

# Edge Detection with WIM and WAM

## 1 Introduction

The location of fronts in the sea-surface temperature (SST) images provides information on a variety of processes in the ocean. Automated objective methods to detect SST fronts have been in the development for many years. Typical edge-detection methods such as the Sobel operator are discrete approximations to the gradient. Gradient-based edge detectors are characterized by spurious responses when applied to noisy data. These so-called local operators use one or another fixed threshold to distinguish an edge from "normal" variability. Gradient operators are known to have many problems and are therefore hard to use for not ideal data (Holyer and Peckinpugh, 1989). Among the several more advanced methods the single-image edge detection (SIED) method of Cayula and Cornillon (1992) has been shown to be superior in tests (Cayula et al., 1991). The method has been used by Peter Cornillon's group at URI (Ullmann and Cornillon 1999, 2000, 2001) and others (Kahru et al. 1995, Diehl et al. 2002) for objective mapping of SST fronts.

The basic idea of the SIED method is to use overlapping windows to investigate the statistical likelihood of an edge by (1) performing a histogram analysis to detect bimodality of the histogram and (2) detecting the cohesiveness of the potential edge. A modification to the SIED method proposed by Diehl et al (2002) uses variogram analysis in two directions to find the best window size in x and y directions instead of a fixed window size.

The SIED method has been implemented in WIM and WAM. You can create edge (front) images interactively with WIM but for creating the edge images and their means for a long series of images it is better to use WAM programs *wam\_edge* and *wam\_edge\_accumulate*.

## 2 Methods

The SIED method as modified by Diehl et al. (2002) is implemented in WIM and WAM. SST data is available from multiple sensors and in multiple time composites. The best sources to use for edge detection are the MODIS-Terra daily, 8-day, and monthly 4 km datasets (available for 2000-2004) as well as the AVHRR Pathfinder version 5 (PF5) daily, 7-day and monthly data (available for 1985-2004). While the MODIS data may have higher accuracy, the AVHRR Pathfinder data have the advantage of a longer time period. Both MODIS and PF5 data are distributed in a form that includes pixels at variable quality levels.

I found that the Diehl et al (2002) method is very sensitive and detects large numbers of small-scale fronts. As our task is to detect the seasonal and inter-annual variability in the locations of the major fronts, I made various modifications.

The threshold value of the between-cluster variance to the within-cluster variance was increased from 0.76 (of Diehl et al., 2002) to 0.8.

Instead of using the variable window method of Diehl et al (2002) you can experiment with larger fixed size window (e.g. 20 x 20; the original Cayula and Cornillon, 2002 used 32 x 32 pixel window).

The daily and even 7- or 8-day composites (especially after screening) are often too sparse and miss too much data. Therefore it is better to use monthly composites for front detection. Bear in mind that using composites instead of individual images can create artificial fronts. However, the frequency of artificial fronts should be minimized by detecting only the large-scale fronts.

### 3 Prerequisites

We assume that you are familiar with the basics of the Windows or DOS command line, i.e. how to open the command window, change directory, issue a command, etc. We also assume that you are familiar and able to run WAM command line programs. If not, please check out the basic WAM and WAM exercises manuals. We also assume that you have a set of images that you are going to use. In our example we use monthly AVHRR Pathfinder (version 5) monthly SST images.

### 4 Screening the images

The first task is to screen the data and keep the best quality (quality 0 for MODIS and 7 for PF5). The pixels with lower quality are usually contaminated by clouds and would interfere with edge detection (the SIED method performs additional extra steps for cloud detection and elimination). You can use *wam\_screen\_modis* for screening the old format MODIS SST data, *wam\_screen\_sst\_ocpg* for screening the new MODIS SST data produced by the Ocean Color Processing Group and *wam\_screen\_pf* for screening AVHRR Pathfinder data. Please see the corresponding section in the WAM Manual (*WAM.pdf*).

### 5 Picking the sub-area

You are probably interested in finding fronts in a certain area and not in the whole global image. You can create subset images with another tool (e.g. *wam\_series*) and then run *wam\_edge* on those. In this example we will create the subset images with *wam\_edge* itself by cutting out a rectangle from the global equal angle image.

