This notebook highlights four major upwelling regions located in low latitudes, which are characterized by high levels of small pelagic fish production. These regions experience strict seasonal upwelling, followed by several months of downwelling conditions that result in low productivity along the coast.

This presentation presents daily SST distributions, which illustrate typical seasonal conditions. These are overlayed by rectangular areas that are suggested for the analysis of marine heatwaves. The coordinates of these aareas are provided above the respective figures.

The images presented here were extracted from the 1km GHRSST data product, version 4.1.

Preparatory section: The code used in ths analysis. Jump two cells forward to see the results.

In [106…

```
from qs.os import is_file, is_str  # import necessary  modules
from qc.os import is_vect
from qc.math import MO_GRID
from qc.geog import MapCanvas
from qc.gph import figsize, implot
#from qs.os import day2jul, jul2day, jul2str
import matplotlib.pyplot as plt
import numpy as np
```

In [156…

```
# define the required fuctions
def as_filename(region, date):
    """
     Constructs file name given a region and date
     ARGS:
      region - can be one of those:
                 NWA - northwest Africa
                 GOG - the  northern Gulf of Guinea
                 ANGOLA - Angola
                 SEAS - Southeastern Arabian Sea (Southwest coast of India)
      date -   date encoded without separators: YYYYMMDD
    """
    if not is_str(region):
        raise SyntaxError('ARG1: region ID required')
    if not is_str(date):
        raise SyntaxError('ARG1: date expression is required')

    data_home='E:/VOLUME/SATELLITE/SAT_DATABASE/GHRSST/4.1/'
    if region == 'NWA':
        pass
    elif region == 'GOG':
        pass
    elif region == 'ANGOLA':
        pass
    elif region == 'SEAS':
        pass
    else:
        raise SyntaxError('ARG1: no data for region ' + region)
    fname= data_home + region + '/DAILY/'+ date[:4] + '/' + date + '_ghrsst_mur.grd.h5'
    if not is_file(fname):
        raise IOError('Something wrong with the or home directory - file not found')
    return fname

def load_image(region, date):
    """
    Loads an image. The image is wrapped in an MO_GRID object

     ARGS:
      see the as_filename function
    """
```

