Reading Raster Data with GDAL

Open Source RS/GIS Python
Week 4

GDAL

- Supports about 100 raster formats
  - ArcInfo grids, ArcSDE raster, Imagine, Idrisi, ENVI, GRASS, GeoTIFF
  - HDF4, HDF5
  - USGS DOQ, USGS DEM
  - ECW, MrSID
  - TIFF, JPEG, JPEG2000, PNG, GIF, BMP
  - See http://www.gdal.org/formats_list.html

Finding available formats

- To see what formats are compiled into your version of GDAL, use this command in the FWTools shell (or terminal window on a Mac)

```
gdalinfo --formats
```

Importing GDAL

- Need to import both gdal and gdalconst
- FWTools:

```
import gdal, gdalconst
```

- Not FWTools:

```
from osgeo import gdal, gdalconst
```

- All gdalconst constants start with a prefix which minimizes the possibility of conflicts with other modules
- Can import a module so you don’t have to prefix things with the module name:

```
import gdal
from gdalconst import *
```

or

```
from osgeo import gdal
from osgeo.gdalconst import *
```

GDAL data drivers

- Similar to OGR data drivers
- Need to register a driver before using it
- Need to have a driver object before creating a new raster data set
- Driver names (code) are available at http://www.gdal.org/formats_list.html

- Register all drivers at once
  - Works for reading data but not for creating data sets

```
gdal.AllRegister()
```

- Get the Imagine driver and register it
  - Works for reading and creating new Imagine files

```
driver = gdal.GetDriverByName('HFA')
driver.Register()
```

Opening a raster data set

- Once the driver has been registered, the **`Open(<filename>, <GDALAccess>)`** method can be used to return a Dataset object

```
fn = 'aster.img'
ds = gdal.Open(fn, GA_ReadOnly)
if ds is None:
  print 'Could not open ' + fn
  sys.exit(1)
```

Getting image dimensions

- Dataset objects have properties corresponding to numbers of rows, columns and bands in the data set

```
cols = ds.RasterXSize
rows = ds.RasterYSize
bands = ds.RasterCount
```

- Notice no parentheses – because they're properties not methods

Getting georeference info

- GeoTransforms are lists of information used to georeference an image
- From the GDAL documentation:

```
adfGeoTransform[0] /* top left x */
adfGeoTransform[1] /* w-e pixel resolution */
adfGeoTransform[2] /* rotation, 0 if image is "north up" */
adfGeoTransform[3] /* top left y */
adfGeoTransform[4] /* rotation, 0 if image is "north up" */
adfGeoTransform[5] /* n-s pixel resolution */
```

- Coordinates are for *top left corners* of pixels (unlike Imagine, which uses *centers*)

- Use the **`GetGeoTransform()`** method on a Dataset object to get a GeoTransform

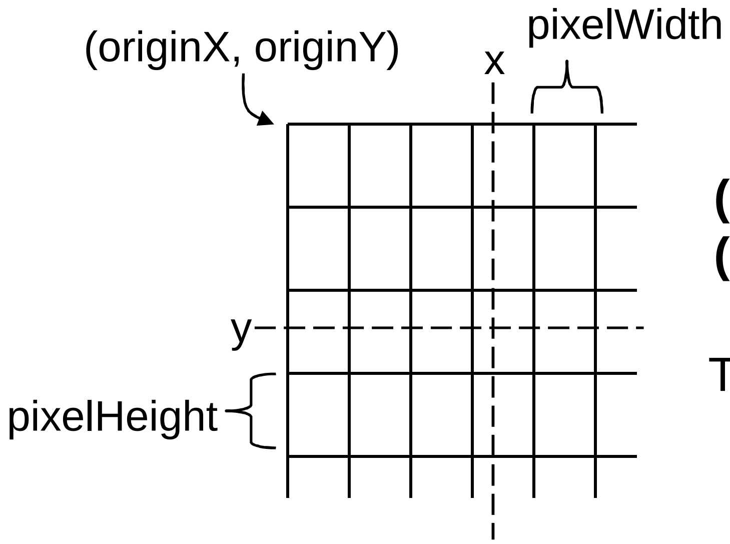
```
geotransform = ds.GetGeoTransform()
originX = geotransform[0]
originY = geotransform[3]
pixelWidth = geotransform[1]
pixelHeight = geotransform[5]
```

```
adfGeoTransform[0] /* top left x */
adfGeoTransform[1] /* w-e pixel resolution */
adfGeoTransform[2] /* rotation, 0 if image is "north up" */
adfGeoTransform[3] /* top left y */
adfGeoTransform[4] /* rotation, 0 if image is "north up" */
adfGeoTransform[5] /* n-s pixel resolution */
```