First we will experiment with the interactive edge detection in WIM. Open a sample global SST image with WIM and select your area of interest, i.e. select a rectangle with the left mouse button down, and then click on the *Cut* icon (Scissors) on the toolbar. Note and write down the Upper-Left and Lower-Right pixel coordinates – you will need them later. Try to use an image size with a horizontal dimension that is divisible with 4. Then select *Edge-SIED* from the WIM menu. Now select again the previous image (click on the SST image “*CutImg*”) and overlay the edges on top of it with the *Overlay* tool in the toolbar. You can repeat the same with different window sizes and note the differences. You may find that some edges correspond to coastlines. We will eliminate those by

creating an extended land mask image that will limit the edges to the open sea area only. In this example we will be using screened AVHRR Pathfinder version 5 monthly ascending data for 2004. We pick our area of interest in the Gulf of Mexico and adjoining areas in the Caribbean and Central America with the upper-left and lower-right coordinates, respectively, 1845, 1336 and 2445, 1936. You can extract exactly this sub-area by selecting the *Cut* (scissors) tool from the toolbar without selecting a rectangle and typing in the corresponding pixel coordinates. Now create the coastlines for this sub-image with *Geo-Get Map Overlay* with pixel value 255. You can use any high-resolution coastlines file, e.g. *coast\_high.b*. Now fill the land areas with pixel value 1 using *Edit-Draw-Fill*. Be careful not to let the “paint” overflow into the ocean areas from coastlines that don’t touch the image edge. In these cases extend the coastlines to the image edge with a line or pen tool and pixel value 255. The result should look something like that below.



Fig. 1. Landmask of the area of interest.

Now expand the land mask using *Edge-Dilate-1*. The result is shown below.



Fig. 2. Dilated landmask of the area of interest.

Dilation of the landmask prevents detecting edges along coastlines. Please remember to stretch the colors from 0 to 255 – otherwise some pixel values may be invisible. The idea of the mask above is that pixels with value 0 will be used in the subsequent edge detection analysis and nonzero pixels will be excluded. As you can see, we have expanded the land areas in order to exclude ocean pixels immediately next to the coast. Save the dilated landmask to a HDF file, e.g. *landmask\_gom\_dilated1x.hdf*. Now we are ready to create the monthly edge images.

## 6 Running *wam\_edge*

Open a command window, change directory (*cd*) to a proper path and issue the following command:

```
wam_edge 2004*.hdf 20 landmask_gom_dilated1x.hdf 1845 1336 2445 1936
```

Note that we are using all images in this folder matching *2004\*.hdf*, a window size 20, landmask image *landmask\_gom\_dilated1x.hdf*, upper left corner 1845, 1336 and lower-right corner 2445, 1936. You can see the syntax (all possible arguments) by invoking *wam\_edge* without arguments. If successful, this will create a set of subset image (*\*\_Cut.hdf*) and a corresponding edge image (*\*\_Cut.hdf\_Sied.hdf*) for each matching SST image. A sample edge image is shown in Fig. 3.