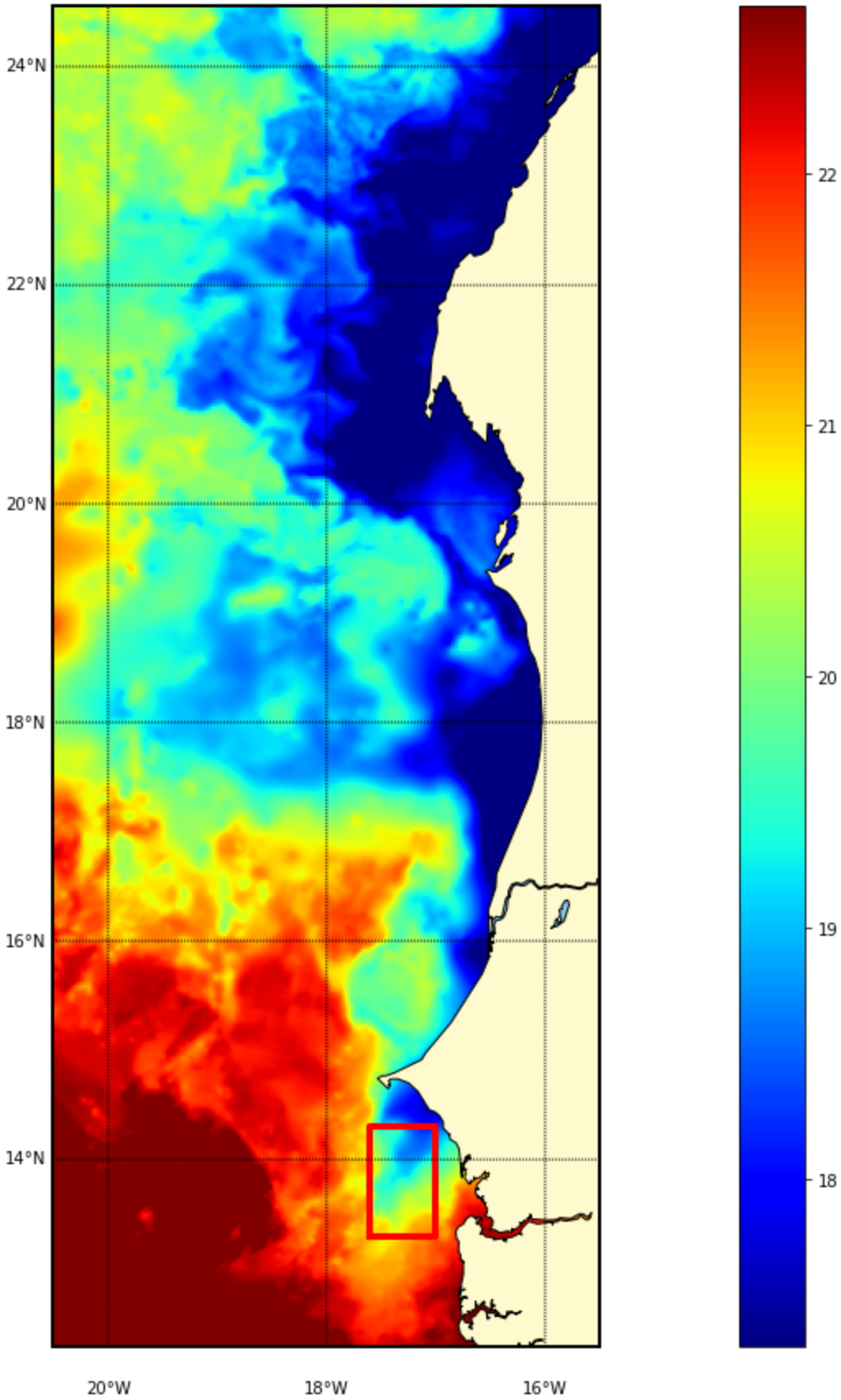
```
    fname = as_filename(region, date)
    grid = MO_GRID()
    grid.h5load(fname)
    grid.set_subarea()
    return grid

def  make_box(range):
    """
    Given the corner coordinates
     returns matrices required to draw a rectange
    """
    if not is_vect(range, length=4):
        raise ValueError('ARG2: coordinates of the box required')
    bottom = range[1]
    left = range[0]
    top = range[3]
    right = range[2]
    x = [left, right, right, left, left]
    y = [bottom, bottom, top, top, bottom]
    return x, y

def draw_sst(grid, box, color='red', thick=4, figx=10, figy=15):
    """
    produces sst map for input data
    ARGS:
     grid - MO_GRID object
     box  - box to be plottet over the image
    """

    x, y = make_box(box)

    org = grid.origin()
    spa = grid.spacing()
    img = grid.image()
    lon = np.arange(img.shape[0]) * spa[0] + org[0] - spa[0]/2
    lat = np.arange(img.shape[1]) * spa[1] + org[1] - spa[1]/2
    figsize(figx, figy)
    fig = plt.figure()
    ma= MapCanvas()
    ma.open(limit=gr.subarea(), latdel=2, londel=2)
    implot(fig,img[::-1], lat, lon, vbar=True)
    ma.close()

    plt.plot(x,y, c=color, lw=thick)
    plt.show()
```

RESULTS

BOX1: the southern Canary System. Senegal and Gambia. The image presents the winter-time conditions. The box ccordinates [-17.6, 13.3, -17.0, 14.3]

