corr, [nx*ny nb])';
error_map = vecnorm(err);
average_error_NF = mean(error_map);

[average_error_VCA average_error_sisal average_error_NF]
```

```
ans =
    0.6044    0.1140    0.2208
```




sisal
1.5
1
0.5
0
0
20
40
60
80
100
120
140



[76]:
```
% inspect the HSI
cwd = pwd
cd './metingen/project pixelmovement/VNIR'
HSI_Palpator
cd(cwd)
```

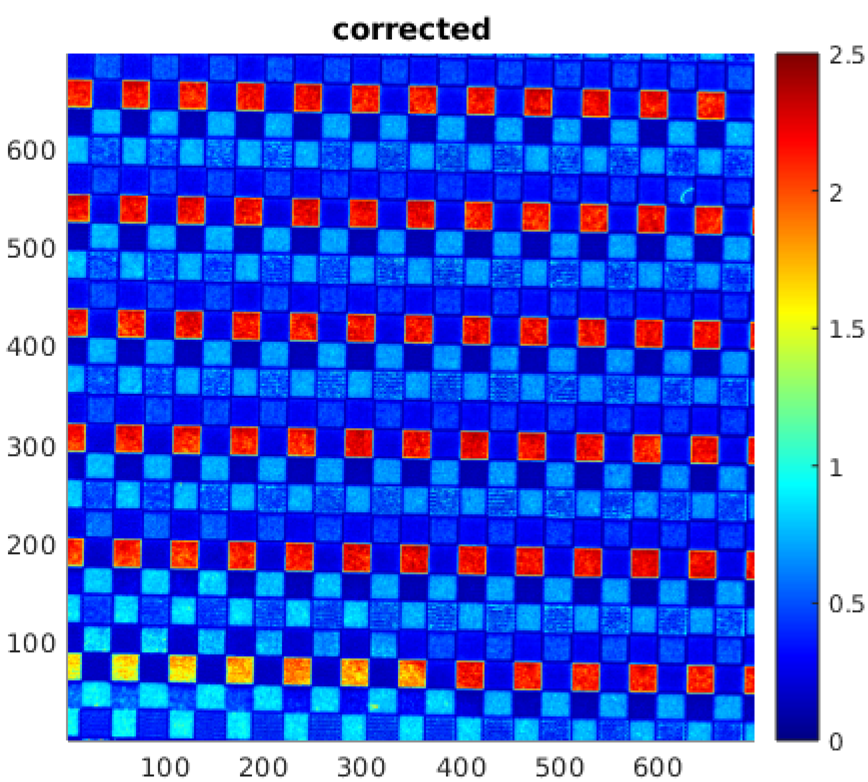
```
cwd =
    '/home/tim/Dropbox/Master Thesis/Project Pixel Drift'
```

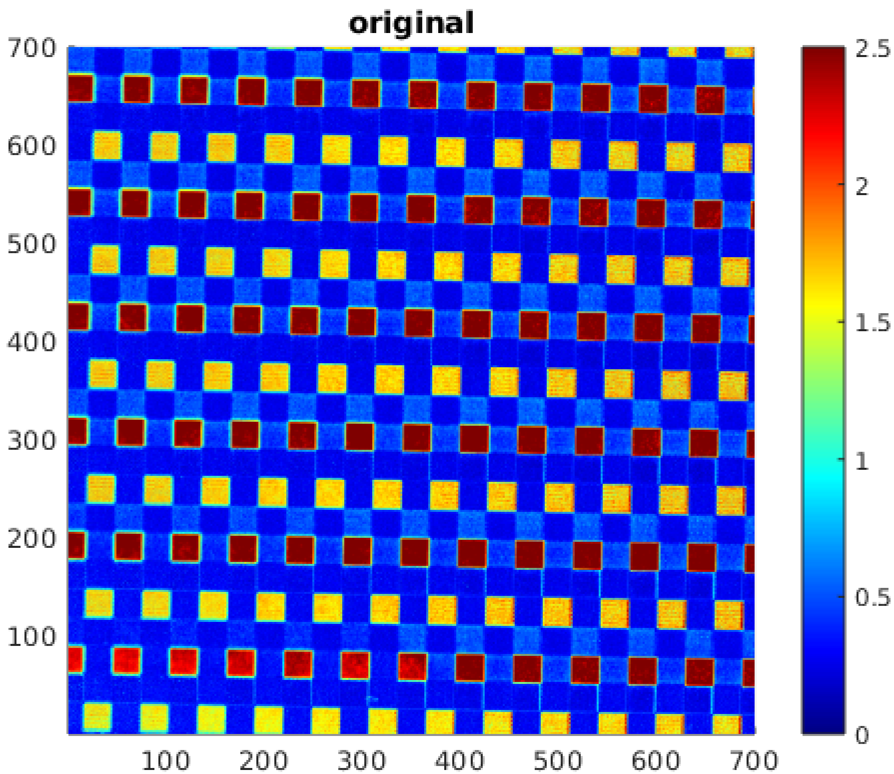
let's compare the methods in error maps

[145]:
```
[nx,ny,nb] = size(HSI);
err = E_VCA_OG *A_VCA_OG - reshape(HSI, [nx*ny, nb])';
error_map = vecnorm(err);
HSI_plot_frame(reshape(error_map,[nx, ny]))
colormap jet
caxis([0 2.5])
colorbar
'original'
average_error_original = mean(error_map)
title('original')
```