Computing pixel offsets

- Need to get pixel offsets from the upper left corner for specific coordinates x,y

```
xOffset = int((x – originX) / pixelWidth)
yOffset = int((y – originY) / pixelHeight)
```



```
(x – originX) / pixelWidth  ~= 3.25
(y – originY) / pixelHeight ~= 2.5
```

Take the integer values and we get (3,2)

Getting individual pixel values

- Get the Band object by passing the band index (1-based) to the Dataset’s **`GetRasterBand(<index>)`** method

```
band = ds.GetRasterBand(1)
```

- Read the data into a 2D Numeric array with **`ReadAsArray(<xoff>, <yoff>, <xsize>, <ysize>)`**

```
data = band.ReadAsArray(xOffset, yOffset, 1, 1)
```

- Even though we only read one pixel value, it is in a two-dimensional array
- Since we read one pixel in each direction, the array is of size 1x1
- Need to specify both offsets, which are 0 in this case

```
value = data[0,0]
```

Reading an entire image at once

- Use 0 offsets and pass the numbers of rows and columns to the **`ReadAsArray()`** method

```
data = band.ReadAsArray(0, 0, cols, rows)
```

- Read individual pixels using [yoff, xoff] (math matrix notation is [row,col], not [x,y])
- To read the pixel in the 95th column and 43rd row:

```
value = data[42, 94]
```

Memory management

- Set variables to None
- Especially important if you created large arrays with **`ReadAsArray()`**

```
band = None
dataset = None
```

Script example 1

```
# script to get pixel values at a set of coordinates
# by reading in one pixel at a time
# Took 0.47 seconds on my machine
import os, sys, time, gdal
from gdalconst import *
# start timing
startTime = time.time()
# coordinates to get pixel values for
xValues = [447520.0, 432524.0, 451503.0]
yValues = [4631976.0, 4608827.0, 4648114.0]
# set directory
os.chdir(r'Z:\Data\Classes\Python\data')
# register all of the drivers
gdal.AllRegister()
# open the image
ds = gdal.Open('aster.img', GA_ReadOnly)
if ds is None:
  print 'Could not open image'
  sys.exit(1)
```

```
# get image size
rows = ds.RasterYSize
cols = ds.RasterXSize
bands = ds.RasterCount

# get georeference info
transform = ds.GetGeoTransform()
xOrigin = transform[0]
yOrigin = transform[3]
pixelWidth = transform[1]
pixelHeight = transform[5]

# loop through the coordinates
for i in range(3):

  # get x,y
  x = xValues[i]
  y = yValues[i]

  # compute pixel offset
  xOffset = int((x - xOrigin) / pixelWidth)
  yOffset = int((y - yOrigin) / pixelHeight)

  # create a string to print out
  s = str(x) + ' ' + str(y) + ' ' + str(xOffset) + ' ' + str(yOffset) + ' '

  # loop through the bands
  for j in range(bands):
    band = ds.GetRasterBand(j+1) # 1-based index
    # read data and add the value to the string
    data = band.ReadAsArray(xOffset, yOffset, 1, 1)
    value = data[0,0]
    s = s + str(value) + ' ‘
  # print out the data string
  print s
# figure out how long the script took to run
endTime = time.time()
print 'The script took ' + str(endTime - startTime) + ' seconds'
```

Script example 2

```
# script to get pixel values at a set of coordinates
# by reading in entire bands
# Took 1.69 seconds on my machine

import os, sys, time, gdal
from gdalconst import *

# start timing
startTime = time.time()

# coordinates to get pixel values for
xValues = [447520.0, 432524.0, 451503.0]
yValues = [4631976.0, 4608827.0, 4648114.0]

# set directory
os.chdir(r'Z:\Data\Classes\Python\data')

# register all of the drivers
gdal.AllRegister()

# open the image
ds = gdal.Open('aster.img', GA_ReadOnly)
if ds is None:
  print 'Could not open image'
  sys.exit(1)
```

```
# get image size
rows = ds.RasterYSize
cols = ds.RasterXSize
bands = ds.RasterCount

# get georeference info
transform = ds.GetGeoTransform()
xOrigin = transform[0]
yOrigin = transform[3]
pixelWidth = transform[1]
pixelHeight = transform[5]

# create a list to store band data in
bandList = []

# read in bands and store all the data in bandList
for i in range(bands):
  band = ds.GetRasterBand(i+1)
  data = band.ReadAsArray(0, 0, cols, rows)
  bandList.append(data)

# loop through the coordinates
for i in range(3):

  # get x,y
  x = xValues[i]
  y = yValues[i]
```

```
# compute pixel offset
  xOffset = int((x - xOrigin) / pixelWidth)
  yOffset = int((y - yOrigin) / pixelHeight)
  # create a string to print out
  s = str(x) + ' ' + str(y) + ' ' + str(xOffset) + ' ' + str(yOffset) + ' ‘
  # loop through the bands and get the pixel value
  for j in range(bands):
    data = bandList[j]
    value = data[yOffset, xOffset] # math matrix notation order
    s = s + str(value) + ' ‘
  # print out the data string
  print s
# figure out how long the script took to run
endTime = time.time()
print 'The script took ' + str(endTime - startTime) + ' seconds'
```