In [147…

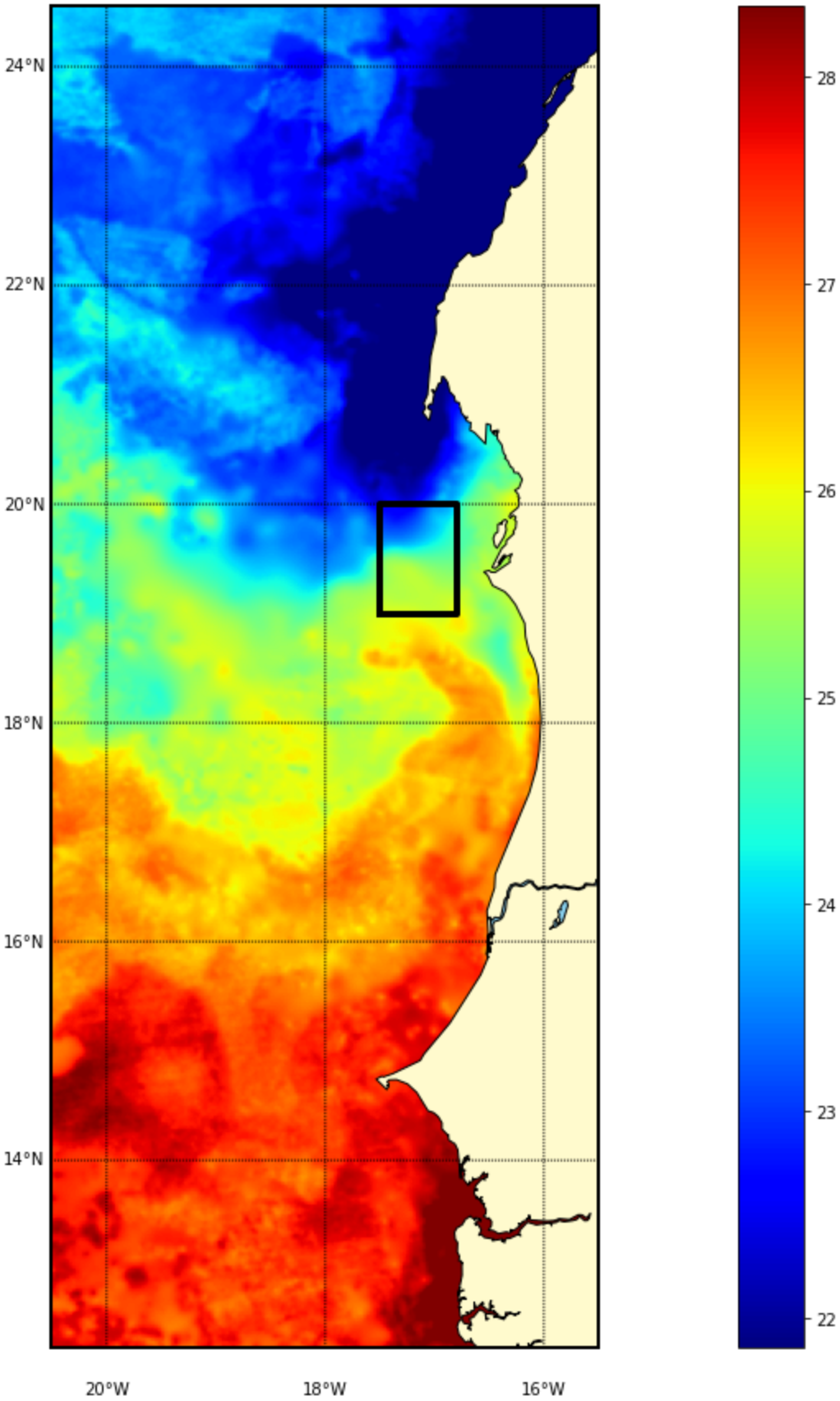
```
range = [-17.6, 13.3, -17.0, 14.3]  # coordinates of the Senegal-Gambia box
gr =  load_image('NWA', '20180115')
draw_sst(gr, range)
```



BOX:2. Northern Mauritania. Summer conditions, intrusion of tropical water. The box coordinates [-17.5, 19.0, -16.8, 20.0]