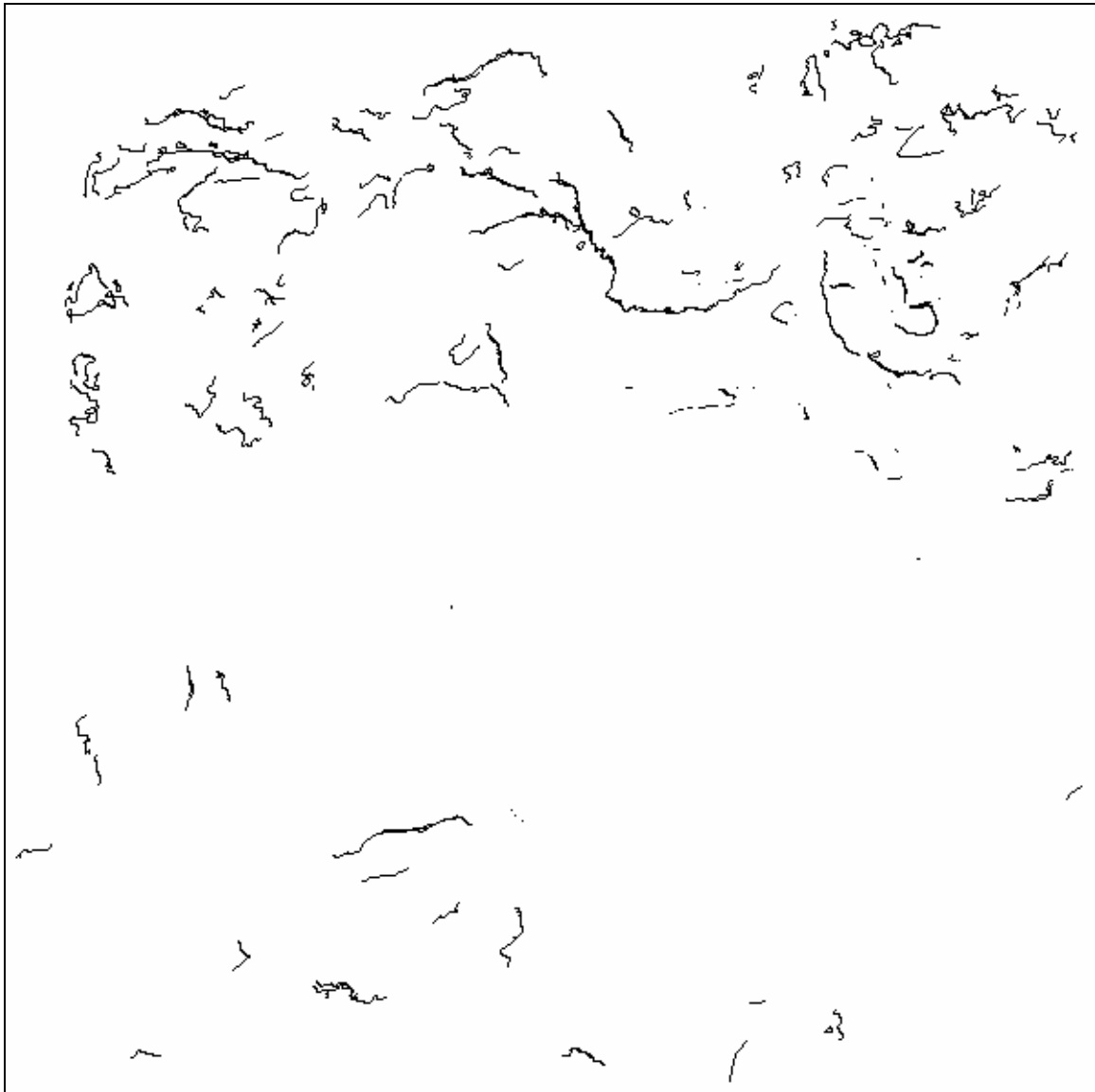


Fig. 3. Edges detected for December-2004 Pathfinder SST (after reverse-stretching the colors).

In our exercise we have 12 source images corresponding to 12 monthly SST composites of 2004. We should now have 12 edge images like Fig. 3 (*\*Sied.hdf*) corresponding to each month of 2004.

Please note that the command created a whole set of subset images (*\*\_Cut.hdf*) and edge images. The edge image names are created by adding a string “*\_Sied.hdf*” to the SST image name. When you run the same command again you have to be careful **not** to match both the original global SST images and the subset (*\*\_Cut.hdf*) images in the same command. When running *wam\_edge* with global images we want to extract the subset at the same time but when applying *wam\_edge* directly to the subset images we **do not** want to extract a subset again. When applying *wam\_edge* to the subset images is:

```
wam_edge 2004*_Cut.hdf 20 landmask_gom_dilated1x.hdf
```

Please note that we don't specify a subset (Cut) range this time.

## 7 Running *wam\_edge\_accumulate*

After we have a series of edge images we want to somehow average them into a mean, composited image. Simple averaging is not appropriate as different areas may have different number of cloud-free data. This is especially relevant when using daily SST data as daily images have much larger percentage of cloudy areas compared to the monthly composites. We will use *wam\_edge\_accumulate* to make mean edge images.

In a command window, issue the following command:

```
wam_edge_accumulate 2004*_Cut.hdf 1
```

Please note that we are **not** matching directly the edge images (*\*Sied.hdf*) but the source (subset) images (*\*\_Cut.hdf*). It is just easier to find the matching name pairs this way by adding the string *\_Sied.hdf* to a matching SST image. The number 1 in the command means that we are making 1 set of averages, i.e. the overall mean. If we use 12 instead of 1 we would be making monthly averages instead of the overall average. For example, if we use daily or 8-day images in edge detection we can make monthly averages by using “12” in the command. In our example we already use monthly images for a particular year (2004) and our overall mean will be for that year (2004). We need to have both the edge images and the corresponding SST image in the same folder. The SST images are needed to calculate the number of valid pixels. If successful, this will create three types of images (HDF and the corresponding PNG image): *front count*, *valid SST* and *front frequency* (see Figs. 4, 5, 6 below). The names of these files are created from the command you issue and you may want to rename them to make more sense.