```
figure

[nx,ny,nb] = size(hsi_corr);
err = E_VCA_corr* A_VCA_corr - reshape(hsi_corr, [nx*ny, nb])';
error_map = vecnorm(err);
HSI_plot_frame(reshape(error_map,[nx, ny]))
colormap jet
caxis([0 2.5])
colorbar
title('corrected')
'corrected'
average_error_original = mean(error_map)
```

```
ans =
    'original'
average_error_original =
    0.7739
ans =
    'corrected'
average_error_original =
    0.6044
```





Comparing the 3 methods

The unmixing methods use stochastical methods and give varying results. On average ± standard devition we get:

We now try to unmix a checkerboard which looks like

reconstruction error	VCA (x 100)∣ sisal (x 1)∣N-finder ( )x 100)		
Original	0.47 ± 0.24	0.2219	0.316 ± 0.018
Pixeldrift corrected	0.332 ± 0.088	0.1921	0.2826 ± 0.0022
Original reduced	0.27 ± 0.10	0.1205	0.35 ± 0.15
Pixeldrift corrected and reduced	0.263 ± 0.090	0.1123	0.28 ± 0.14

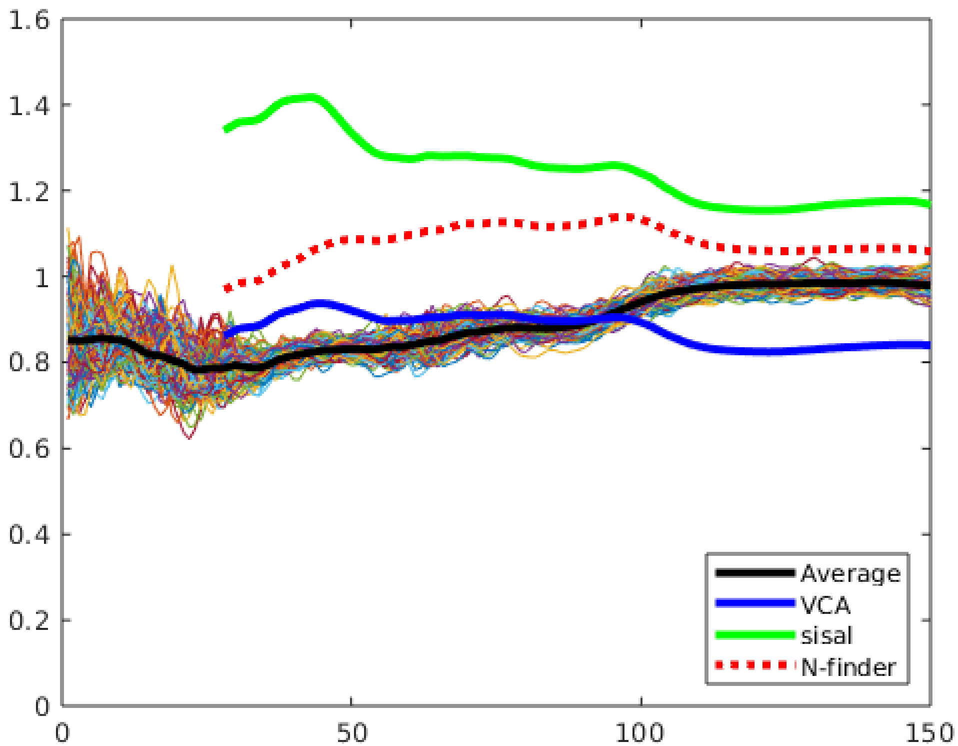
Conclusion Improves Sisal, but has barly effect on N-finder and VCA.
It isn't a magic bullet.

2.2.2 endmember analysis

White

[150]:
```
load('white.mat')
plot(collected_spectra,'HandleVisibility','off'), ylim([0, 1.6])
hold on
gem = mean(collected_spectra');
plot(gem','k','LineWidth',3)
dataset = 1
switch dataset
    case 1
        plot(28:150,E_VCA_corr(:,1),'b','LineWidth',3)
        plot(28:150,E_sisal_corr(:,1),'g','LineWidth',3)
        plot(28:150,E_NF_corr(:,4),':r','LineWidth',3)
    case 2
        plot(28:150,E_VCA_og(:,1),'b','LineWidth',3)
        plot(28:150,E_sisal_og(:,1),'g','LineWidth',3)
        plot(28:150,E_NF_og(:,2),':r','LineWidth',3)
    case 3
        plot(E_VCA_OG(:,1),'b','LineWidth',3)
        plot(E_sisal_OG(:,1),'g','LineWidth',3)
        plot(E_NF_OG(:,2),':r','LineWidth',3)
end
legend('Average','VCA','sisal','N-finder','location','southeast')
```