In [148…

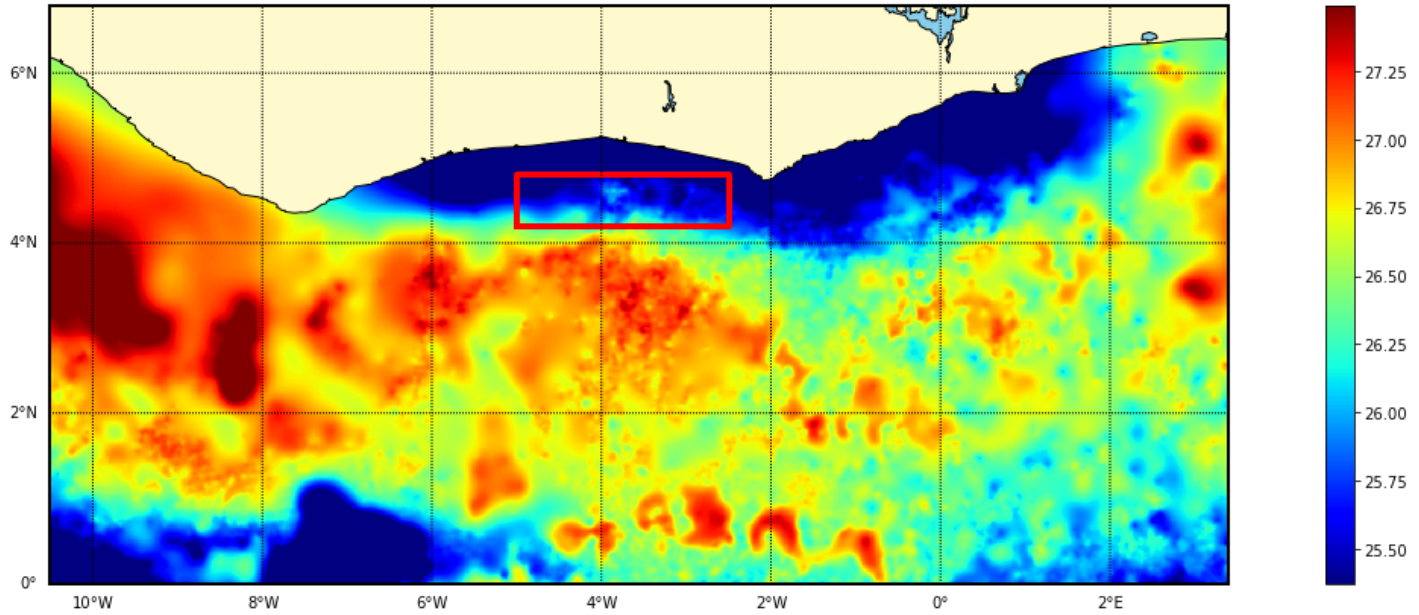
```
range = [-17.5, 19.0, -16.8, 20.0]  # coordinates of the northern Mauritania  box
gr =  load_image('NWA', '20180815')
draw_sst(gr, range, color='black')
```



BOX3: the Gulf of Guinea - summer upwelling, the Cote d'Ivoire Box. The box coordinates: [-5, 4.2, -2.5, 4.8]

In [164…

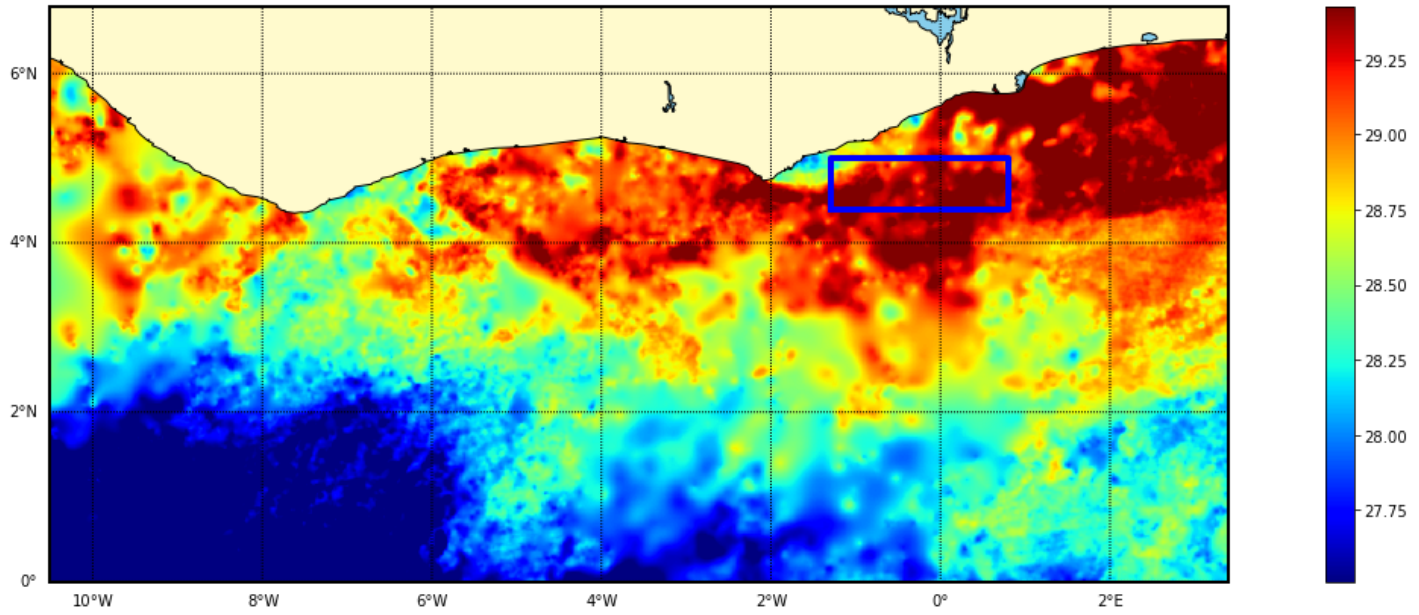
```
range = [-5, 4.2, -2.5, 4.8]  # coordinates of the Cote d'Ivoire box
gr =  load_image('GOG', '20180715')
draw_sst(gr, range, color='red', figx=18, figy=7)
```