Take a look at the content of each of the HDF files with WIM. Explain the meaning of pixel values of these images. A command option that we did not use is for reduction of

the resulting images. In case of very large images you may want to reduce the size of the resulting images, e.g. by 2 or 3 times.

Both *wam\_edge* and *wam\_edge\_accumulate* create attributes "Start Year", "Start Day", "End Year", "End Day" and save these attributes to all HDF files that they save. This makes it possible to create time series (e.g. with *wam\_statist*) using the results from both programs. If you are using nonstandard input data (e.g. files that *wam\_edge* cannot get the date from) then it is possible that this does not work.

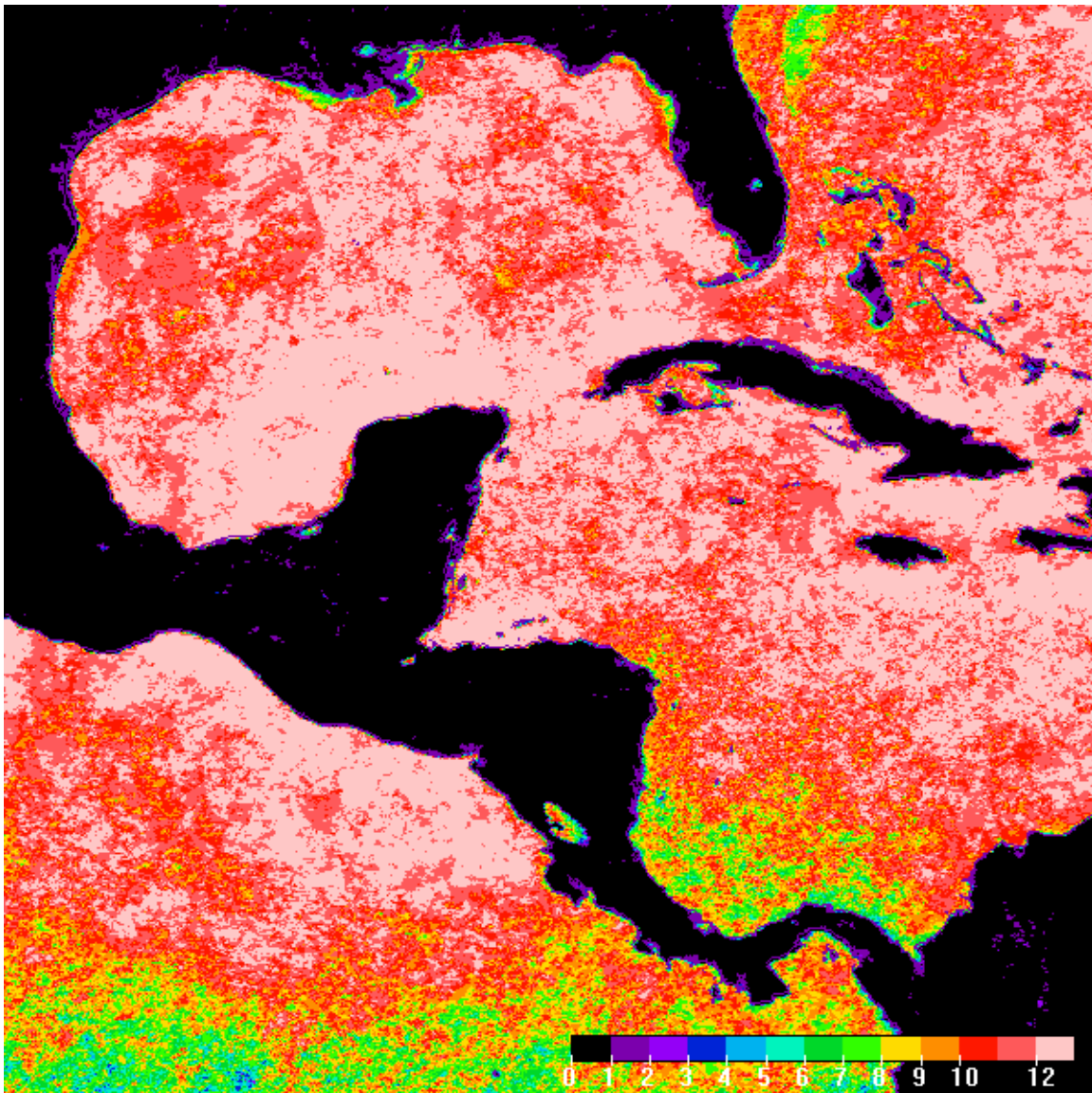


Fig. 4. Number of valid SST pixels used for edge detection. The color scale was added manually with *View-Annotate*.