Assignment 4a

- Read pixel values from an image
  - Print out the pixel values for all three bands of aster.img at the points contained in sites.shp
  - Use any method of reading the raster data that you want, but I would suggest one pixel at a time (fastest in this case since we don't need much data)
  - Turn in your code and the output (right-click in the Crimson Editor output window to copy all output)

Reading raster data efficiently

- Reading one pixel at a time is about as inefficient as you can get (DON’T DO IT unless you just need a few pixel values here and there)
- Reading the entire image at once is pretty efficient, but not the best
  - Plus, you might not have enough RAM to hold it all or process it

- Anyone seen the Block Size information in Erdas Imagine?
- Has to do with how the values are stored on disk
- Most efficient way to access raster data is by blocks
- Unfortunately, don't always know block size

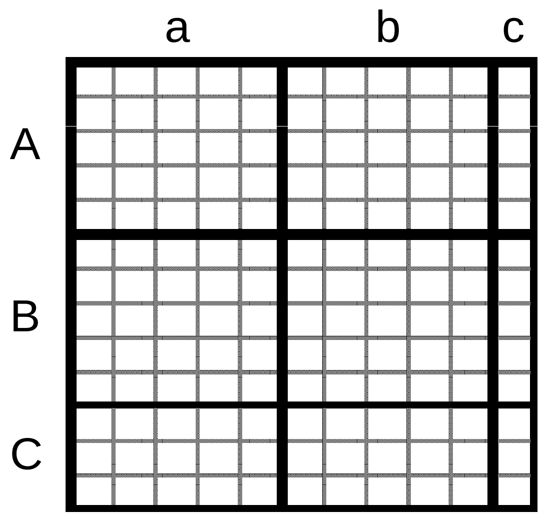
Getting block size

- This week's data has a module called utils
- Can use it to get block size like this:

```
import utils
blockSize = utils.GetBlockSize(band)
xBlockSize = blockSize[0]
yBlockSize = blockSize[1]
```

Tiled images

- Some file types, like most GeoTIFFs, are not tiled
  - A block is a row
- By default Erdas Imagine files are tiled into blocks that are 64x64 pixels
- This example has 5x5 tiles



Reading one row at a time

- Loop through the rows and read all pixels in that row during each iteration

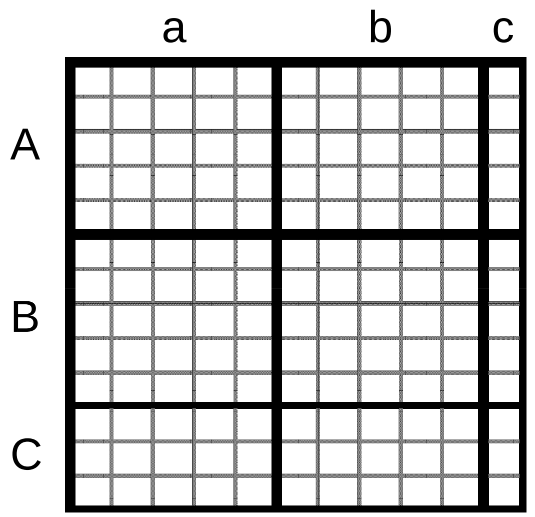
```
for i in range(rows):
  data = band.ReadAsArray(0, i, cols, 1)
  # do something with the data here, before
  # reading the next row
```

- The built-in **`range(n)`** function creates a list of numbers from 0 to n-1

```
>>> print range(10)
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
```

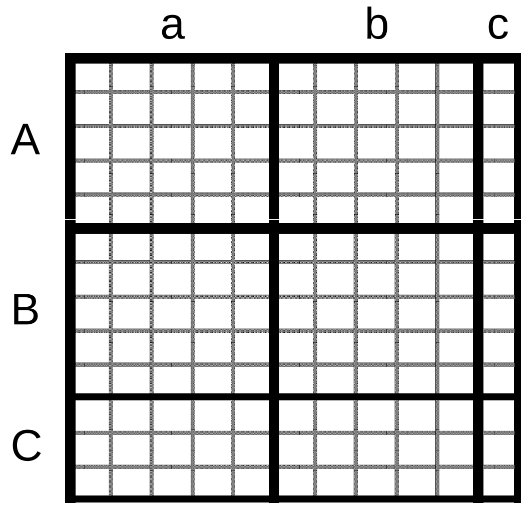
Reading a row of blocks

- It’s almost as easy to read in a row of blocks
- Need to check that we can get a whole block in the y direction – get an error if request more data than exists in the file