BOX5: the Gulf of Guinea - late autumn downwelling, the Ghana Box. The box ccorinates: [-1.3, 4.4, 0.8, 5.0]

In [205…

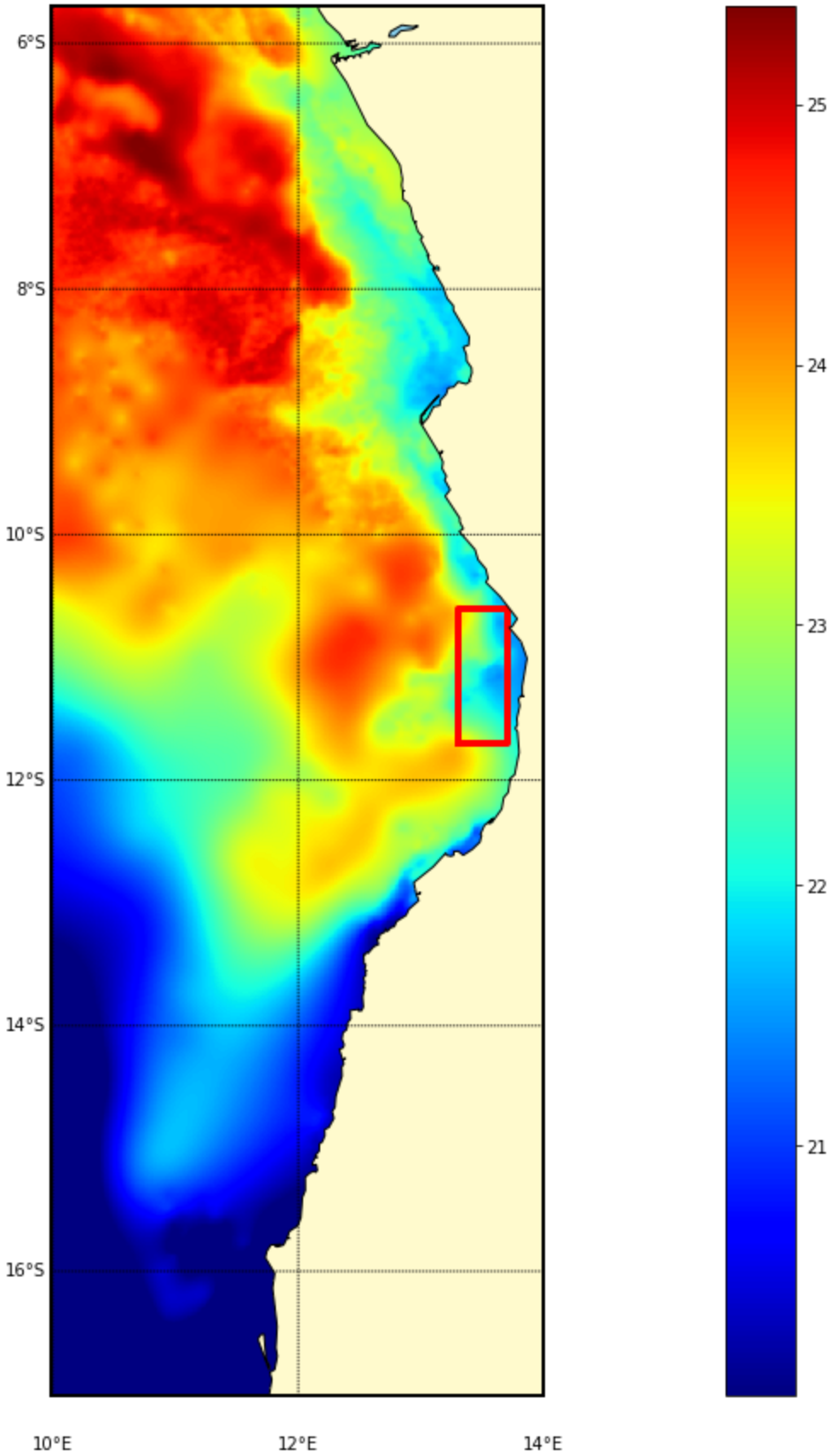
```
range = [-1.3, 4.4, 0.8, 5.0]  # coordinates of the Ghana box
gr =  load_image('GOG', '20181115')
draw_sst(gr, range, color='blue', figx=18, figy=7)
```