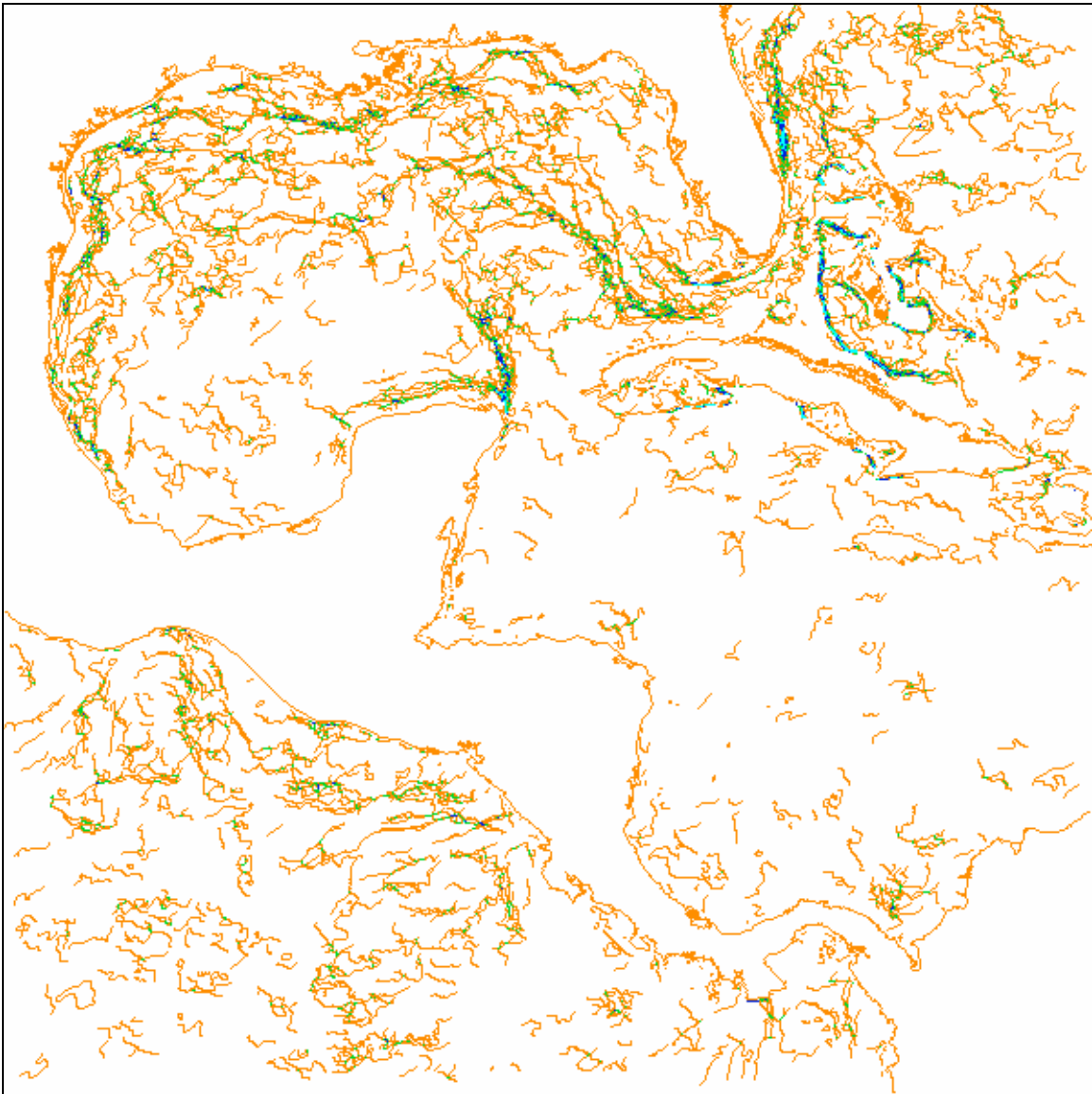


Fig. 5. Number of detected edges (for each pixel). The color scale was changed manually with the *Colors* tool.