- Use **`range(start, stop, step)`** to loop through each group of blocks

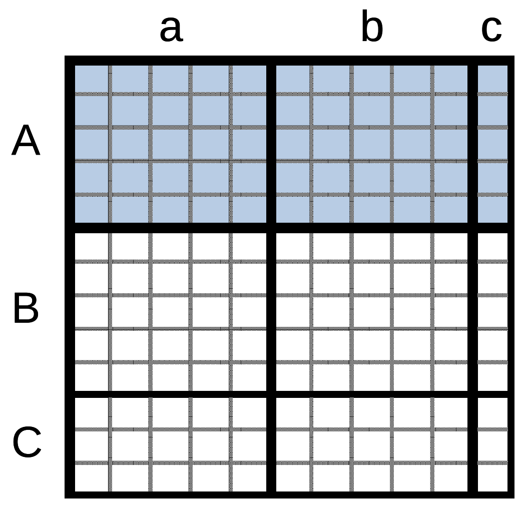
```
>>> print range(0, 13, 5)
[0, 5, 10]

bSize = 5
for i in range(0, rows, bSize):
  if i + bSize < rows:
      size = bSize
  else:
      size = rows - i
  data = band.ReadAsArray(0, i, cols, size)
  # do something with the data here, before
  # reading the next set of blocks
```



```
rows = 13
bSize = 5
for i in range(0, rows, bSize):
  if i + bSize < rows:
     size = bSize
  else:
     size = rows - i
  data = band.ReadAsArray(0, i, cols, size)
```

i = [**<u>0</u>**, 5, 10]

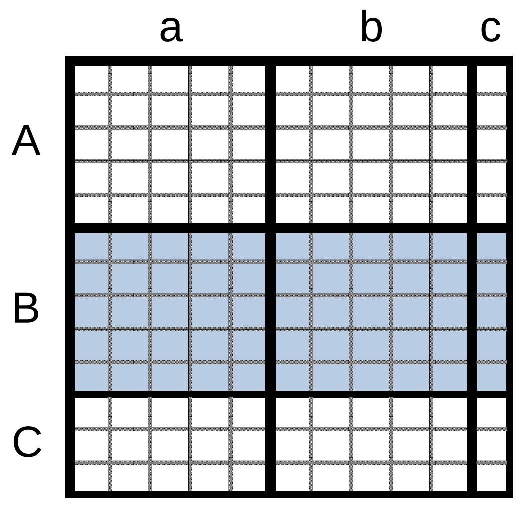
0 + 5 < 13, so size = 5
ReadAsArray(0, 0, 11, 5)



```
rows = 13
bSize = 5
for i in range(0, rows, bSize):
  if i + bSize < rows:
     size = bSize
  else:
     size = rows - i
  data = band.ReadAsArray(0, i, cols, size)
```

i = [0, **5**, 10]

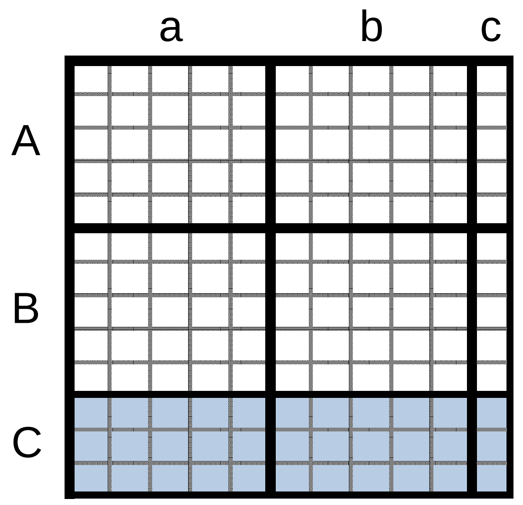
5 + 5 < 13, so size = 5
ReadAsArray(0, 5, 11, 5)



```
rows = 13
bSize = 5
for i in range(0, rows, bSize):
  if i + bSize < rows:
     size = bSize
  else:
     size = rows - i
  data = band.ReadAsArray(0, i, cols, size)
```

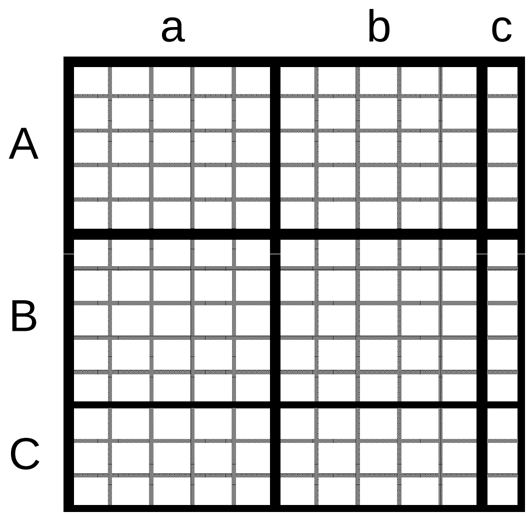
i = [0, 5, **10**]