BOX6: Central Angola - upwelling. The box ccordinates: [13.3, -11.7, 13.7, -10.6]

In [204…

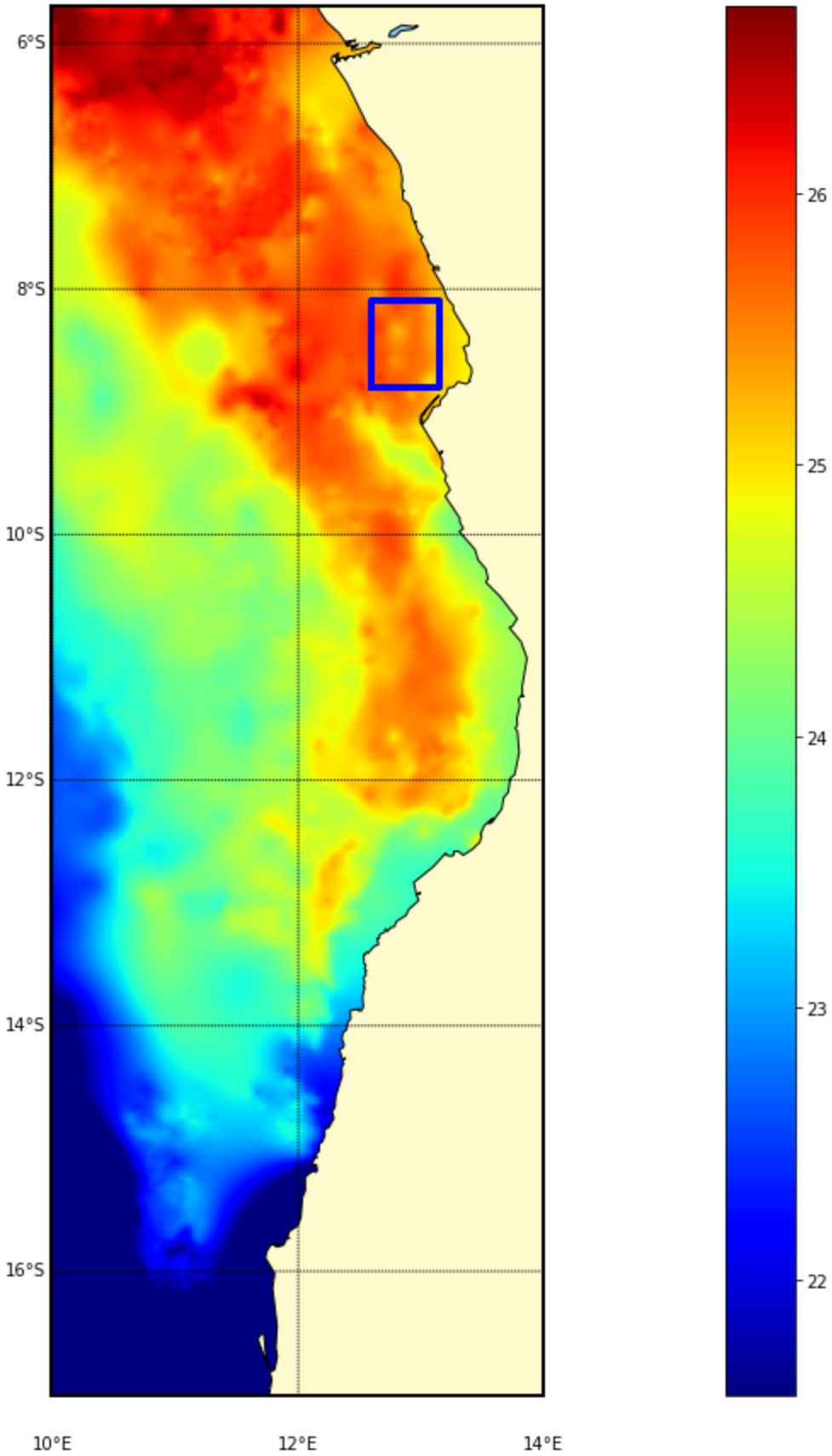
```
range = [13.3, -11.7, 13.7, -10.6]  # coordinates of the central Angola box
gr =  load_image('ANGOLA', '20180715')
draw_sst(gr, range, color='red')
```