```
dataset =
     1
```



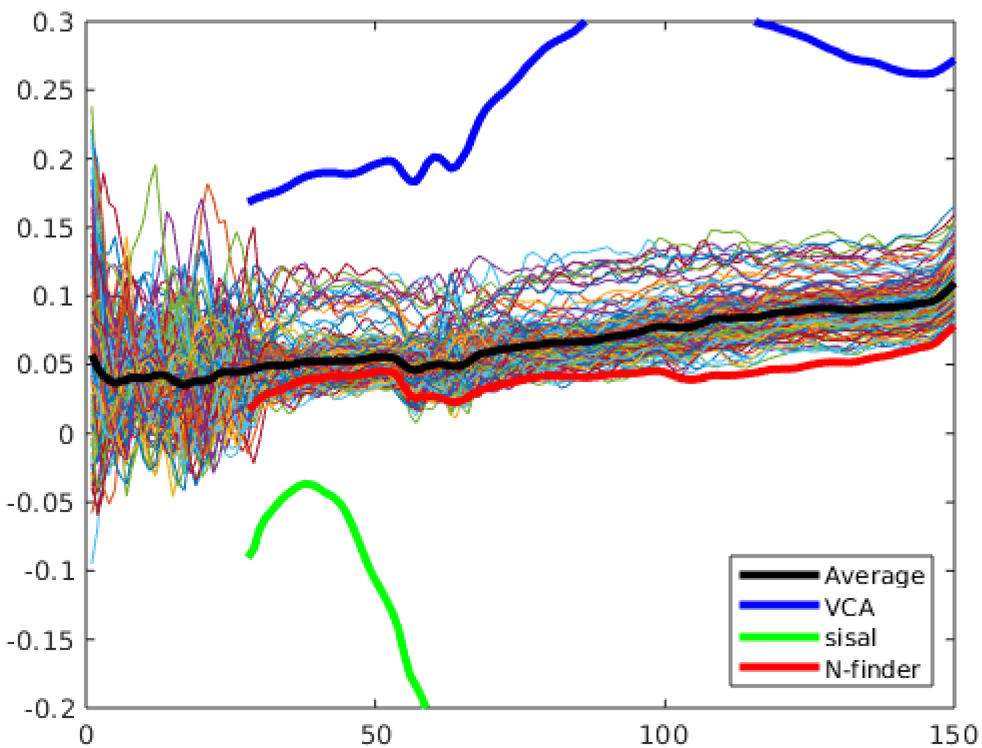
? Why so bad ?

Black

[166]:
```
load black
figure

plot(collected_spectra,'HandleVisibility','off'), ylim([0 .5])
hold on
gem = mean(collected_spectra');
plot(gem','k','LineWidth',3)