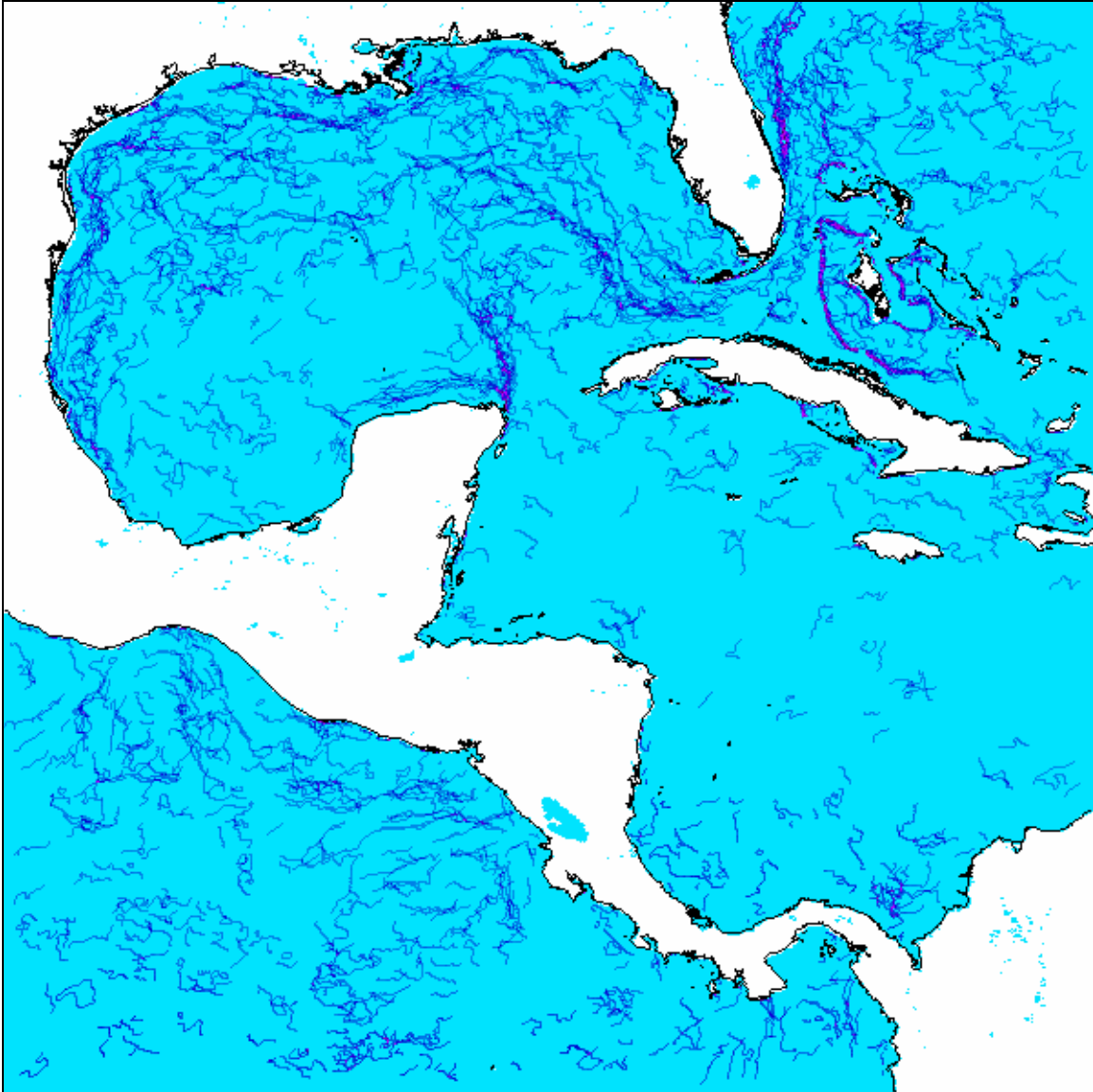


Fig. 5. Frequency of detected edges (i.e. the number of detected edges per the number of valid SST for each pixel).

### References

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