10 + 5 > 13, so size = 13 – 10 = 3
ReadAsArray(0, 10, 11, 3)

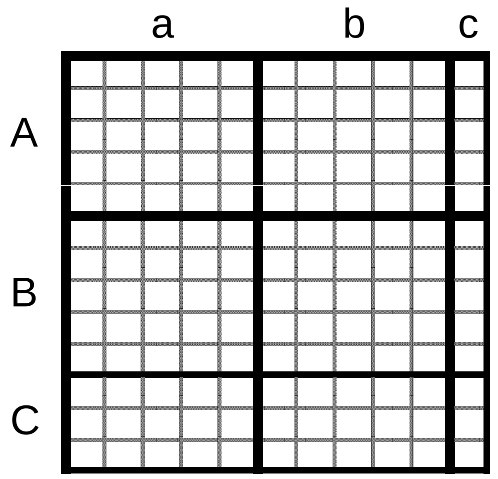


Reading block by block

- The most efficient way to read data
- Use one loop for the rows and one for the columns
- Need to check that there is an entire block in both directions



```
rows = 13, cols = 11
range(0,13,5) & range(0,11,5) both return [0, 5, 10]

xBSize = 5
yBSize = 5
for i in range(0, rows, yBSize):
  if i + yBSize < rows:
      numRows = yBSize
  else:
      numRows = rows – i
  for j in range(0, cols, xBSize):
      if j + xBSize < cols:
            numCols = xBSize
      else:
            numCols = cols – j
      data = band.ReadAsArray(j, i, numCols, numRows)
      # do something with the data here, before
      # reading the next block
```

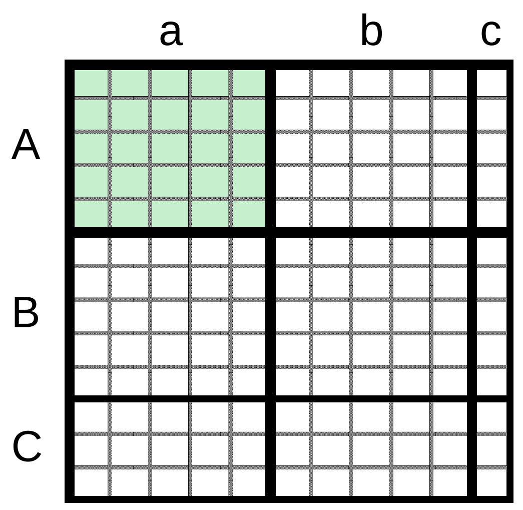


```
rows = 13, cols = 11, xBSize = 5, yBSize = 5
for i in range(0, rows, yBSize):
  if i + yBSize < rows:
    numRows = yBSize
  else:
    numRows = rows – i
  for j in range(0, cols, xBSize):
    if j + xBSize < cols:
      numCols = xBSize
    else:
      numCols = cols – j
    data = band.ReadAsArray(j, i, numCols, numRows)
```

i = [**<u>0</u>**, 5, 10]
0 + 5 < 13, so numRows = 5

j = [**<u>0</u>**, 5, 10]
0 + 5 < 11, so numCols = 5

ReadAsArray(0, 0, 5, 5)

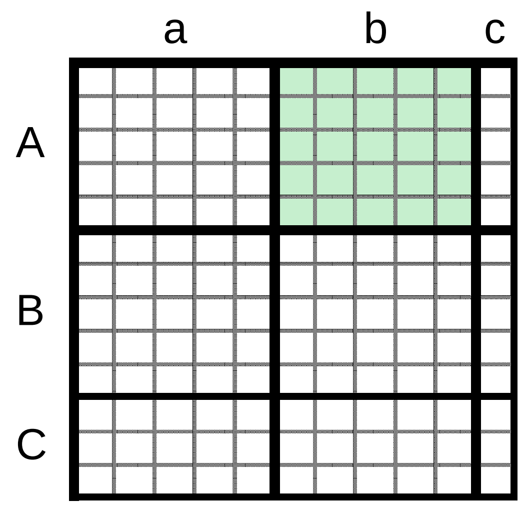


```
rows = 13, cols = 11, xBSize = 5, yBSize = 5
for i in range(0, rows, yBSize):
  if i + yBSize < rows:
    numRows = yBSize
  else:
    numRows = rows – i
  for j in range(0, cols, xBSize):
    if j + xBSize < cols:
      numCols = xBSize
    else:
      numCols = cols – j
    data = band.ReadAsArray(j, i, numCols, numRows)
```

i = [**0**, 5, 10]
0 + 5 < 13, so numRows = 5

j = [0, **5**, 10]
5 + 5 < 11, so numCols = 5

ReadAsArray(5, 0, 5, 5)

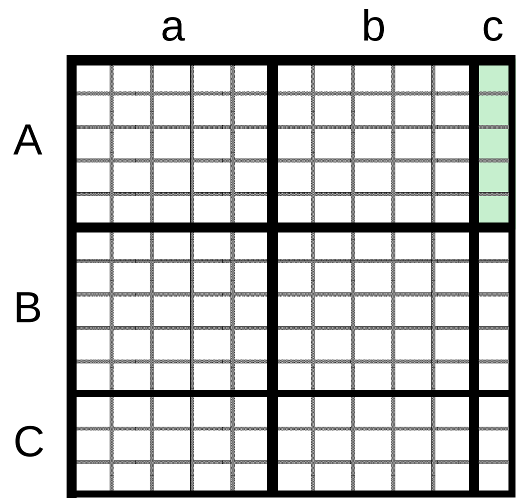


```
rows = 13, cols = 11, xBSize = 5, yBSize = 5
for i in range(0, rows, yBSize):
  if i + yBSize < rows:
    numRows = yBSize
  else:
    numRows = rows – i
  for j in range(0, cols, xBSize):
    if j + xBSize < cols:
      numCols = xBSize
    else:
      numCols = cols – j
    data = band.ReadAsArray(j, i, numCols, numRows)
```

i = [**<u>0</u>**, 5, 10]
0 + 5 < 13, so numRows = 5

j = [0, 5, **<u>10</u>**]
10 + 5 > 11, so numCols = 11 – 10 = 1

ReadAsArray(10, 0, 1, 5)

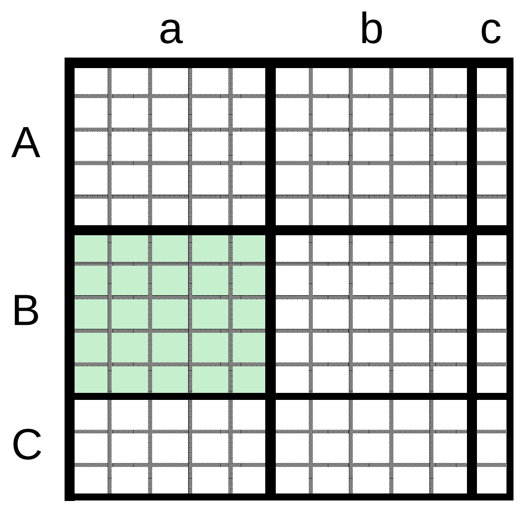


```
rows = 13, cols = 11, xBSize = 5, yBSize = 5
for i in range(0, rows, yBSize):
  if i + yBSize < rows:
    numRows = yBSize
  else:
    numRows = rows – i
  for j in range(0, cols, xBSize):
    if j + xBSize < cols:
      numCols = xBSize
    else:
      numCols = cols – j
    data = band.ReadAsArray(j, i, numCols, numRows)
```

i = [0, **<u>5</u>**, 10]
5 + 5 < 13, so numRows = 5

j = [**<u>0</u>**, 5, 10]
0 + 5 < 11, so numCols = 5

ReadAsArray(0, 5, 5, 5)

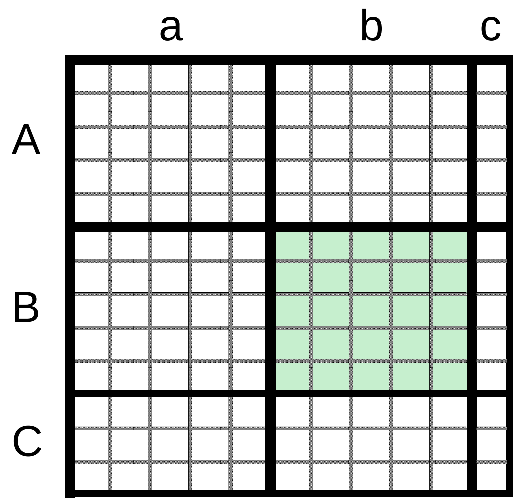


```
rows = 13, cols = 11, xBSize = 5, yBSize = 5
for i in range(0, rows, yBSize):
  if i + yBSize < rows:
    numRows = yBSize
  else:
    numRows = rows – i
  for j in range(0, cols, xBSize):
    if j + xBSize < cols:
      numCols = xBSize
    else:
      numCols = cols – j
    data = band.ReadAsArray(j, i, numCols, numRows)
```

i = [0, **5**, 10]
5 + 5 < 13, so numRows = 5

j = [0, **5**, 10]
5 + 5 < 11, so numCols = 5

ReadAsArray(5, 5, 5, 5)