dataset = 1
switch dataset
    case 1
        plot(28:150,E_VCA_corr(:,5),'b','LineWidth',3)
        plot(28:150,E_sisal_corr(:,2),'g','LineWidth',3), ylim([-.2 .3])
        plot(28:150,E_NF_corr(:,1),'r','LineWidth',3)
    case 2
        plot(28:150,E_VCA_og(:,2),'b','LineWidth',3)
        plot(28:150,E_sisal_og(:,4),'g','LineWidth',3), ylim([-.2 .3])
        plot(28:150,E_NF_og(:,2),':r','LineWidth',3)
end
```

```
legend('Average','VCA','sisal','N-finder','location','southeast')
```

```
dataset =
     1
```

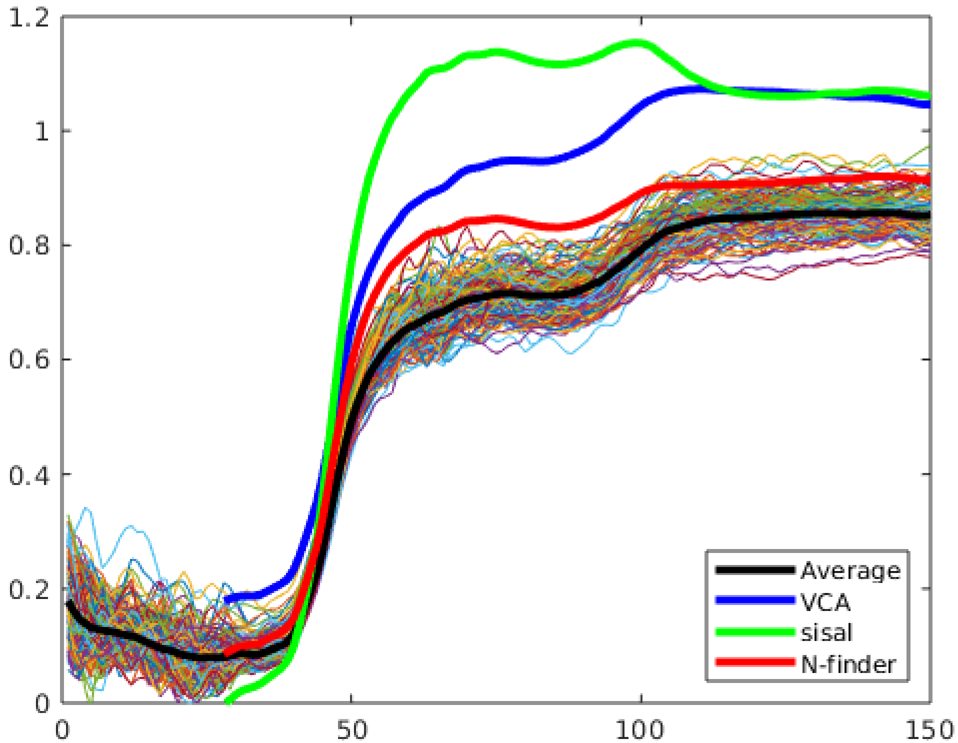


Magenta

[168]:
```
load magenta
figure
plot(collected_spectra,'HandleVisibility','off')
hold on
gem = mean(collected_spectra');
plot(gem','k','LineWidth',3)

dataset = 1
switch dataset
    case 1
        plot(28:150,E_VCA_corr(:,4),'b','LineWidth',3)
        plot(28:150,E_sisal_corr(:,3),'g','LineWidth',3),
        plot(28:150,E_NF_corr(:,5),'r','LineWidth',3)
        ylim([0 1.2])
end
```