BOX7: Northern Angola - downwelling. The box coordinates: [12.6, -8.8, 13.15, -8.1]

In [203…

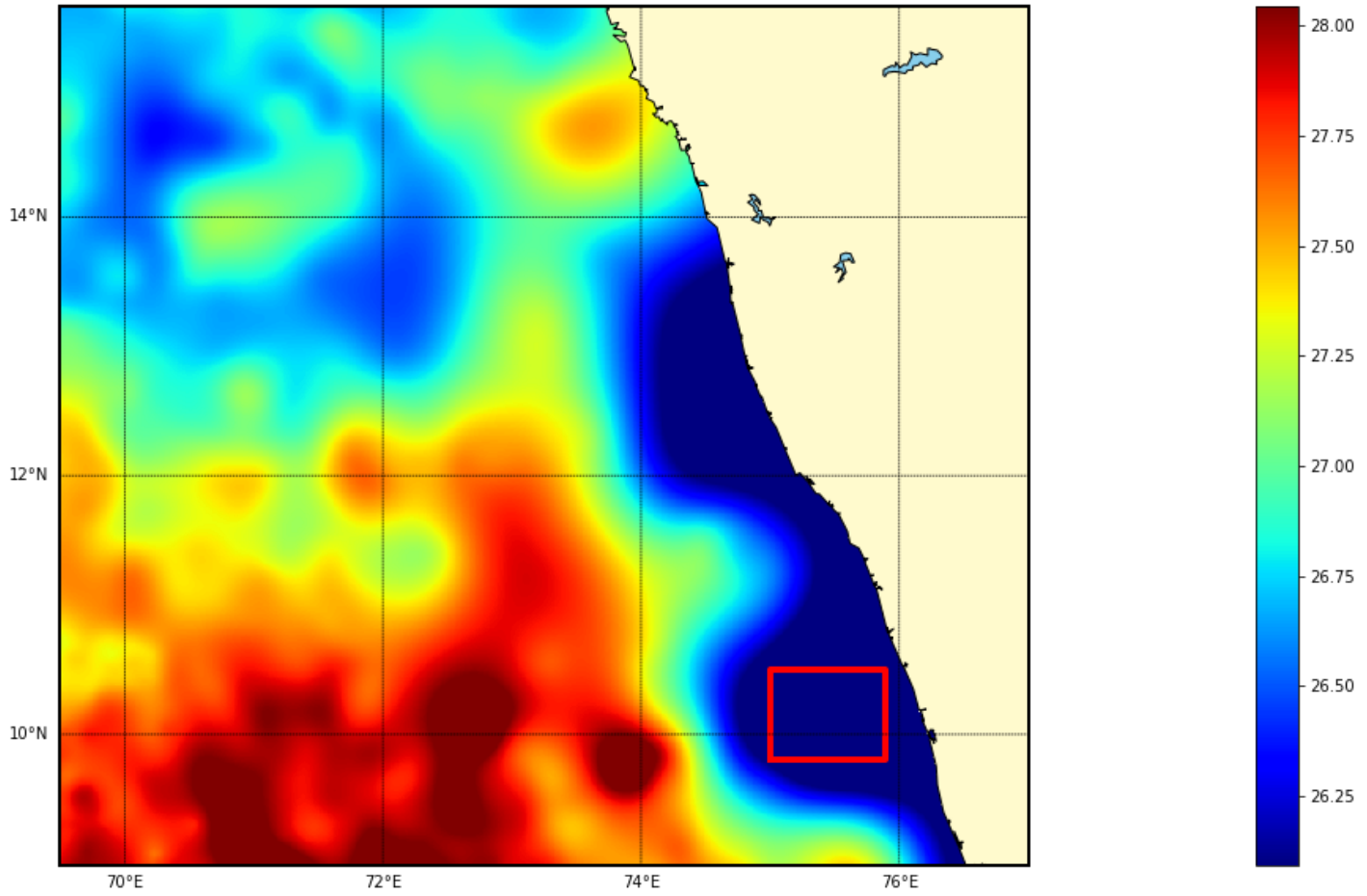
```
range = [12.6, -8.8, 13.15, -8.1]  # coordinates of the Northern Angola Box
gr =  load_image('ANGOLA', '20181015')
draw_sst(gr, range, color='blue')
```



BOX8: Southeast Arabian Sea upwelling. The box coordinates: [75, 9.8, 75.9, 10.5]