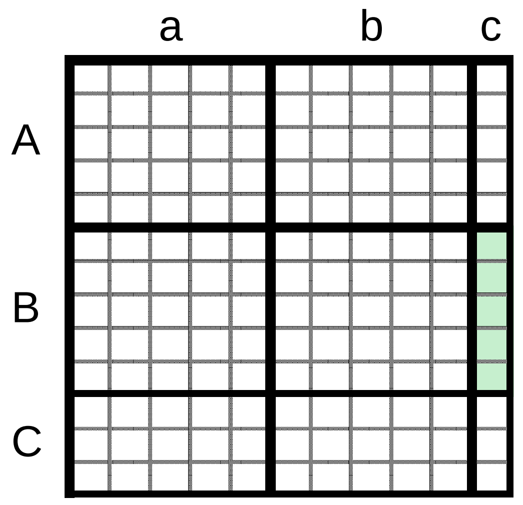


```
rows = 13, cols = 11, xBSize = 5, yBSize = 5
for i in range(0, rows, yBSize):
  if i + yBSize < rows:
    numRows = yBSize
  else:
    numRows = rows – i
  for j in range(0, cols, xBSize):
    if j + xBSize < cols:
      numCols = xBSize
    else:
      numCols = cols – j
    data = band.ReadAsArray(j, i, numCols, numRows)
```

i = [0, **5**, 10]
5 + 5 < 13, so numRows = 5

j = [0, 5, **10**]
10 + 5 > 11, so numCols = 11 – 10 = 1

ReadAsArray(10, 5, 1, 5)

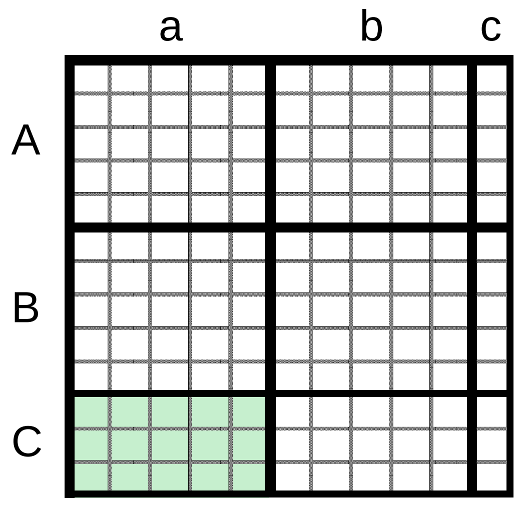


```
rows = 13, cols = 11, xBSize = 5, yBSize = 5
for i in range(0, rows, yBSize):
  if i + yBSize < rows:
    numRows = yBSize
  else:
    numRows = rows – i
  for j in range(0, cols, xBSize):
    if j + xBSize < cols:
      numCols = xBSize
    else:
      numCols = cols – j
    data = band.ReadAsArray(j, i, numCols, numRows)
```

i = [0, 5, **10**]
10 + 5 > 13, so numRows = 13 – 10 = 3

j = [**0**, 5, 10]
0 + 5 < 11, so numCols = 5

ReadAsArray(0, 10, 5, 3)

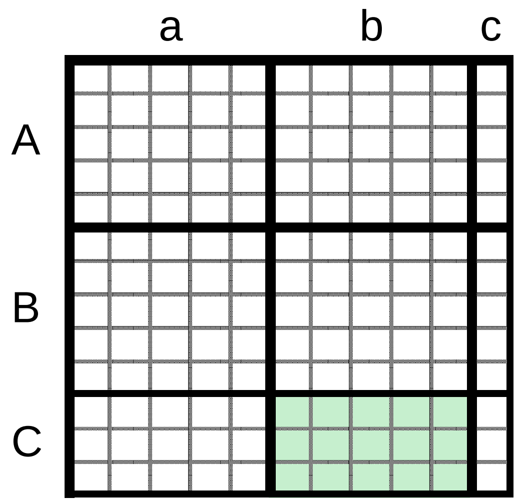


```
rows = 13, cols = 11, xBSize = 5, yBSize = 5
for i in range(0, rows, yBSize):
  if i + yBSize < rows:
    numRows = yBSize
  else:
    numRows = rows – i
  for j in range(0, cols, xBSize):
    if j + xBSize < cols:
      numCols = xBSize
    else:
      numCols = cols – j
    data = band.ReadAsArray(j, i, numCols, numRows)
```

i = [0, 5, **10**]
10 + 5 > 13, so numRows = 13 – 10 = 3

j = [0, **5**, 10]
5 + 5 < 11, so numCols = 5

ReadAsArray(5, 10, 5, 3)

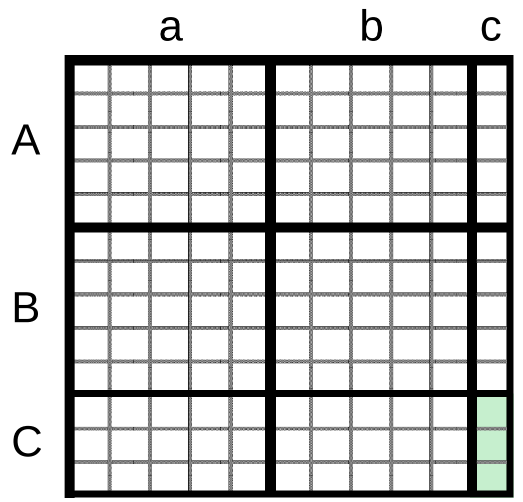


```
rows = 13, cols = 11, xBSize = 5, yBSize = 5
for i in range(0, rows, yBSize):
  if i + yBSize < rows:
    numRows = yBSize
  else:
    numRows = rows – i
  for j in range(0, cols, xBSize):
    if j + xBSize < cols:
      numCols = xBSize
    else:
      numCols = cols – j
    data = band.ReadAsArray(j, i, numCols, numRows)
```

i = [0, 5, **10**]
10 + 5 > 13, so numRows = 13 – 10 = 3

j = [0, 5, **10**]
10 + 5 > 11, so numCols = 11 – 10 = 1

ReadAsArray(10, 10, 1, 3)



Numeric & numpy

- Python modules for processing large arrays
- We'll talk more about it next week
- Use Numeric with FWTools and numpy otherwise

```
import Numeric # FWTools
import numpy # otherwise (ie on Macs)
```

Converting array data types

- If reading byte data (which we are at this point) then the arrays returned by **`ReadAsArray()`** will also by byte
- Sometimes we need the data as a different type

```
data = band.ReadAsArray(j, i, nCols, nRows)
data = data.astype(Numeric.Float) # Numeric
data = data.astype(numpy.float) # numpy
```

- Can do it in one step:

```
data = band.ReadAsArray(j, i, nCols, nRows).astype(Numeric.Float)
```

Creating a mask

- Say we want to do some processing on all pixels with a value greater than 0
- Syntax is the same for numpy

```
mask = Numeric.greater(data, 0)

>>> a = Numeric.array([0, 4, 6, 0, 2])
>>> print a
[0 4 6 0 2]
>>> mask = Numeric.greater(a, 0)
>>> print mask
[0 1 1 0 1]
```

Summing values in an array

- Use `Numeric.sum(<array>)` or `numpy.sum(<array>)`

```
>>> a = Numeric.array([0, 4, 6, 0, 2])
>>> print a
[0 4 6 0 2]
>>> print Numeric.sum(a)
12
```

- If array is 2D then **`sum()`** returns an array

```
>>> b = Numeric.array([a, [5, 10, 0, 3, 0]])
>>> print b
[[ 0  4  6  0  2]
 [ 5 10  0  3  0]]
>>> print Numeric.sum(b)
[ 5 14  6  3  2]
```

- To get one total sum

```
>>> print Numeric.sum(Numeric.sum(b))
30
```

Counting pixels where value > 0

- Create a mask and sum the values

```
>>> print a
[0 4 6 0 2]
>>> mask = Numeric.greater(a, 0)
>>> print mask
[0 1 1 0 1]
>>> print Numeric.sum(mask)
3
```

```
# script to count the number of non-zero pixels in the first band

import os, sys, ogr, gdal, utils, Numeric
from gdalconst import *

os.chdir(r'Z:\Data\Classes\Python\data')

# register all of the GDAL drivers
gdal.AllRegister()

# open the image
ds = gdal.Open('aster.img', GA_ReadOnly)
if ds is None:
  print 'Could not open aster.img'
  sys.exit(1)

# get image size
rows = ds.RasterYSize
cols = ds.RasterXSize
bands = ds.RasterCount

# get the band and block sizes
band = ds.GetRasterBand(1)
blockSizes = utils.GetBlockSize(band)
xBlockSize = blockSizes[0]
yBlockSize = blockSizes[1]

# initialize variable
count = 0
```

```
# loop through the rows
for i in range(0, rows, yBlockSize):
  if i + yBlockSize < rows:
    numRows = yBlockSize
  else:
    numRows = rows – I

  # loop through the columns
  for j in range(0, cols, xBlockSize):
    if j + xBlockSize < cols:
      numCols = xBlockSize
    else:
      numCols = cols – j

    # read the data and do the calculations
    data = band.ReadAsArray(j, i, numCols, numRows).astype(Numeric.Float)
    mask = Numeric.greater(data, 0)
    count = count + Numeric.sum(Numeric.sum(mask))

# print results
print 'Number of non-zero pixels:', count
```

Assignment 4b

- Write a script to calculate the average pixel value for the first band in aster.img
- Read in the data one block at a time
- Do the calculation two ways
  - Including zeros in the calculation
  - Ignoring zeros in the calculation
- Turn in your code and the output