```
legend('Average','VCA','sisal','N-finder','location','southeast')
```

```
dataset =
     1
```



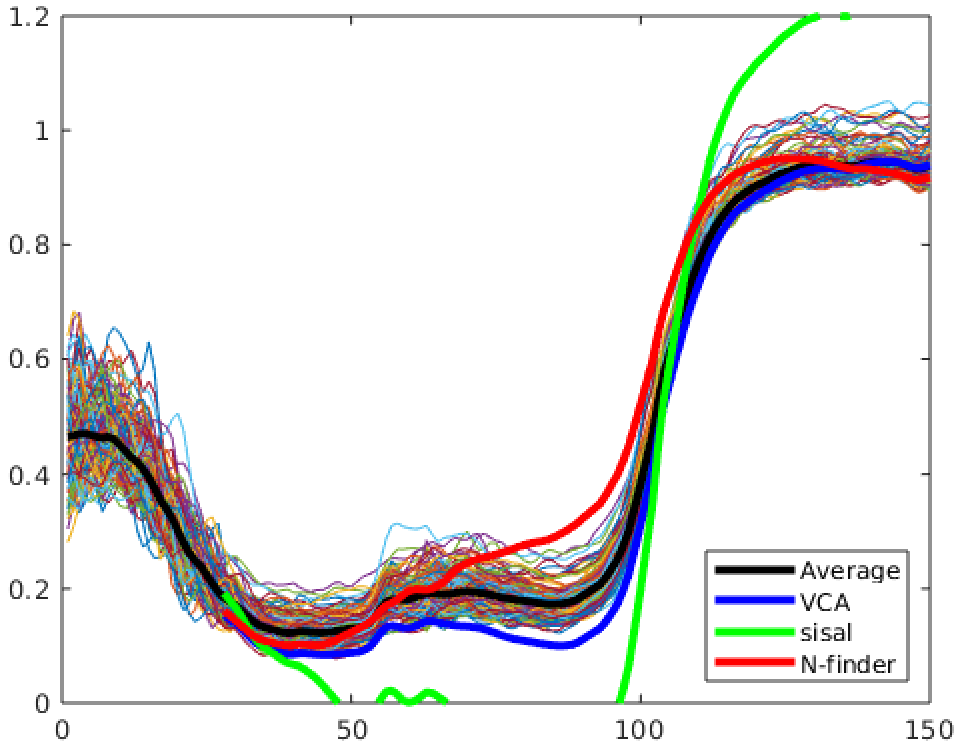
Cyan

[170]:

```
load cyan
figure
plot(collected_spectra,'HandleVisibility','off')
hold on
gem = mean(collected_spectra');
plot(gem','k','LineWidth',3)

dataset = 1
switch dataset
    case 1
        plot(28:150,E_VCA_corr(:,3),'b','LineWidth',3)
        plot(28:150,E_sisal_corr(:,4),'g','LineWidth',3),
        plot(28:150,E_NF_corr(:,2),'r','LineWidth',3)
        ylim([0 1.2])
end
```

```
legend('Average','VCA','sisal','N-finder','location','southeast')
```

```
dataset =
     1
```

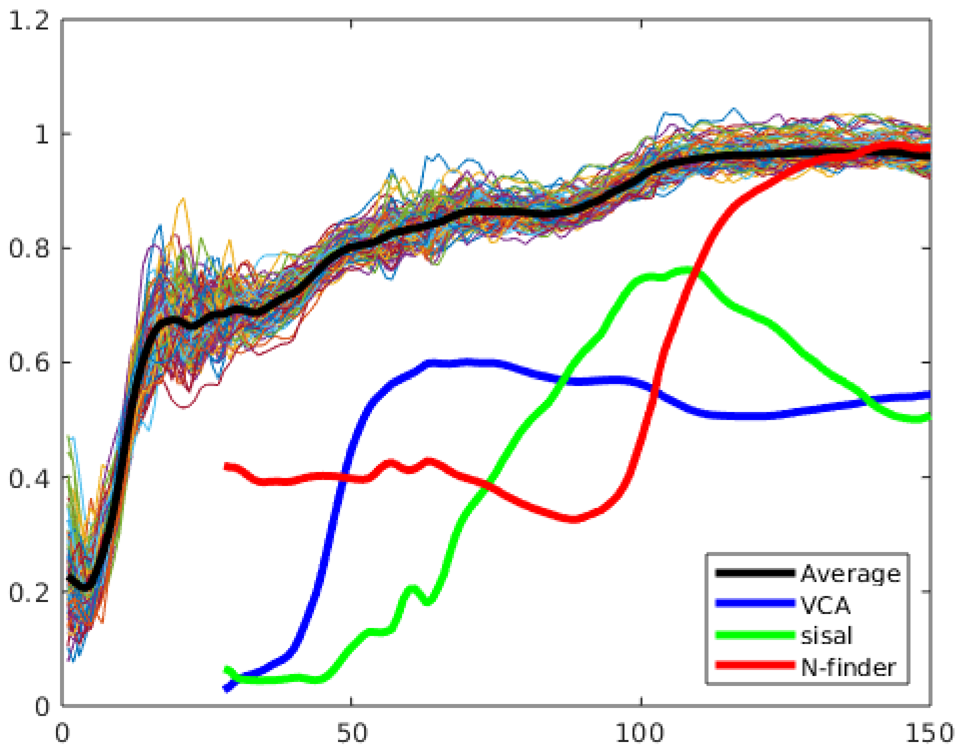


Yellow

[171]:
```
load yellow % wavelength; 570, cuttof is 550nm...
figure
plot(collected_spectra,'HandleVisibility','off')
hold on
gem = mean(collected_spectra');
plot(gem','k','LineWidth',3)

dataset = 1
switch dataset
    case 1
        plot(28:150,E_VCA_corr(:,2),'b','LineWidth',3) %only one left
        plot(28:150,E_sisal_corr(:,5),'g','LineWidth',3),
        plot(28:150,E_NF_corr(:,3),'r','LineWidth',3)
        ylim([0 1.2])
    case 3
```

```
        plot(E_VCA_OG(:,4),'b','LineWidth',3)
        plot(E_sisal_OG(:,2),'g','LineWidth',3)
        plot(E_NF_OG(:,5),':r','LineWidth',3)
end
legend('Average','VCA','sisal','N-finder','location','southeast')
```

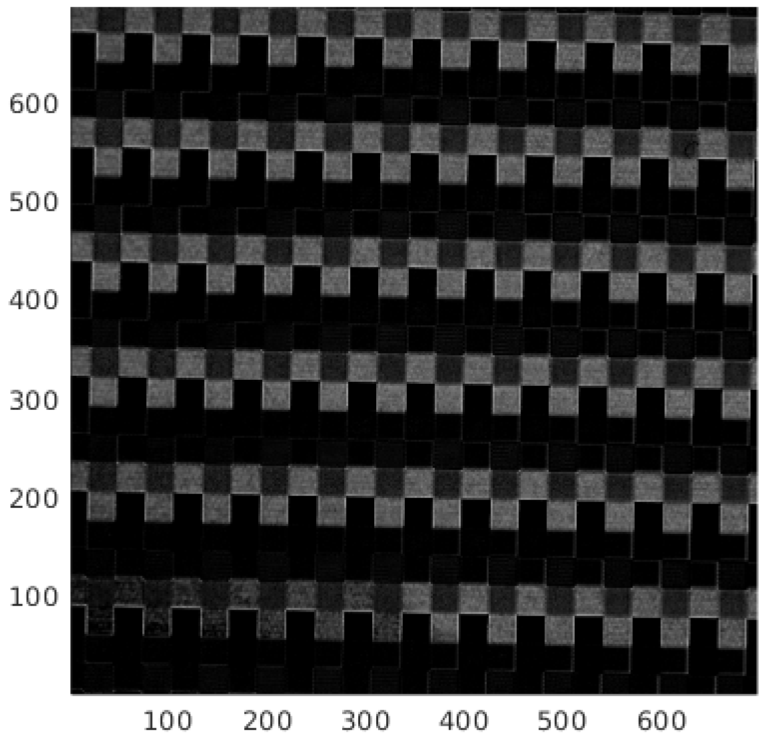
```
dataset =
     1
```

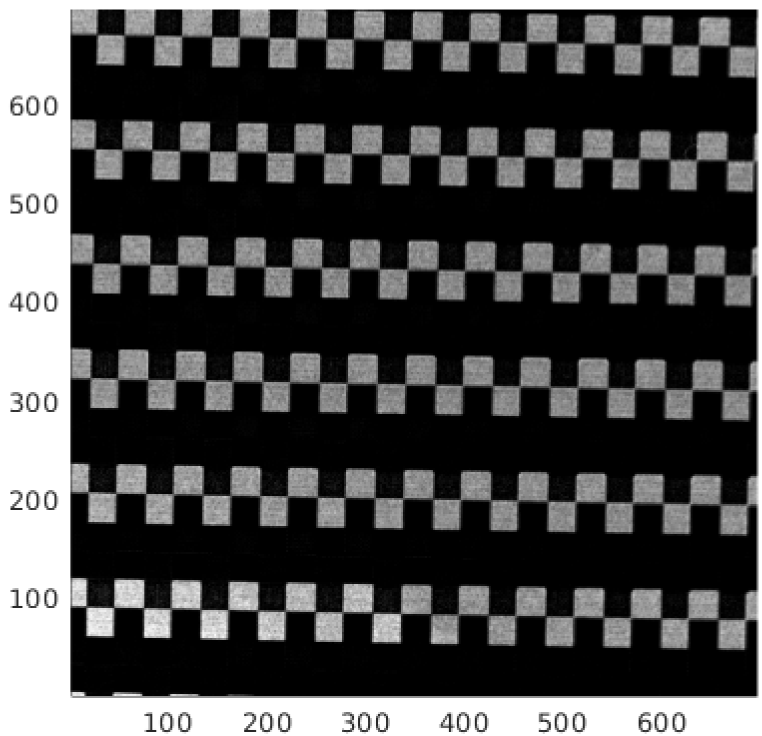


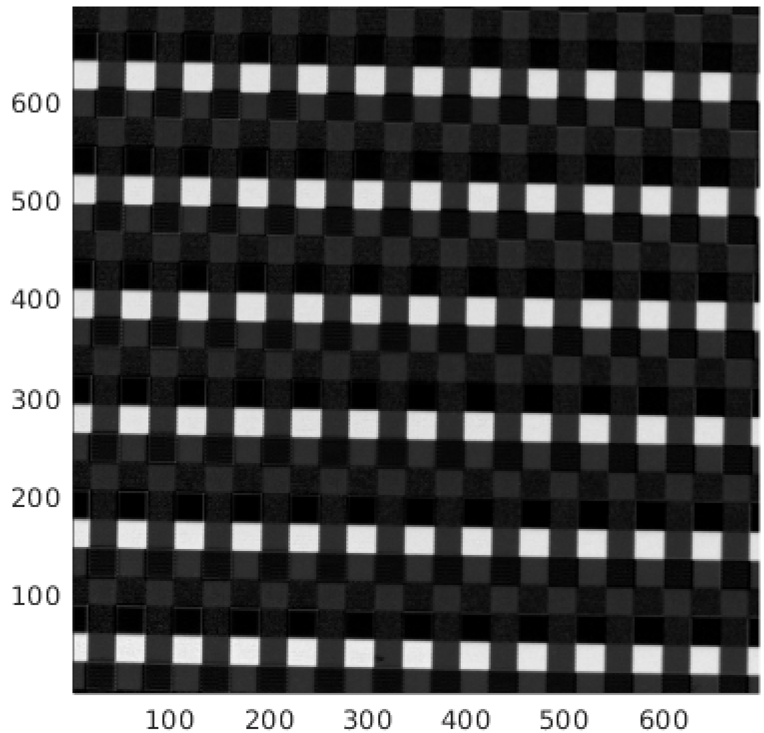
Cutting off the wavelength is not good for business, if business is identifying yellow ### Abundance map

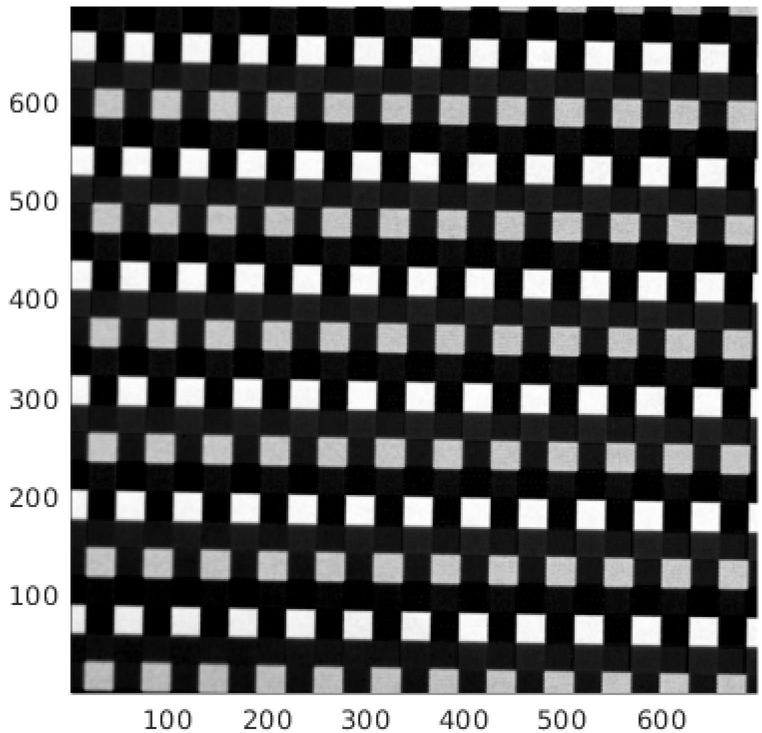
[85]:
```
% [endm_VCA_corr_red, abund_VCA_corr_red, endm_sisal_corr_red,␣
 ↪abund_sisal_corr_red]
abund = A_VCA_corr;
endm = E_VCA_corr;

for i = 1:5
    figure
    abundance_endm = reshape(abund(i,:),[697   697]);
    HSI_plot_frame(abundance_endm)
    colormap gray
```

```
end
```




600
500
400
300
200
100
100
200
300
400
500
600


600
500
400
300
200
100
100 200 300 400 500 600


600
500
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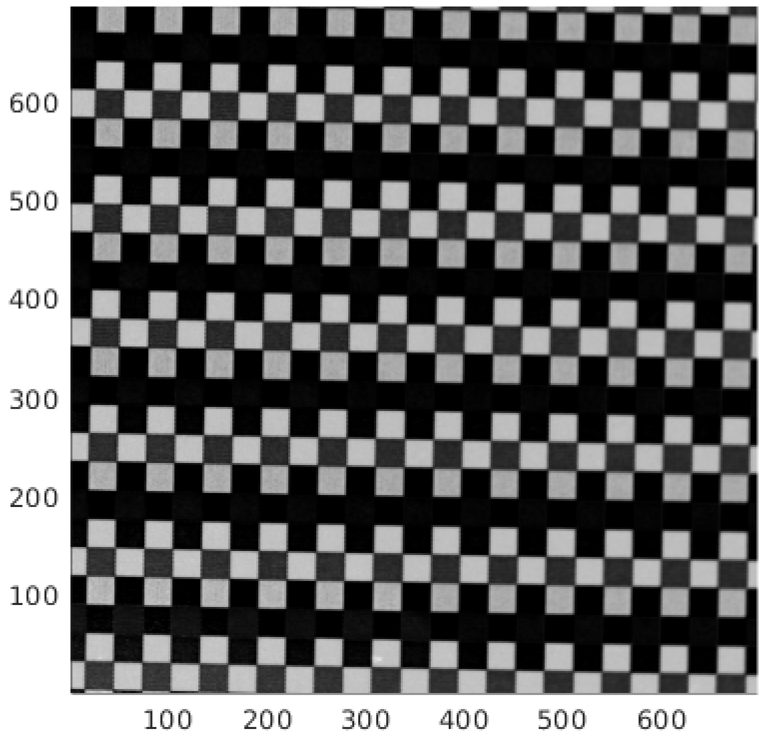
200
100
100
200
300
400
500
600



3 Conclusion

3.1 SWIR

- Pixeldrift siginificant (ength_path_pixel = 2.5 pixels, 0.09 cm ~ 1 mm)
- Pixelcorrection improves the data measurably (but not perfectly)
- blurring inevitable
- cubic interpolation gives best results (for a checkerboard type image).

3.2 VNIR

- short wavelength (470-548 *nm*) verry unreliable.
- Pixeldrift far less important (0.8 pixel, 0.007 cm ~ 0.1 mm) – *order of magnitude smaller*
- Unmixing needs te be finetuned (better algorithms?)

3.2.1 Further investigation

- other unmixing methods?
- downsampling?
- rewrite code in OOP

3.2.2 Remarks

- pixelnoise is correlated when applying corections
- chromatic aberation???

4 to do

1. downsampling
2. measure spectrum via spectrograph
3. chromatic aberation???
4. black hole radiation + IR absorbtion
5. check white and dark? Do correction?
6. update toggle

- Make reddit new (matlab, pythom, remote, datascience, xckd)

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