In [202…

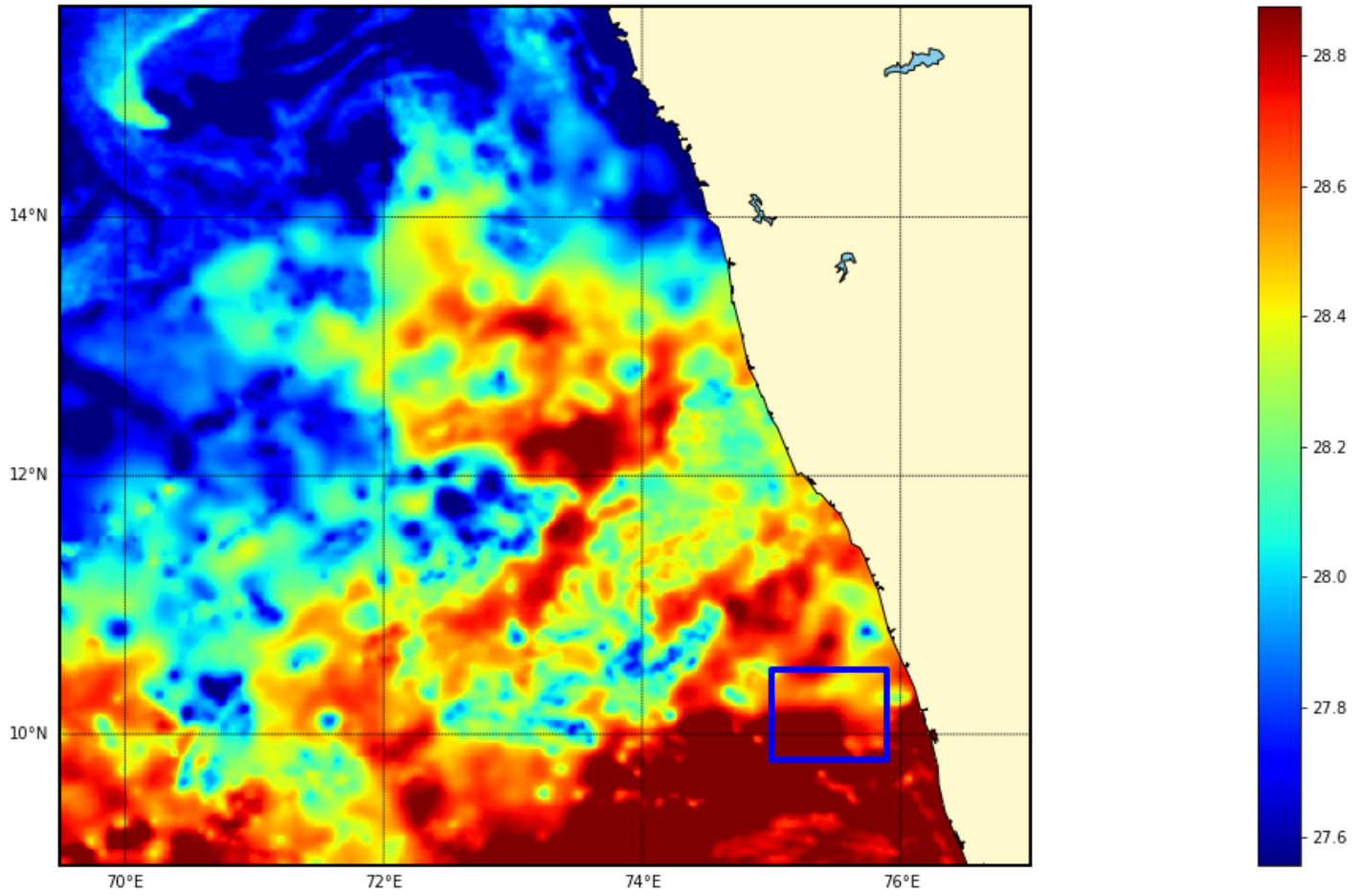
```
range = [75, 9.8, 75.9, 10.5]  # coordinates of the Kerala upwelling cell
gr =  load_image('SEAS', '20180815')
draw_sst(gr, range, color='red', figx=18, figy=10)
```



BOX8: Southeast Arabian Sea downwelling. The same box shown

In [201…

```
range = [75, 9.8, 75.9, 10.5]  # coordinates of theKerala upwelling cell
gr =  load_image('SEAS', '20180215')
draw_sst(gr, range, color='blue', figx=18, figy=10)
```



In [ ]: