

Towards Simultaneous Clear-Sky and Ocean Dynamics Analyses in the NOAA SST System

**Irina Gladkova^{1,2,3}, Yury Kihai^{1,2}, Alexander Ignatov¹,
Fazlul Shahriar^{3,4}, Karlis Mikelsons^{1,2}, Marouan Bouali^{1,2},
Boris Petrenko^{1,2}**

¹NOAA/NESDIS/STAR,

²GST, Inc.,

³City College of New York, NOAA/CREST,

⁴ Graduate Center of CUNY.

Motivation

- ☐ Customarily, clear-sky masks for ocean are independent of downstream ocean dynamics applications, such as
- ☐ detection of ocean thermal fronts, currents, cold upwelling, eddies, and monitoring of their evolution in time
- ☐ Ocean dynamics in satellite SST imagery is analyzed over clear sky pixels, only, and may be strongly affected by the quality of clear-sky scene detection

Quality of Clear-Sky Mask

Majority of current masking algorithms use thresholds. Liberal thresholds result in “cloud leakages”, whereas conservative settings lead to “false alarms”

Conservative SST mask is usually considered preferable, to minimize cloud leakages, **at the expense of excluding a (presumably, relatively small) fraction of clear pixels, globally**

Standard Quality Criteria:

- Minimal cloud leakages; and
- Large geographical coverage

What is the price?

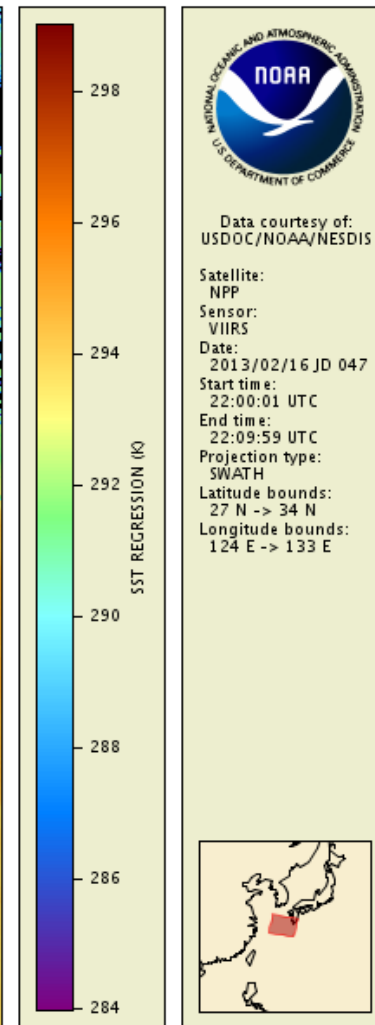
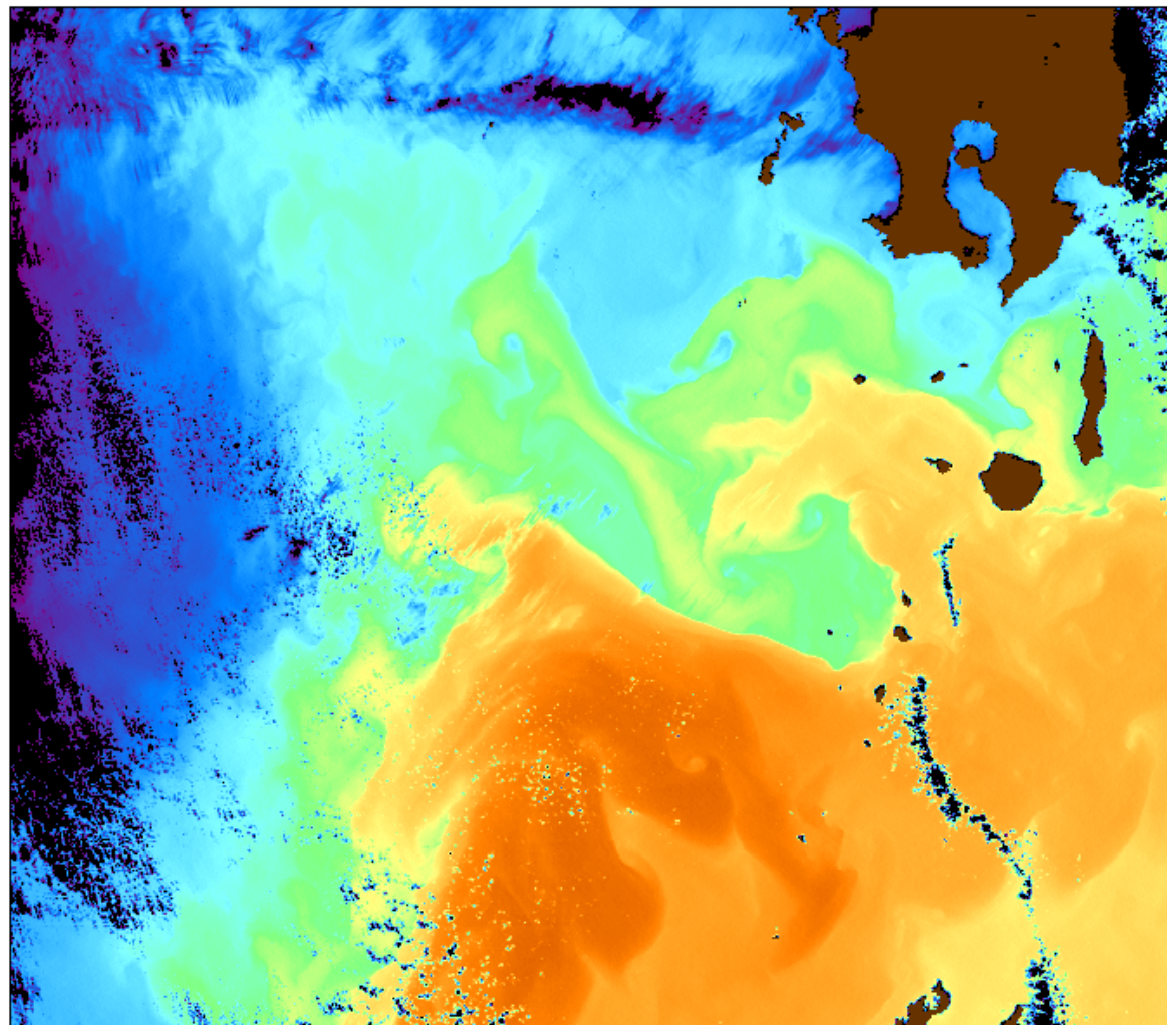
- ☐ The geographic distribution of “false alarms” is highly non-uniform
- ☐ “False alarms” are often persistent from pass to pass
- ☐ Misclassification mostly occurs in those ocean areas where SST is variable and/or significantly colder than surrounding waters and/or climatology
- ☐ It is those highly dynamic and coastal waters that are of most interest to the SST users for fishing, ship navigation, ocean dynamic modeling, climatology and marine biology studies

Objective of this Study

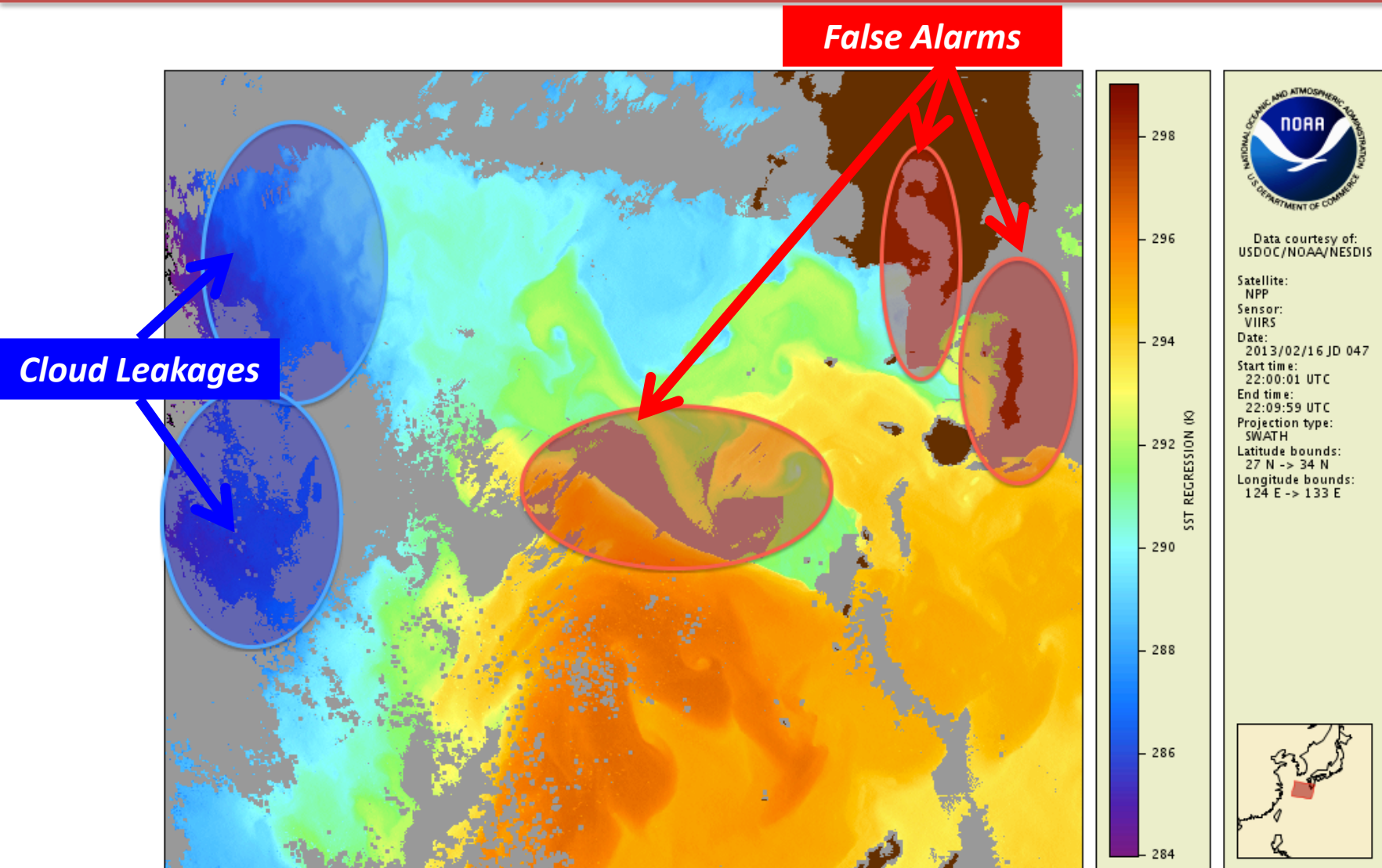
Open up interesting areas of the ocean by incorporating elements of ocean dynamics analysis in Clear-Sky Mask

- ☐ Initially, we want to reclassify (at least, some) “false alarms” back into clear-sky domain for SST users
- ☐ We do not address “cloud leakages”, at this stage of analysis
- ☐ This study makes use of VIIRS superior radiometric and imagery performance
- ☐ Eventually, we plan to extend the method to MODIS 1km, and AVHRR (1km FRAC, and 4km GAC) data

VIIRS SST



ACSPO Clear Sky Mask



Typical False Alarms

Typical clear sky ocean regions misclassified by the ACSM

- Contiguous
- With well-defined boundaries
- Typically located in the vicinity of ocean thermal fronts

Existing image processing techniques

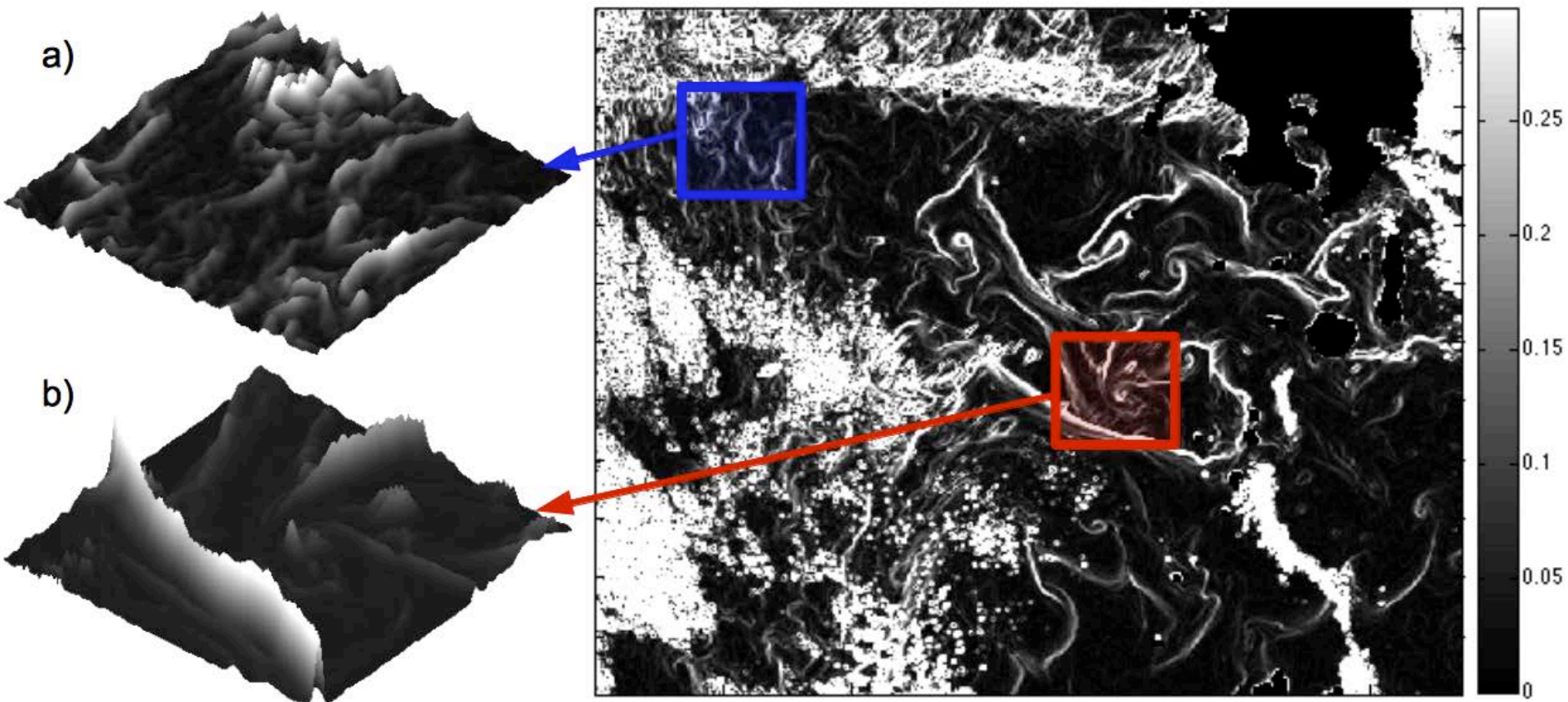
- Segmentation
- Morphological Procedures: erosion and dilation
- Thermal Front Detection

Human Perspective

- ☐ Human eye does not perceive absolute pixel values (i.e., SST values)
- ☐ Instead, it relies on local contrasts and ratios, which more directly correlate with gradients in an image
- ☐ Difference between ocean and cloud patterns is more pronounced in the SST gradient magnitude domain

Gradient Magnitude

Gradient magnitudes viewed as a terrain look like sharp ridges towering over flat valleys.



The Algorithm

Step 1: Identify Search Domain

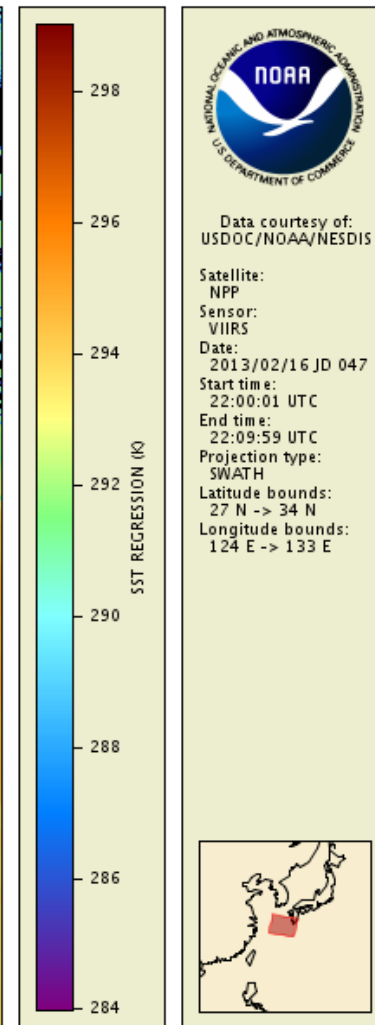
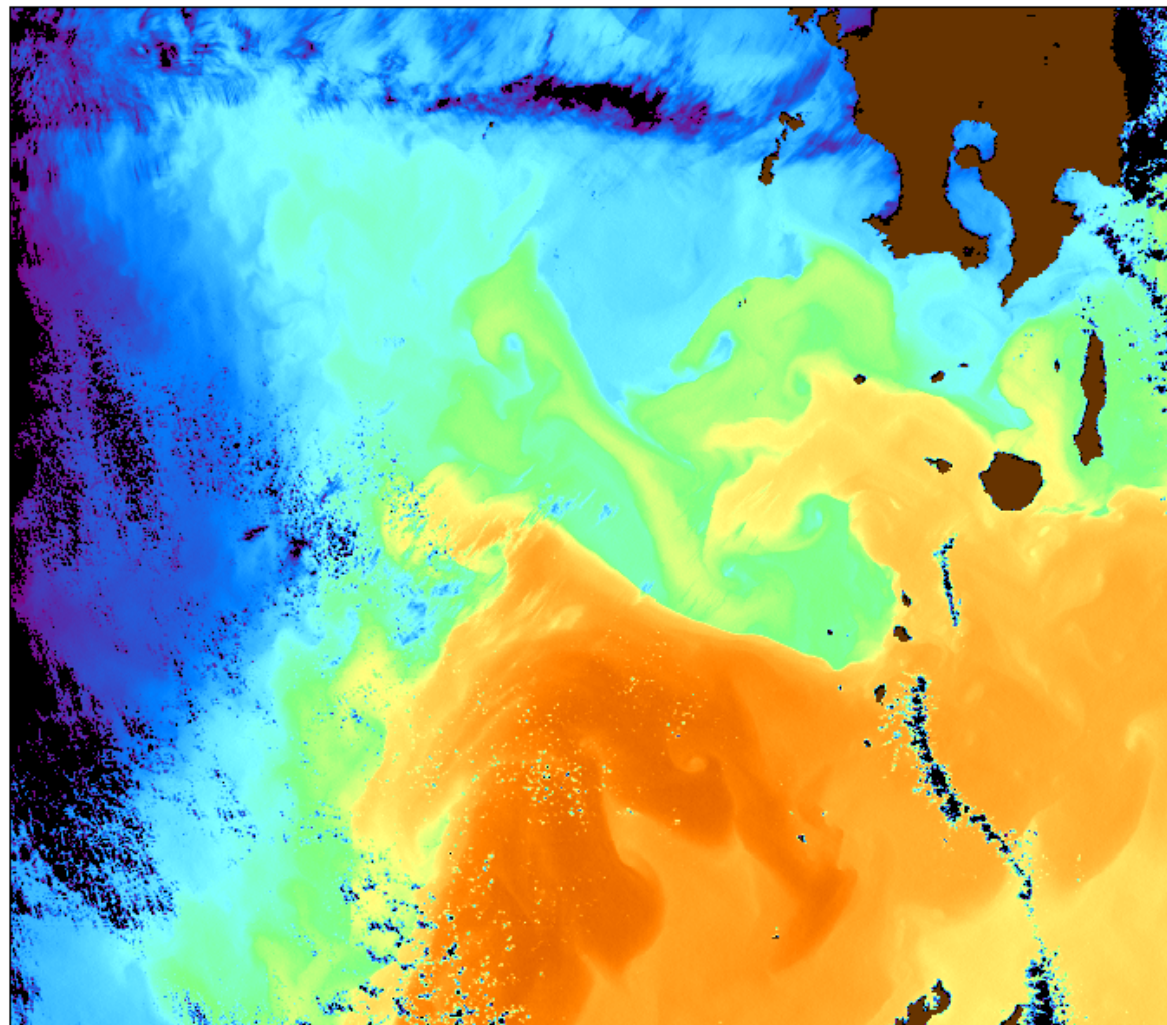
Step 2: Determine SST gradient ridges

Step 3: Determine spatially connected cold SST regions

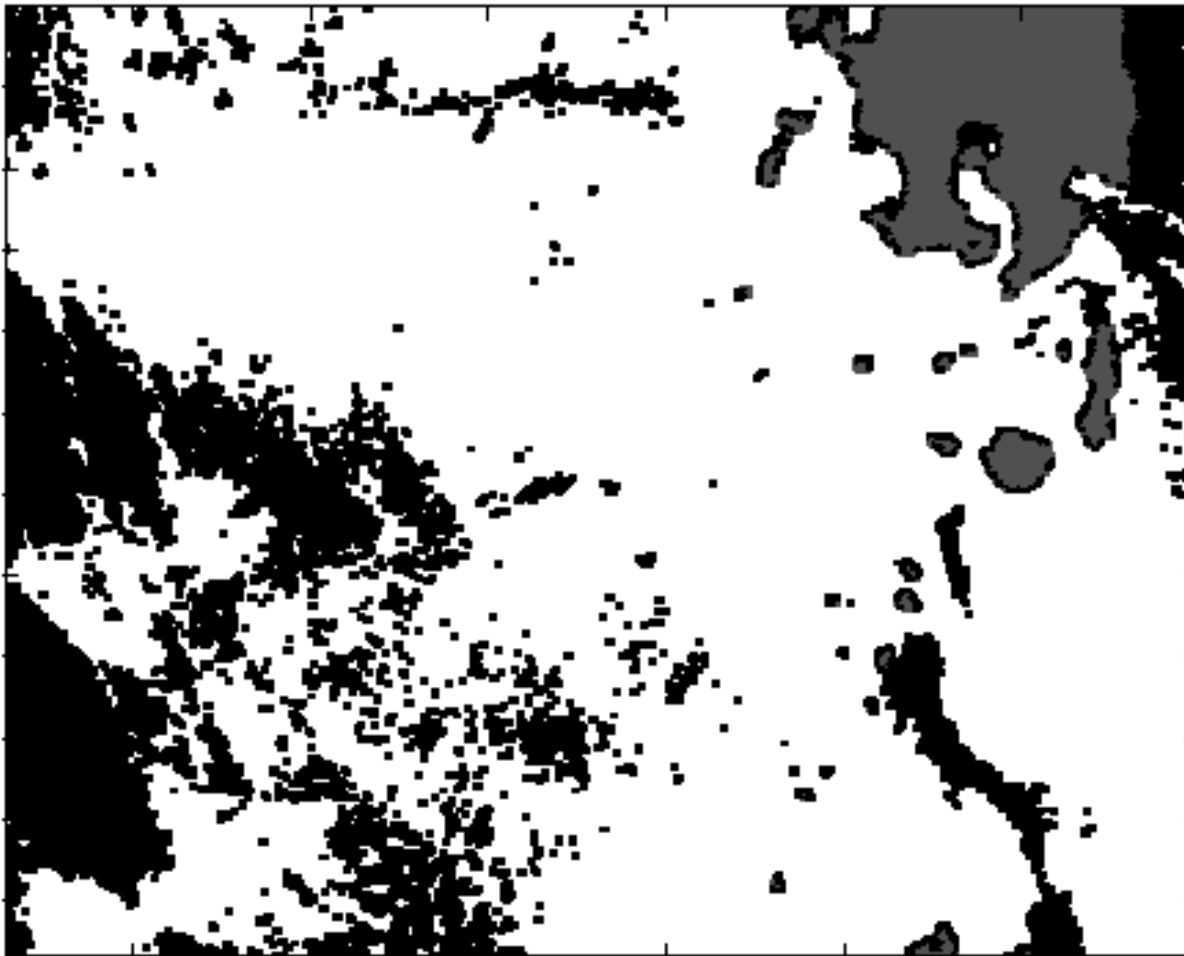
Step 4: Discard SST segments found in Step 3 that do not border the ridges found in Step 2

Step 5: Statistical Test

VIIRS SST

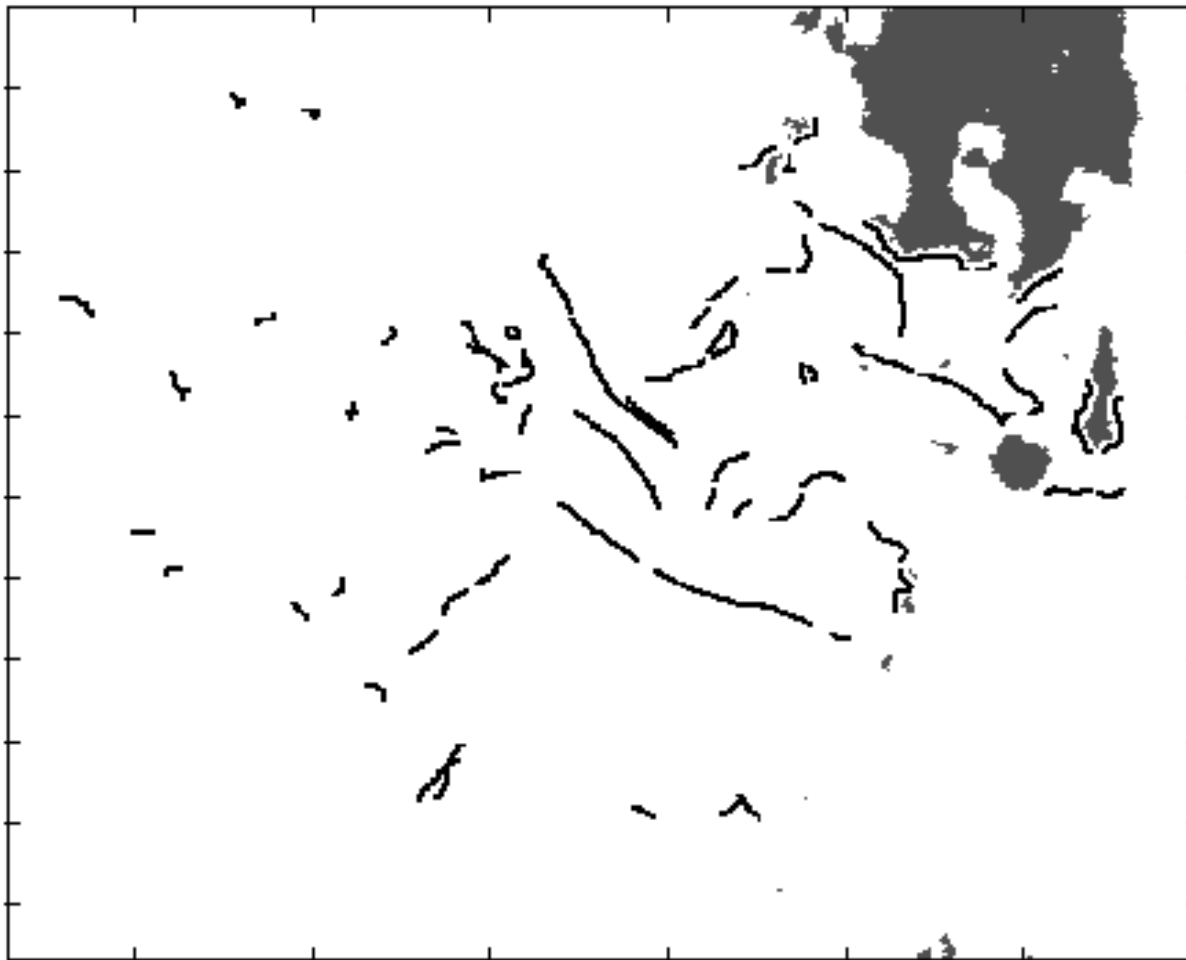


Step1: Search Space



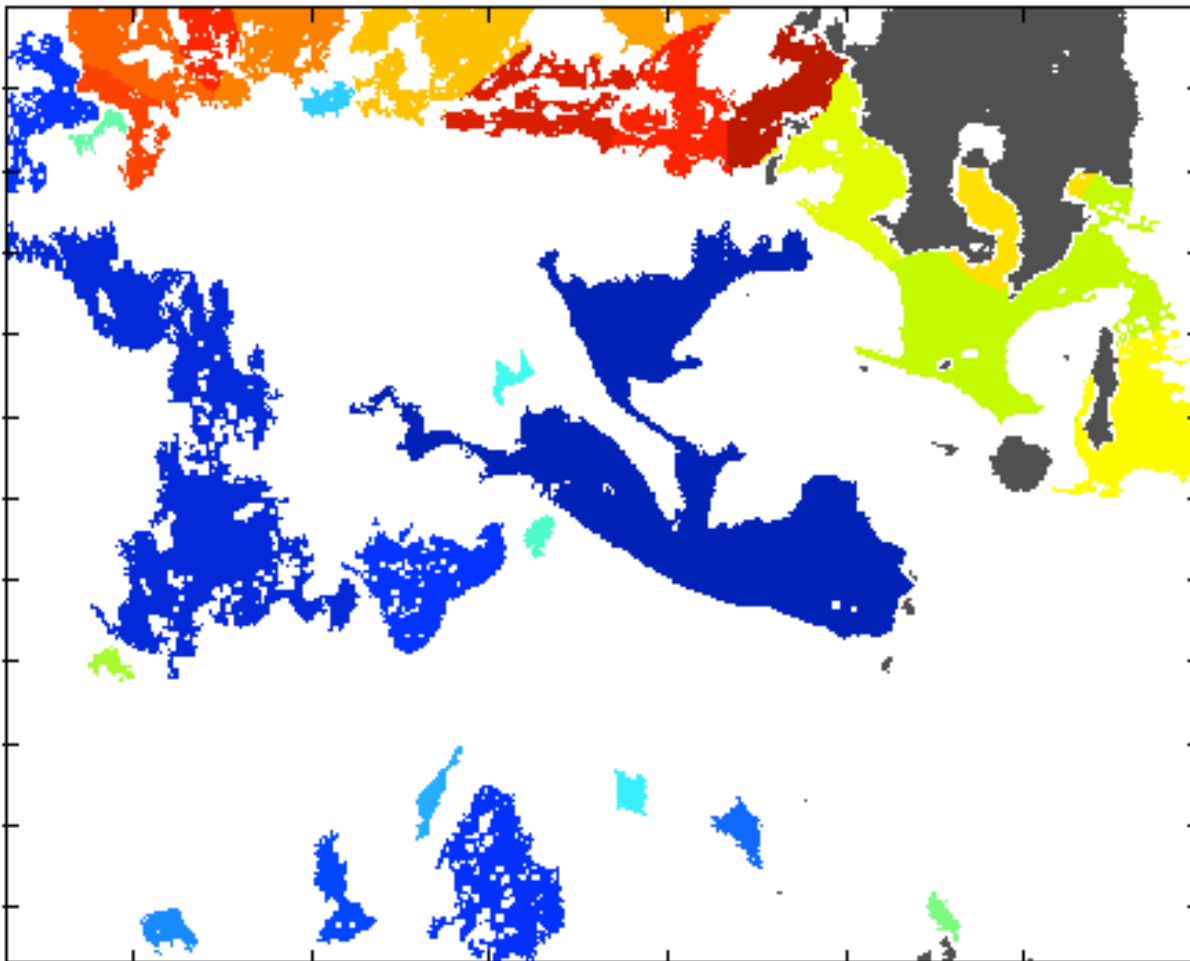
Narrow down search space, in the interest of processing time

Step 2: Gradient Ridges



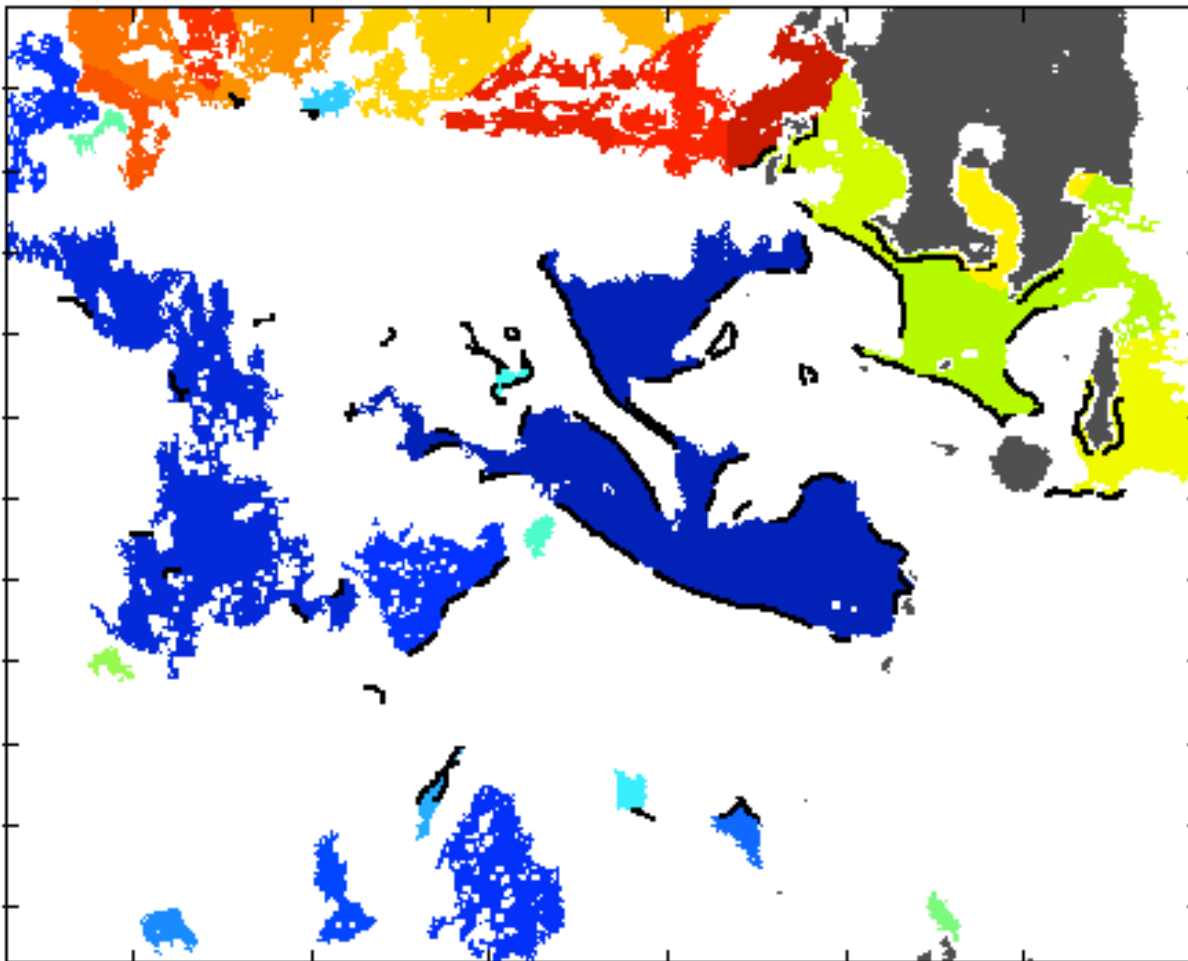
Determine contiguous portions of thermal fronts

Step 3: Segmentation



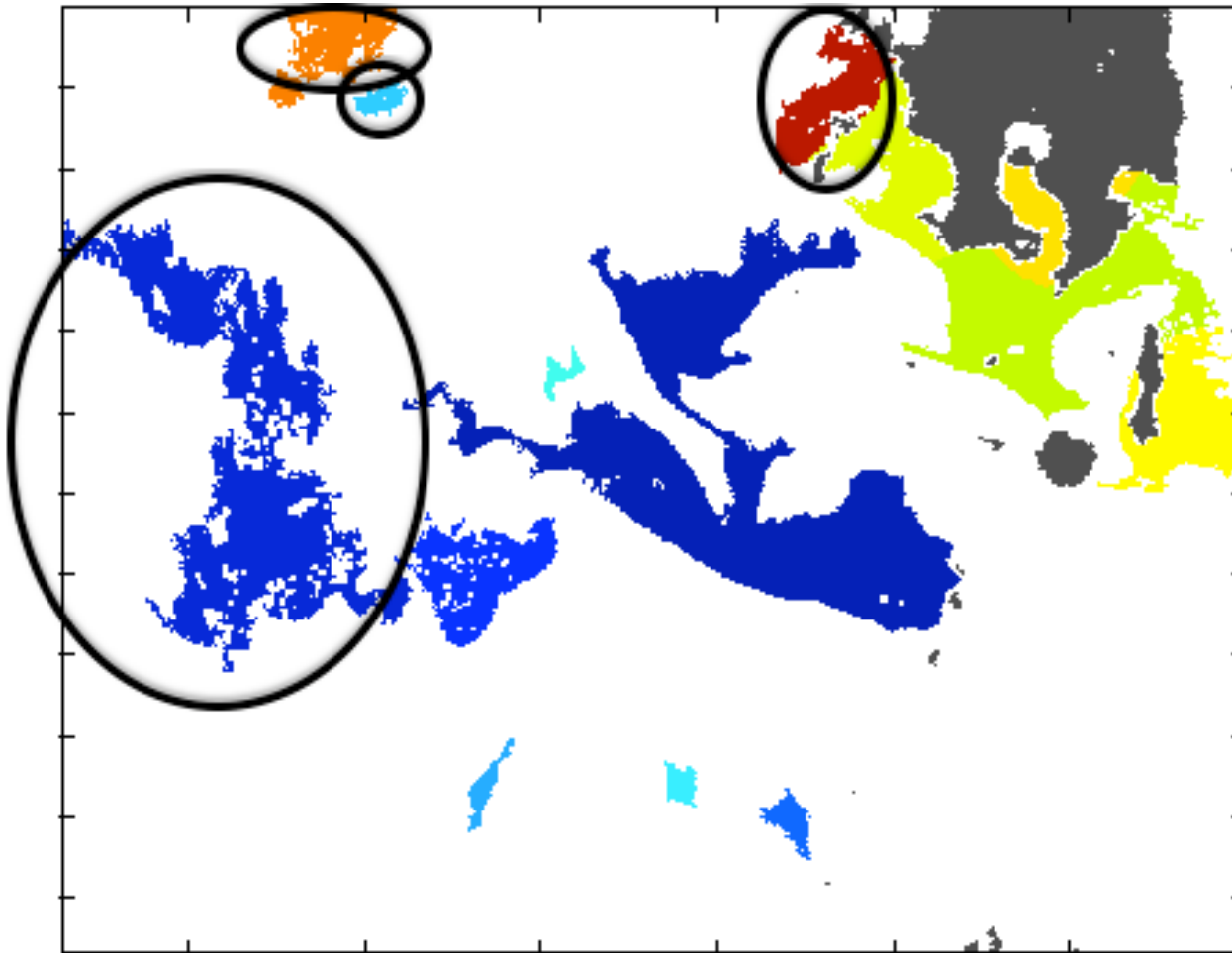
Find spatially connected regions with negative ΔSST

Step 4: Adjacency



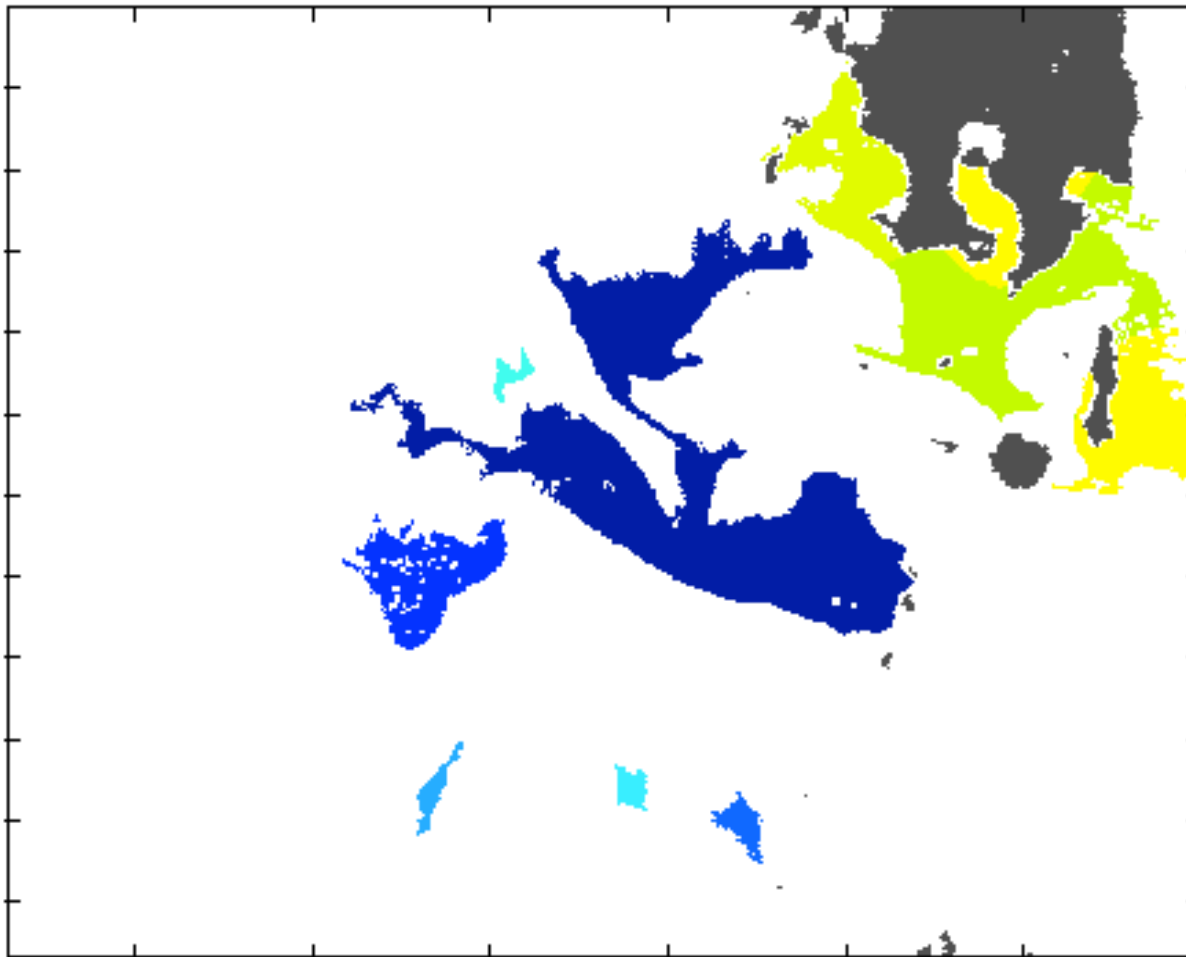
Keep Segments that have adjacent Ridges

Statistical Test



Keep segments which more statistically similar to ocean than cloud

Clear Sky Regions



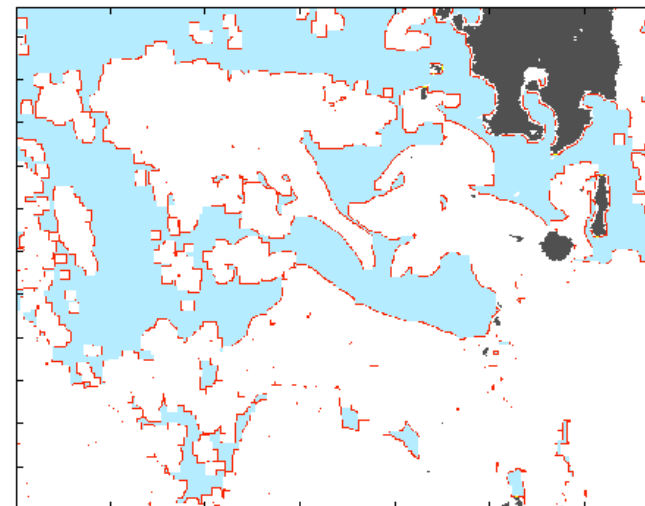
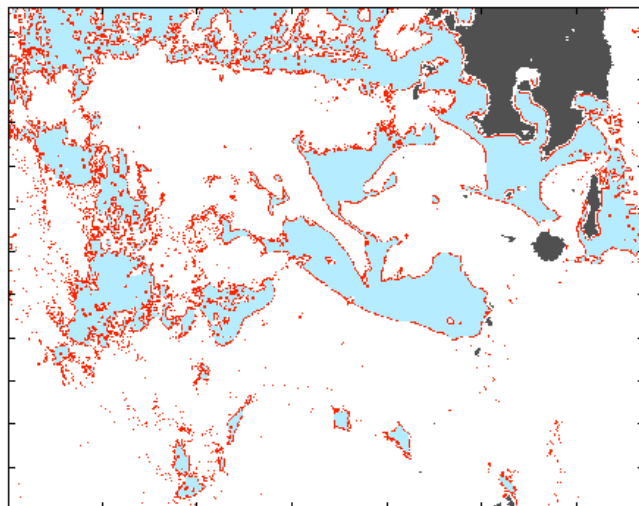
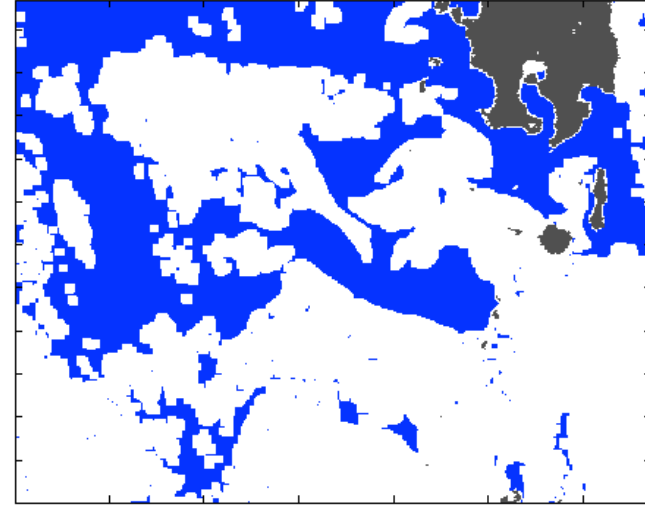
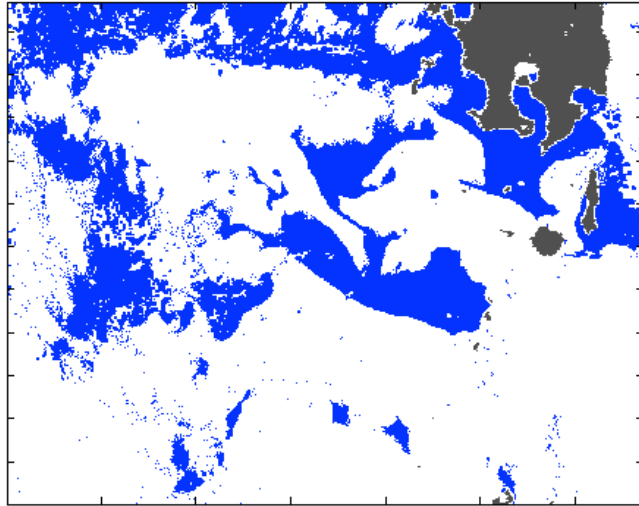
Restore identified “false alarms” back to SST domain

Detection of Gradient Ridges

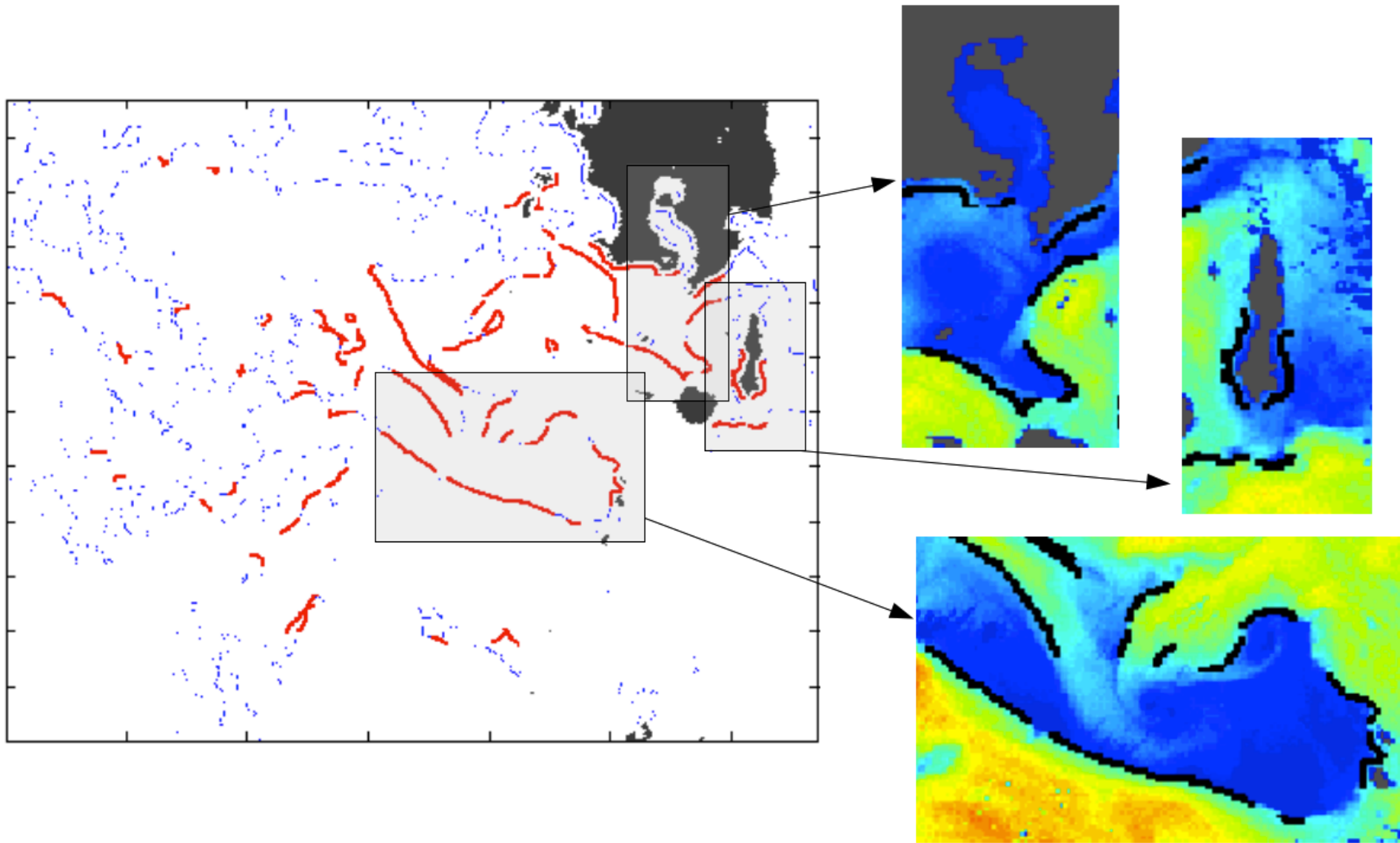
Existing Image Processing Tools:

- Thermal Front Detection
- Edge Detection
- Gradient Ridges and Valleys

Border Stability

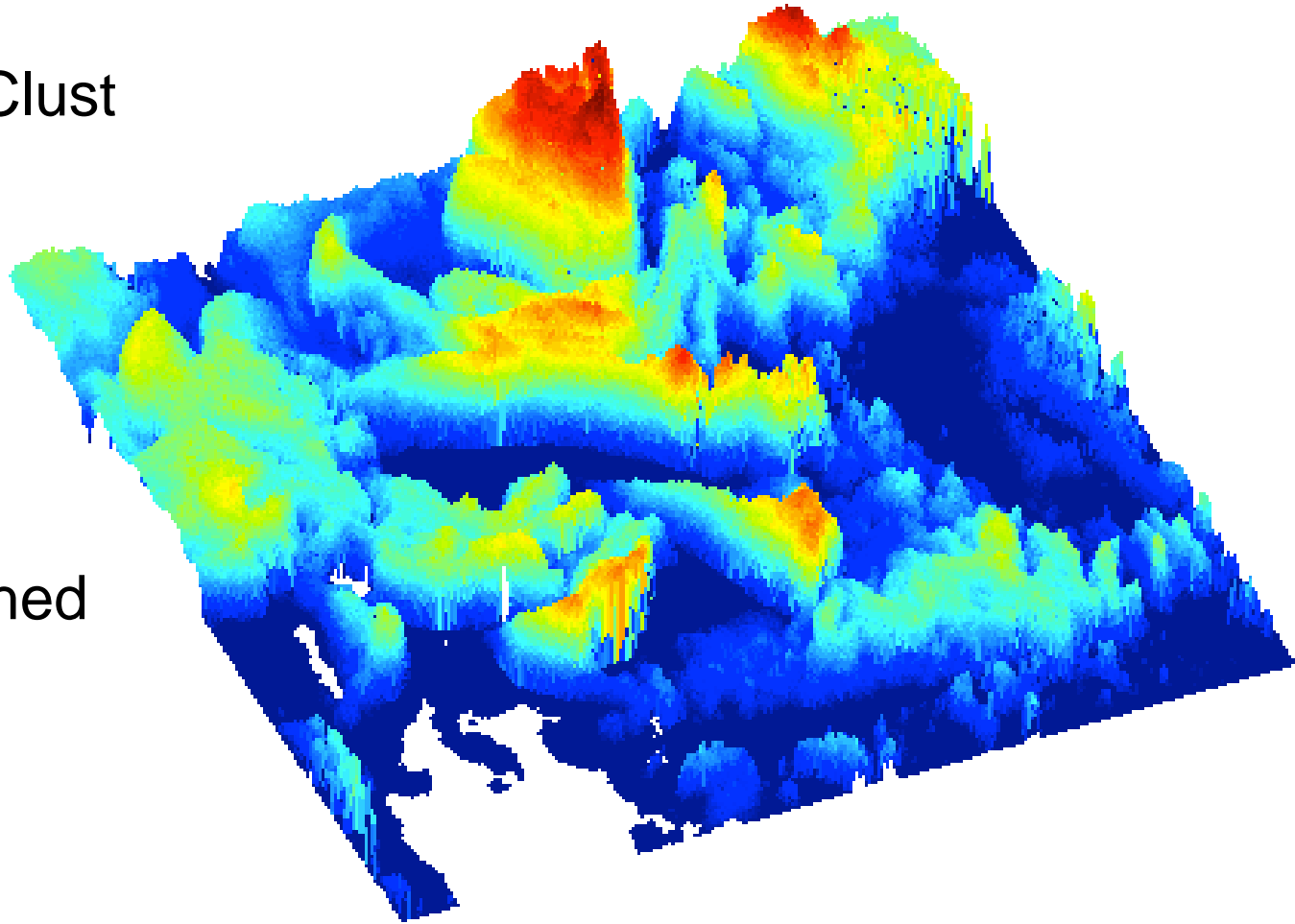


SST Gradient Ridges



Watershed Segmentation

- Segmentation/Clustering is a well studied field
- Many ways to perform segmentation
- We use watershed type applied to ΔSST



Steps of Segmentation

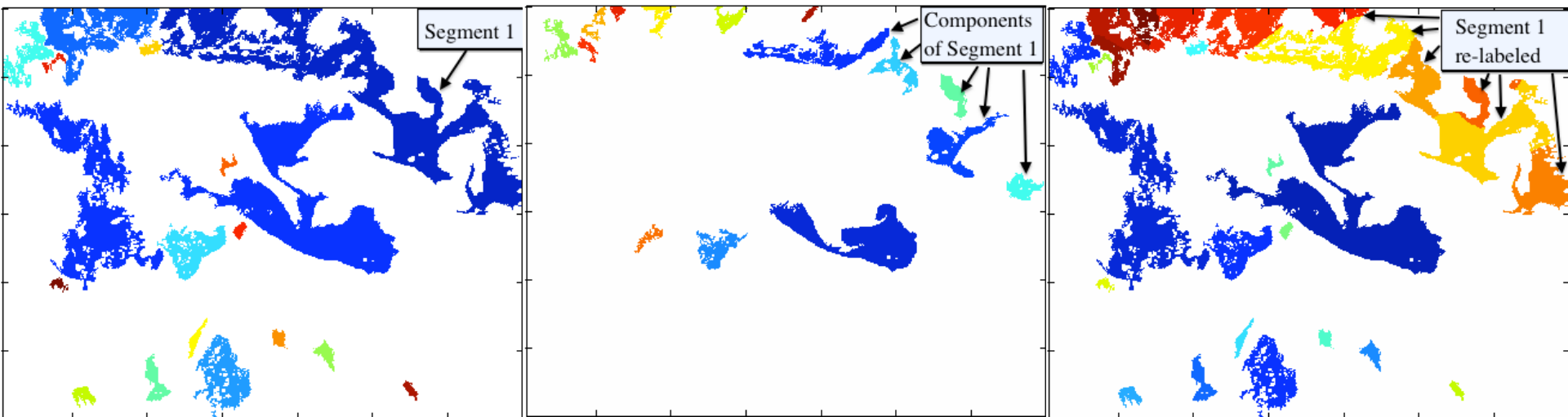
Segments obtained via iterative procedure:

Iter 0: Initial segments

Iter k: Lower the threshold level

Find new “catchment basins”

Re-label in case of split



Data Artifacts

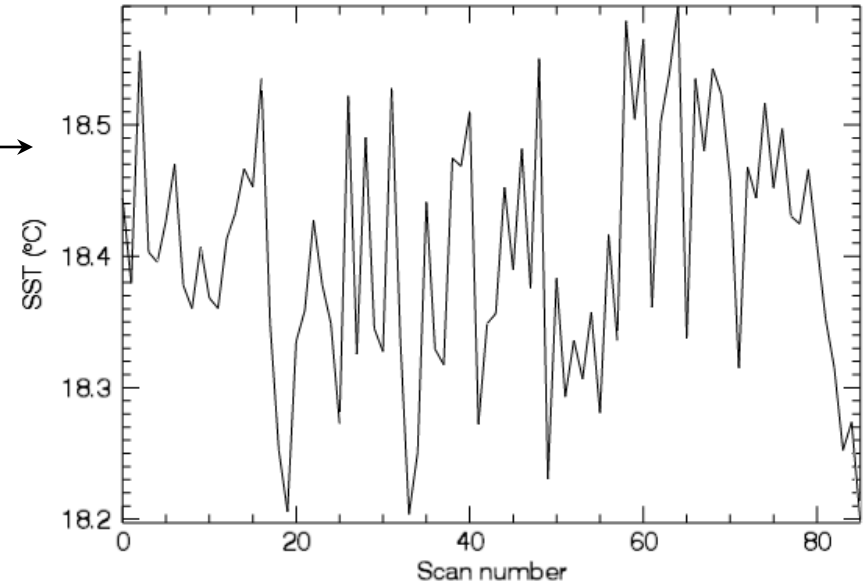
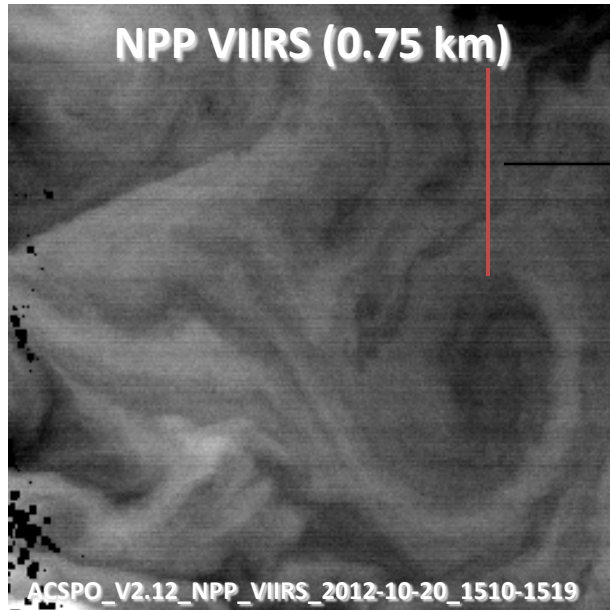
Pattern Recognition techniques assumes that the data is “clean” and free of artifacts. However, VIIRS is subject to:

- Striping
- Pixel deletion zone
- Bow-tie distortions

Destriping

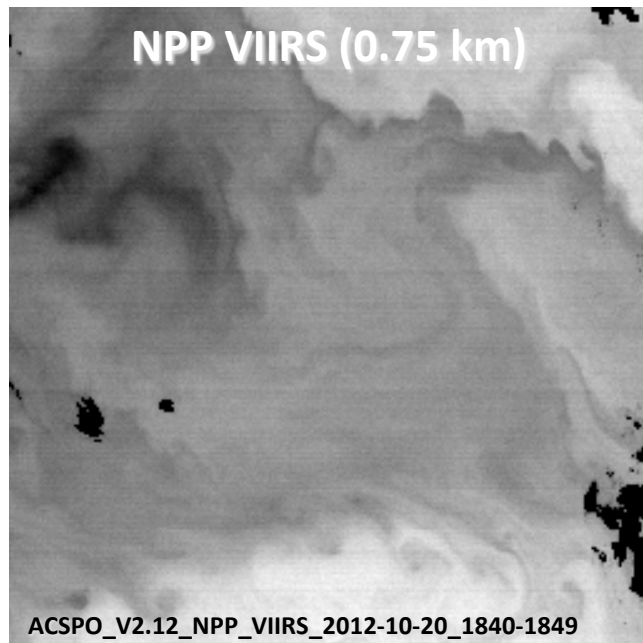
- ❑ VIIRS brightness temperatures are subject to striping due to independent characterization of it's 16 detectors and double-side mirror
- ❑ This leads to spatial discontinuities and severe artifacts in the SST gradient field rendering pattern recognition analysis unusable
- ❑ As a pre-processing step, VIIRS BT's are destriped using STAR destriping code
- ❑ The code is currently finalized for operational implementation

Accuracy of SST retrieval

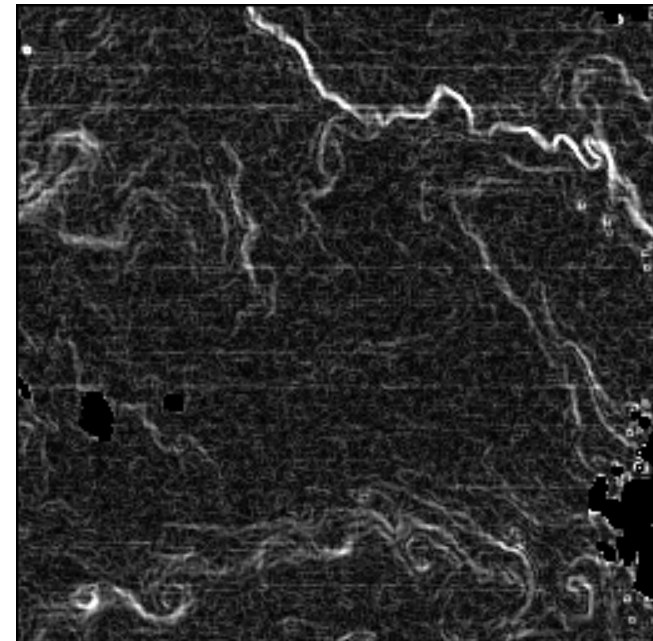


Stripe noise in level 1B or SDRs BTs
can lead to SST errors of up to $\pm 0.3K$

SST Fronts

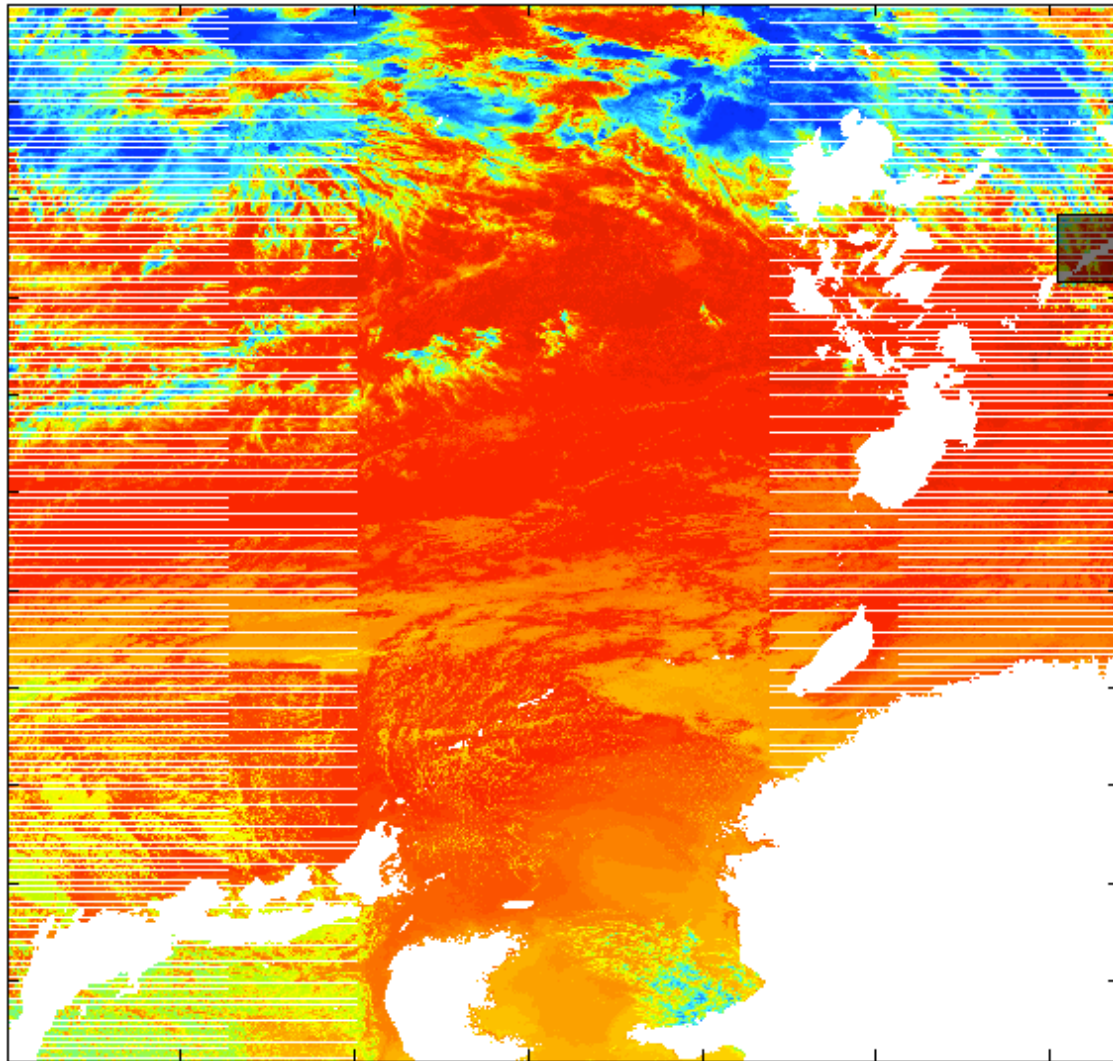


Sobel filter



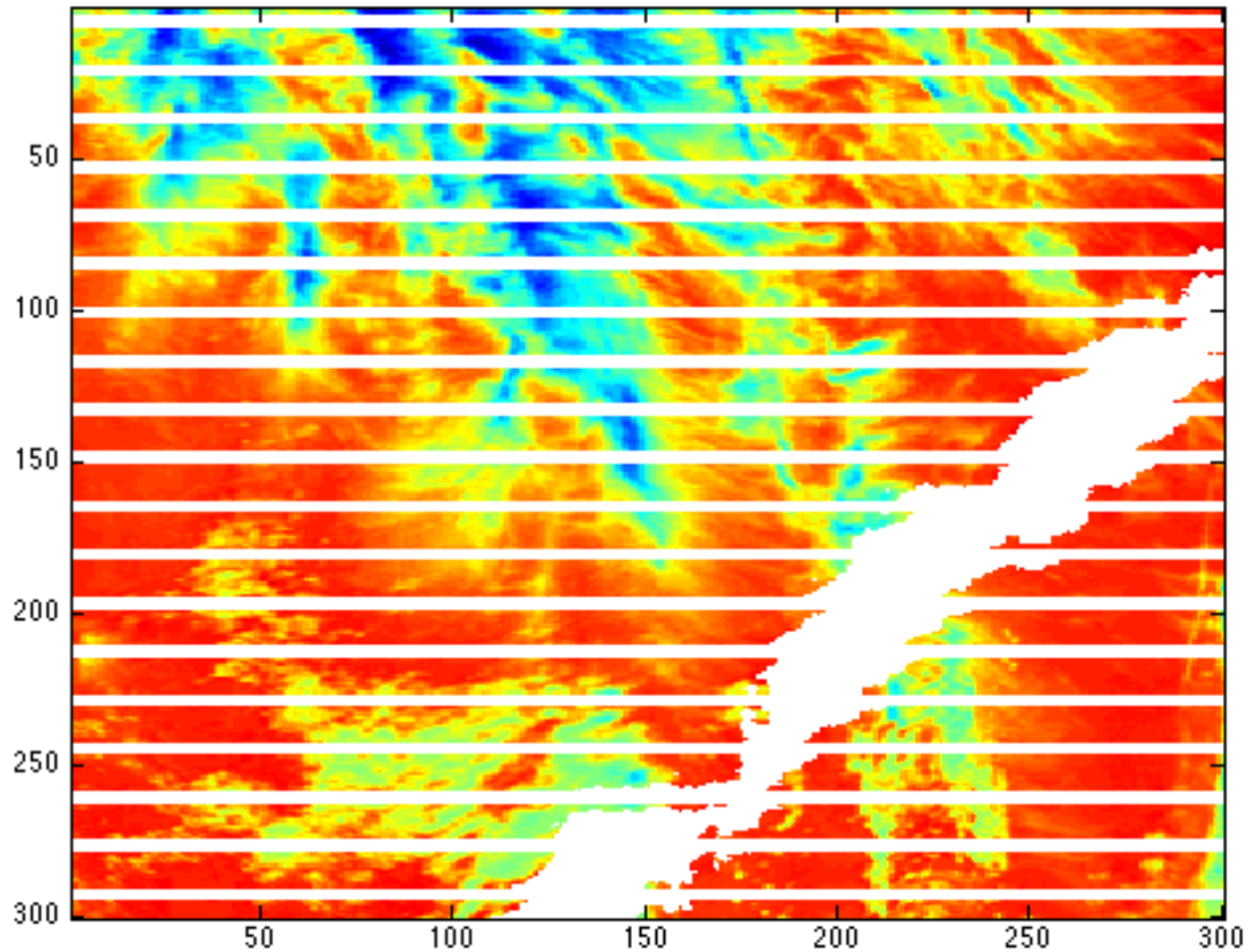
Striping introduces artificial structures and affects the analysis of thermal fronts (orientation, intensity and location)

Bow-tie area

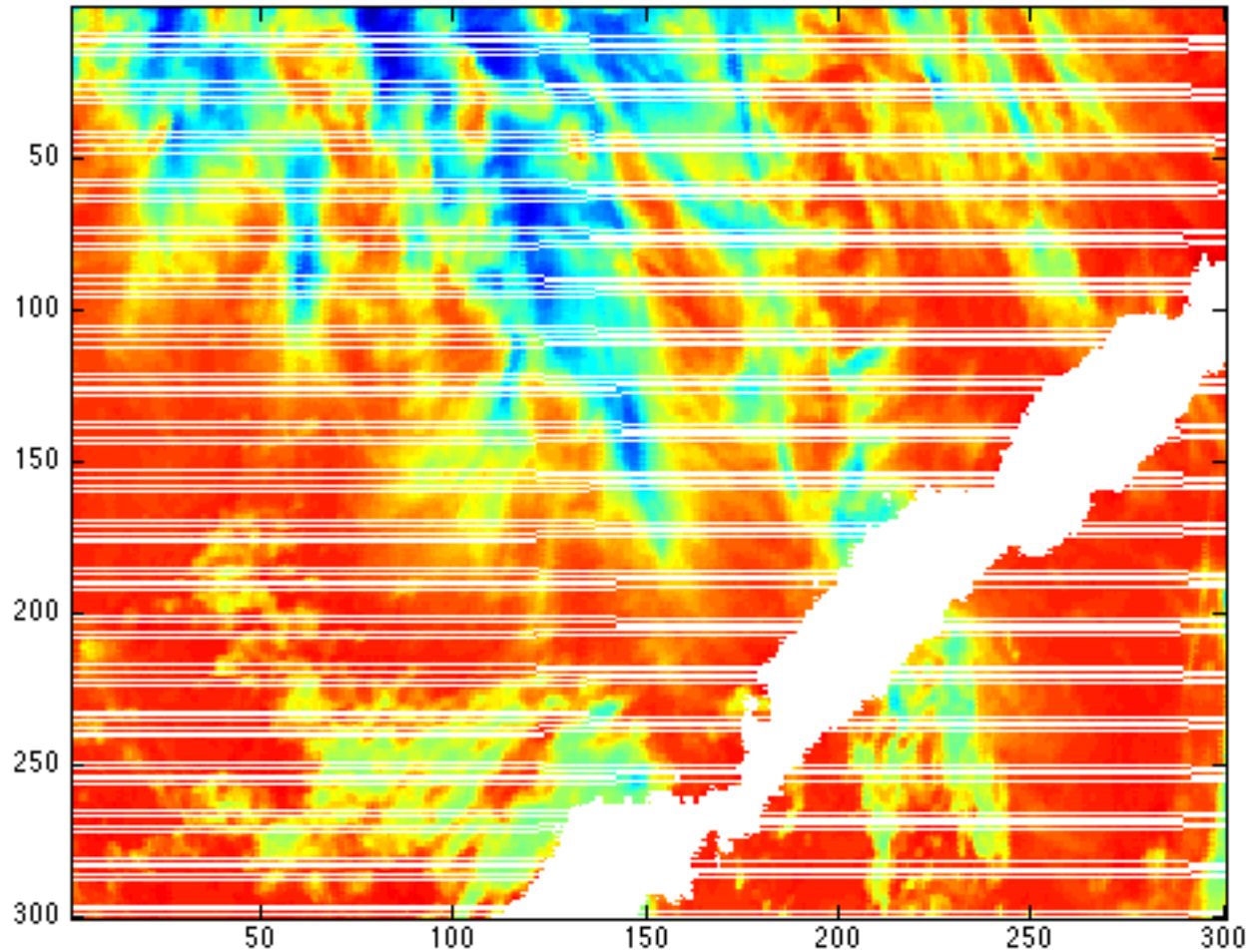


ACSPO_V2.20_NPP_VIIRS_2013-02-16_0430-0440_20130219.232756.nc

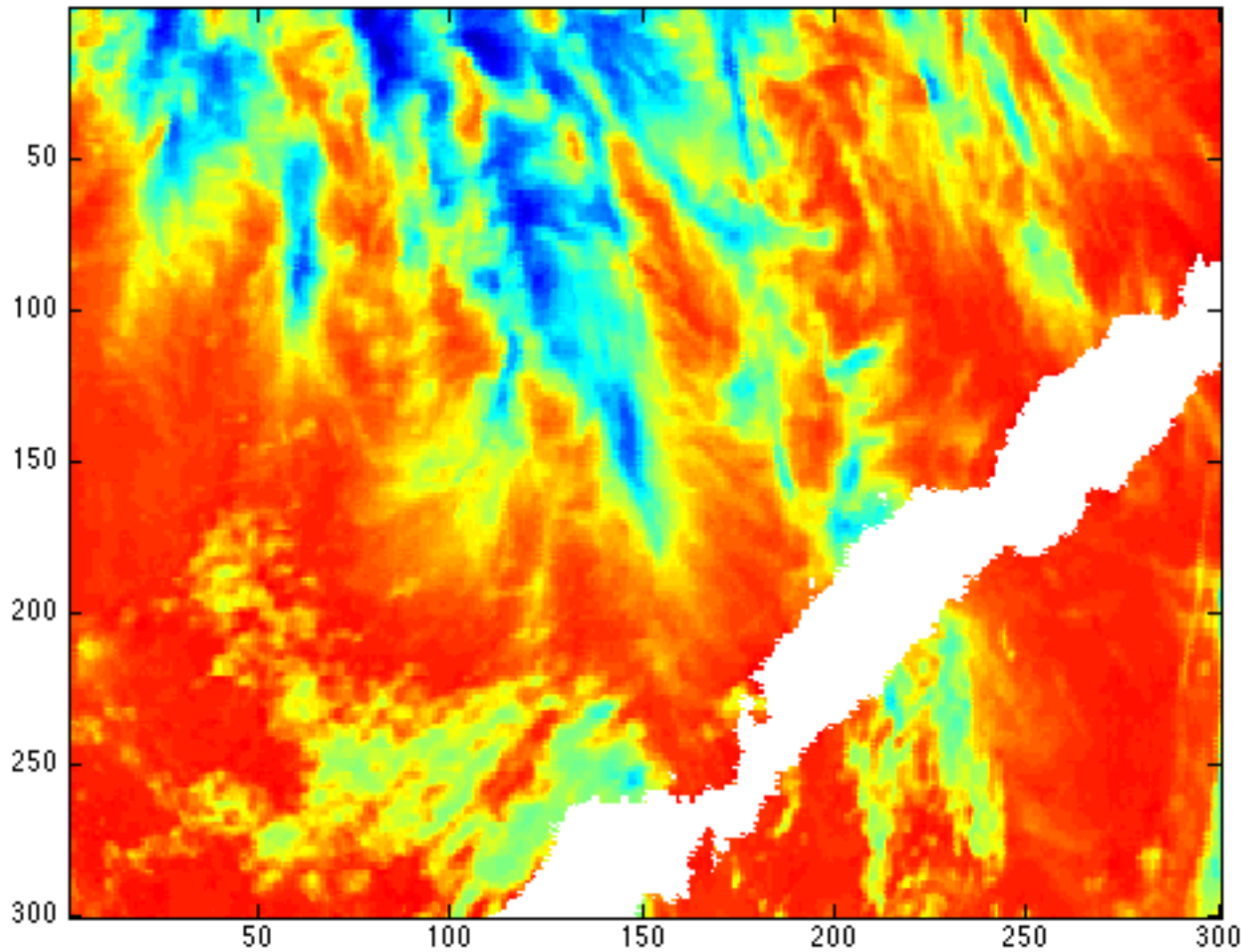
Original SST values



With Monotonic Latitudes



Resampled

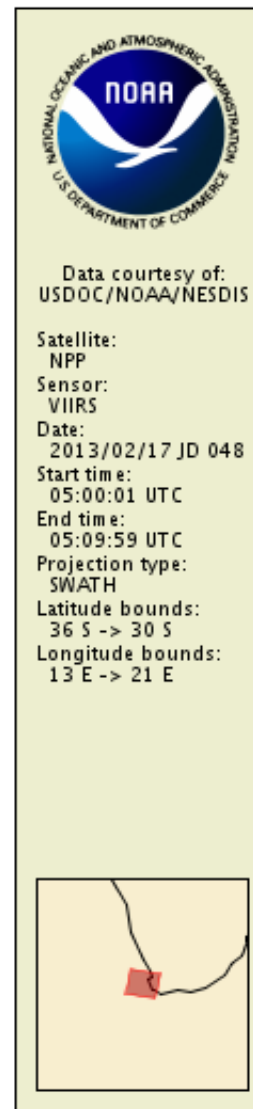
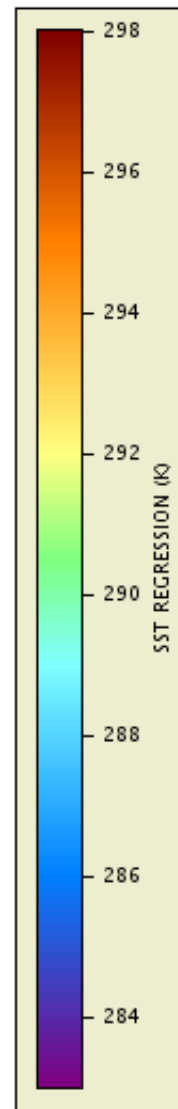
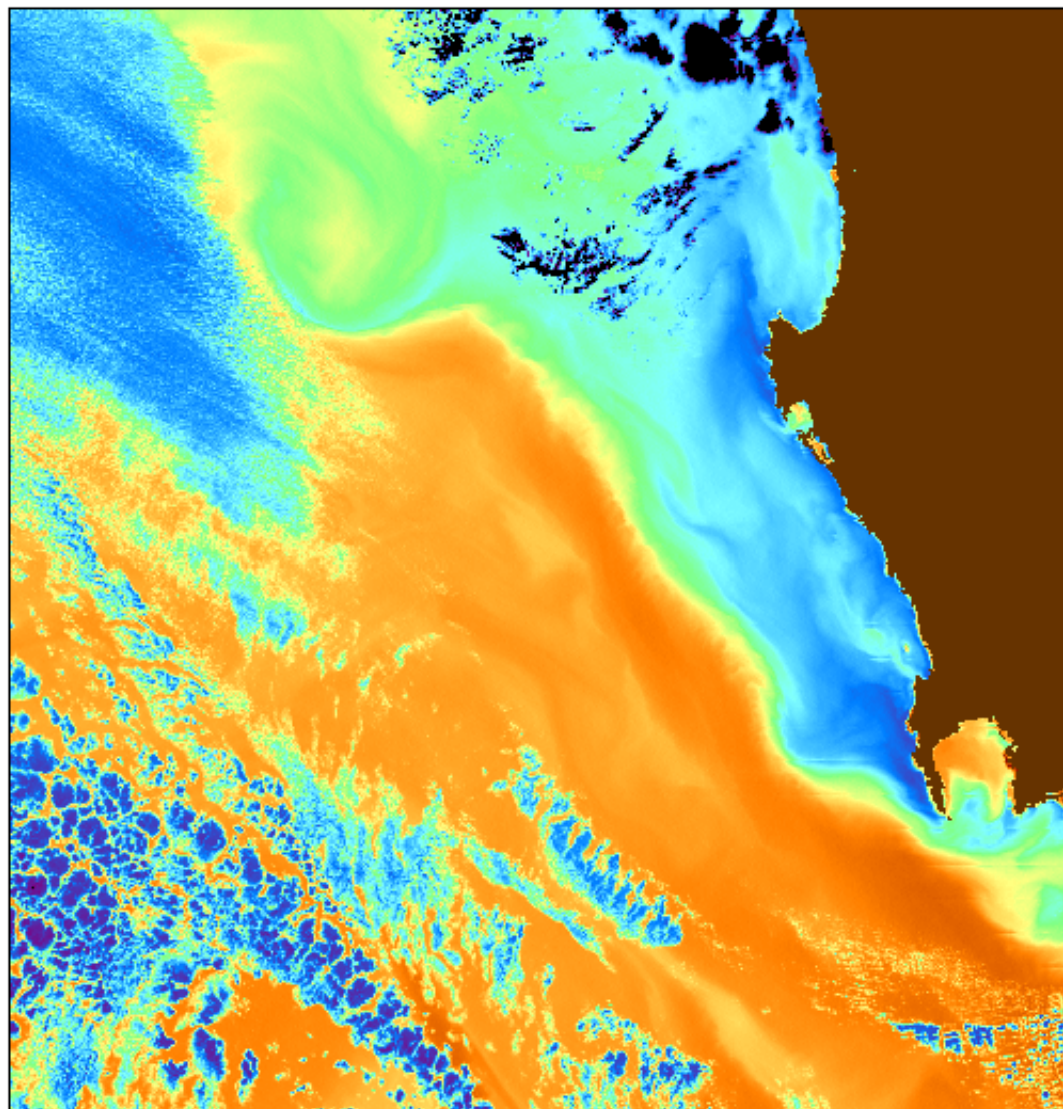


Considered 2 sets of VIIRS data:

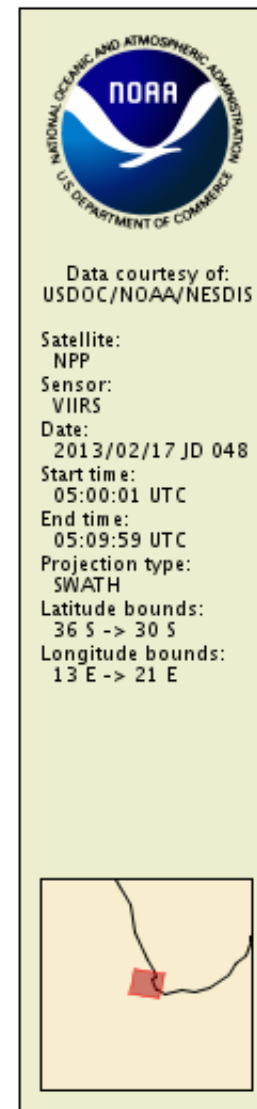
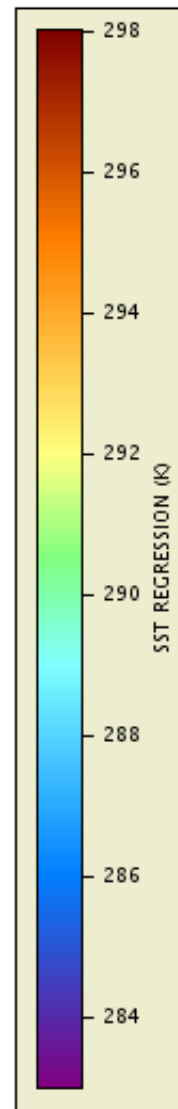
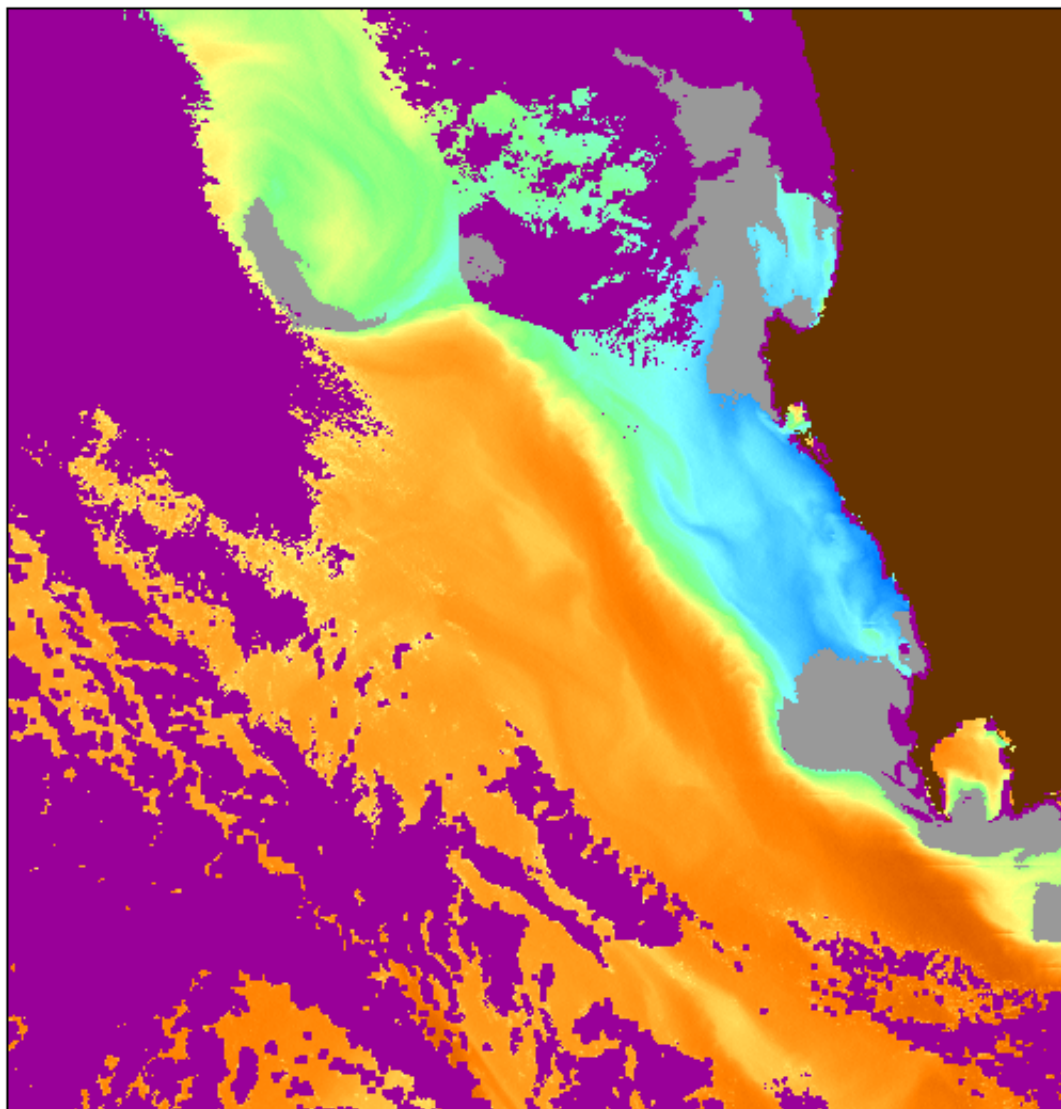
- 48 hand picked and cropped regions with typical clear sky misclassification
- 144 granules representing 1 day global observations

Results were visually inspected and analyzed;
Success rate is promising but more work is needed.

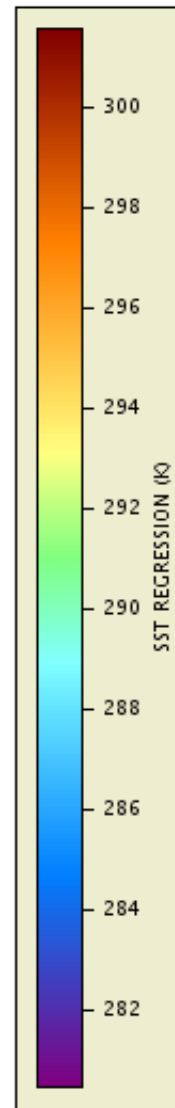
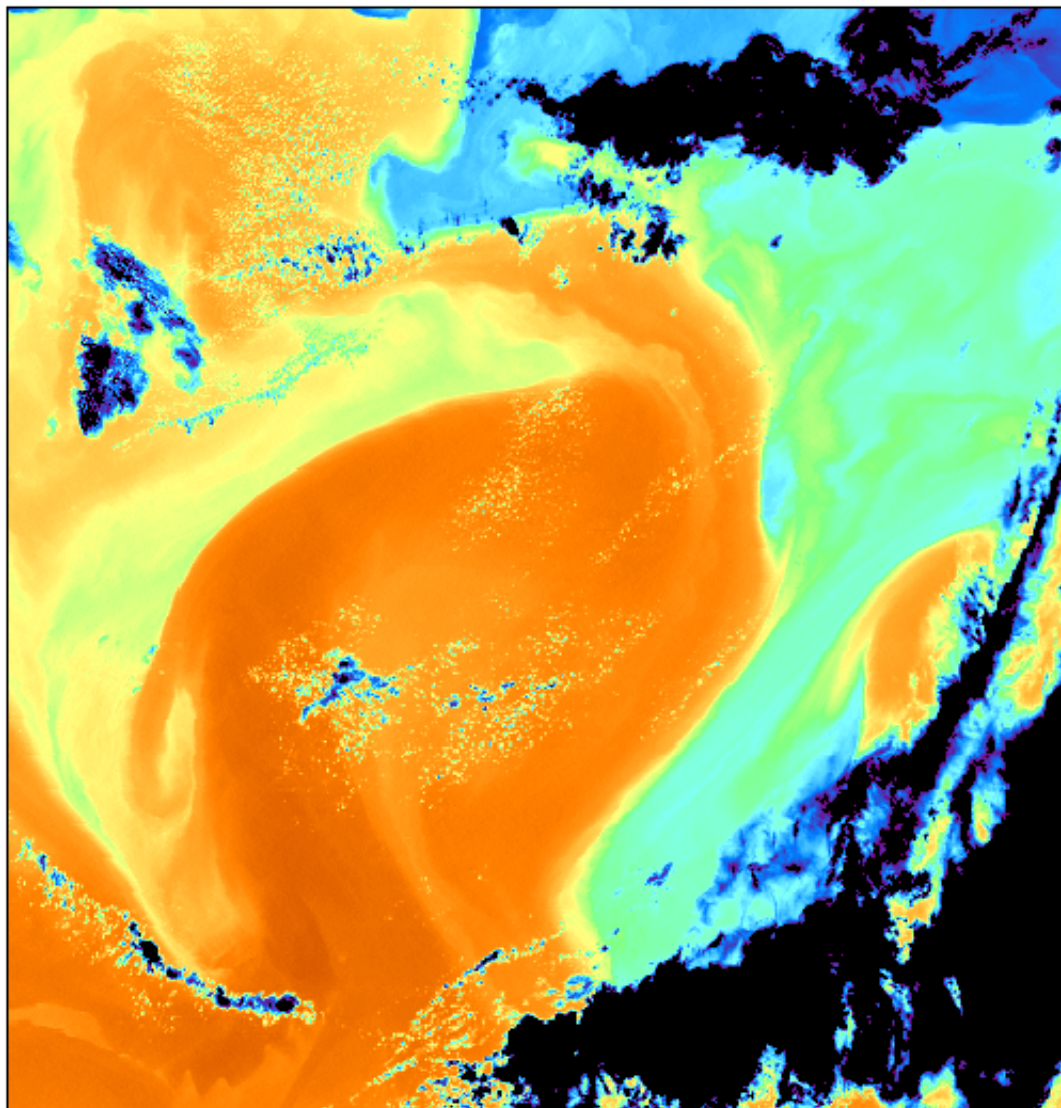

South Africa, 02/17/13 (night)



South Africa, 02/17/13 (night)



Gulf Stream, 05/10/13 (day)

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

Data courtesy of:
USDOC/NOAA/NESDIS

Satellite:
NPP

Sensor:
VIIRS

Date:
2013/05/10 JD 130


Start time:
21:10:00 UTC

End time:
21:19:59 UTC

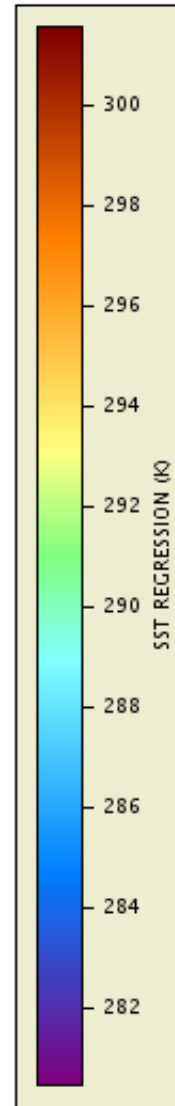
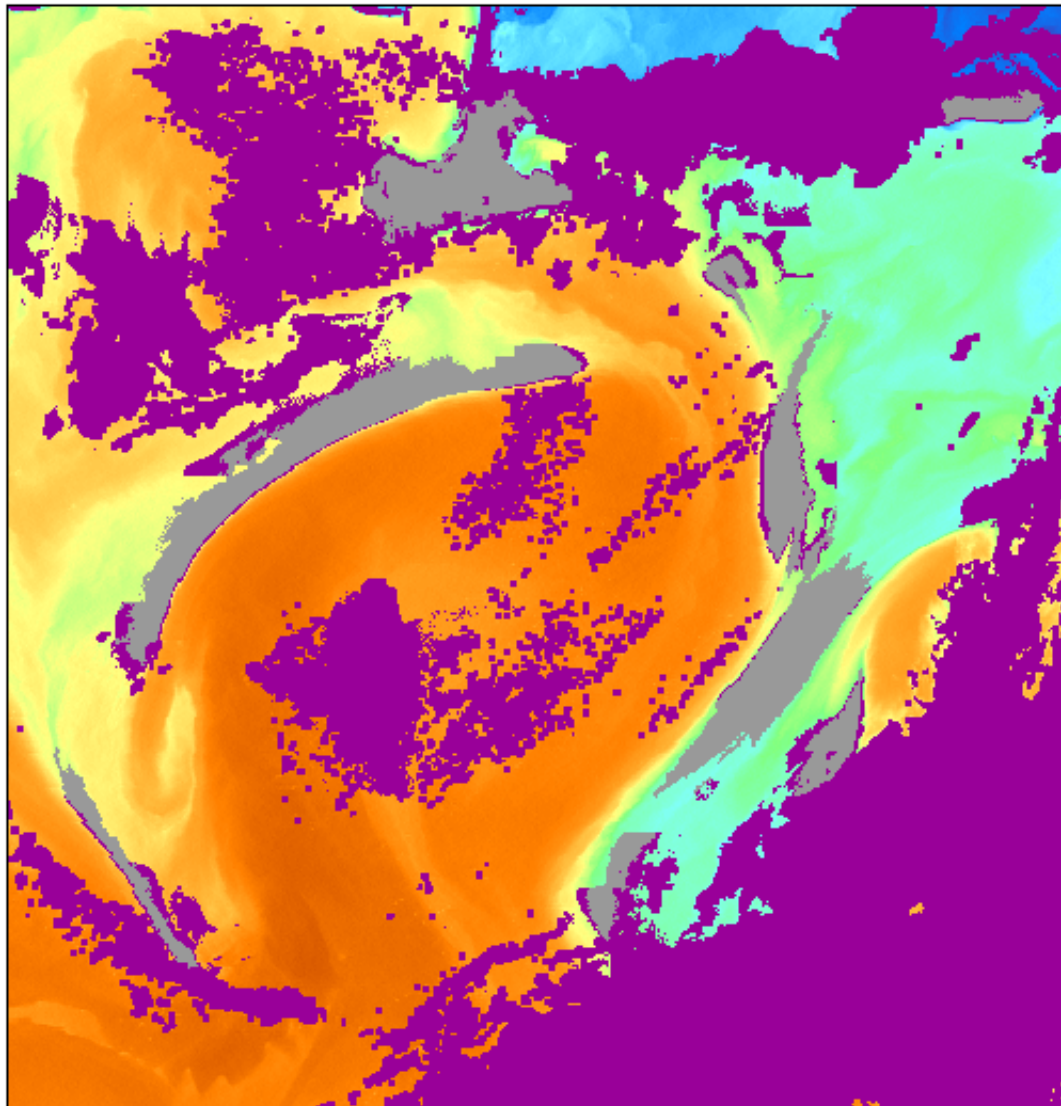

Projection type:
SWATH

Latitude bounds:
36 N -> 42 N

Longitude bounds:
70 W -> 63 W



Gulf Stream, 05/10/13 (day)

Data courtesy of:
USDOC/NOAA/NESDIS

Satellite:
NPP

Sensor:
VIIRS

Date:
2013/05/10 JD 130


Start time:
21:10:00 UTC

End time:
21:19:59 UTC

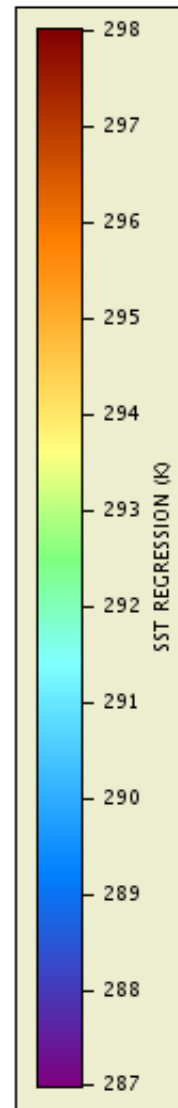
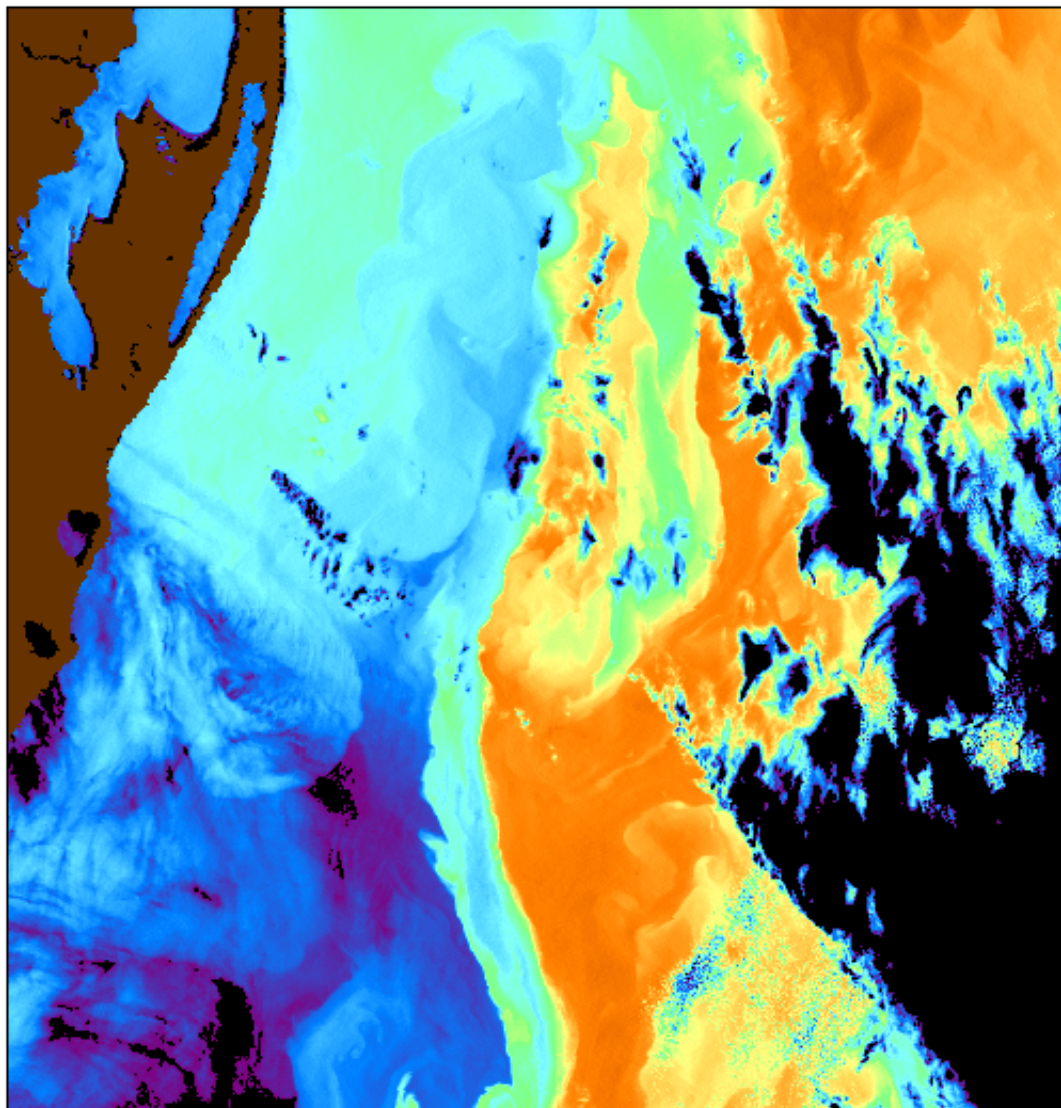

Projection type:
SWATH

Latitude bounds:
36 N -> 42 N

Longitude bounds:
70 W -> 63 W



Uruguay, 05/05/13 (night)

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

Data courtesy of:
USDOC/NOAA/NESDIS

Satellite:
NPP

Sensor:
VIIRS

Date:
2013/05/10 JD 130


Start time:
08:30:00 UTC

End time:
08:40:00 UTC

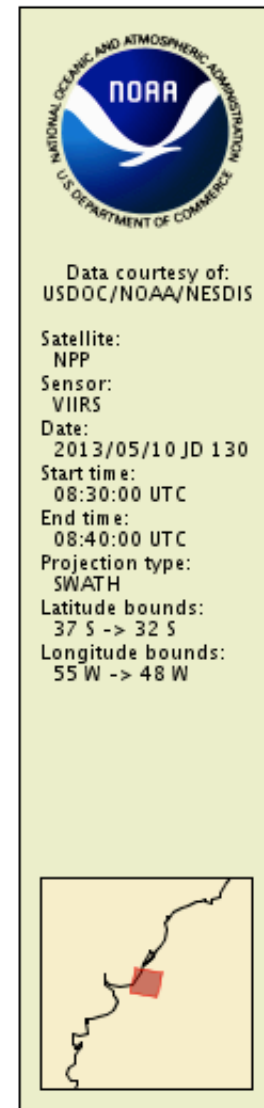
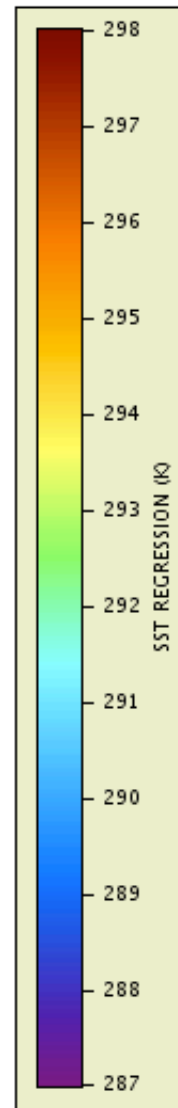
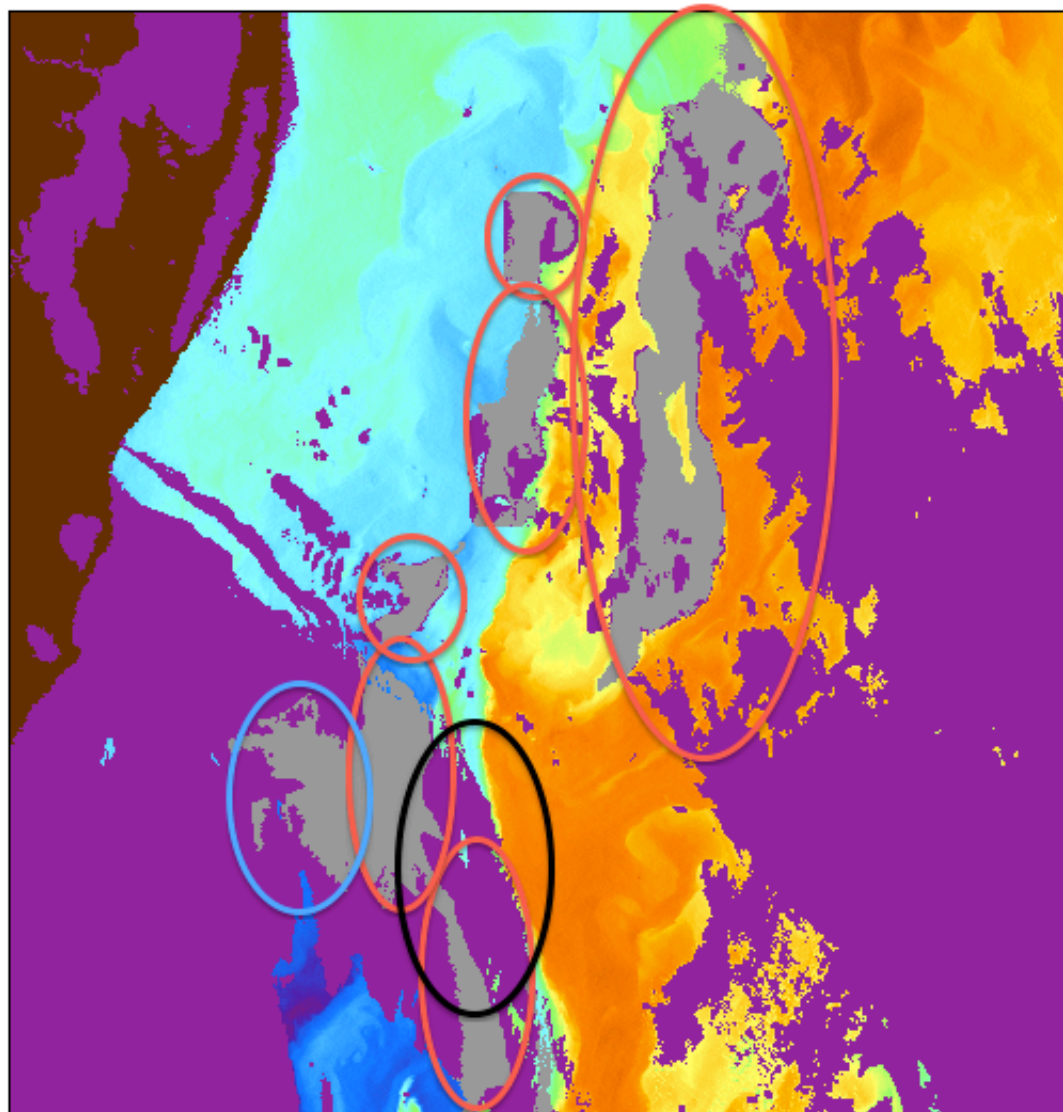
Projection type:
SWATH

Latitude bounds:
37 S -> 32 S

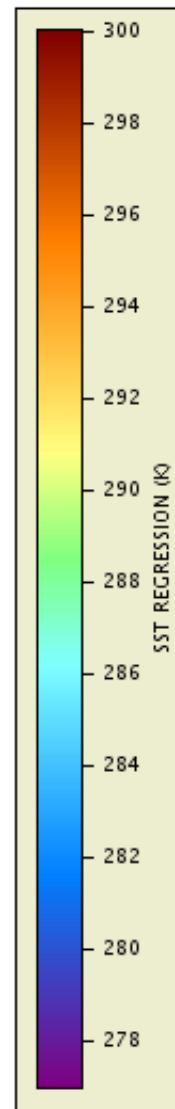
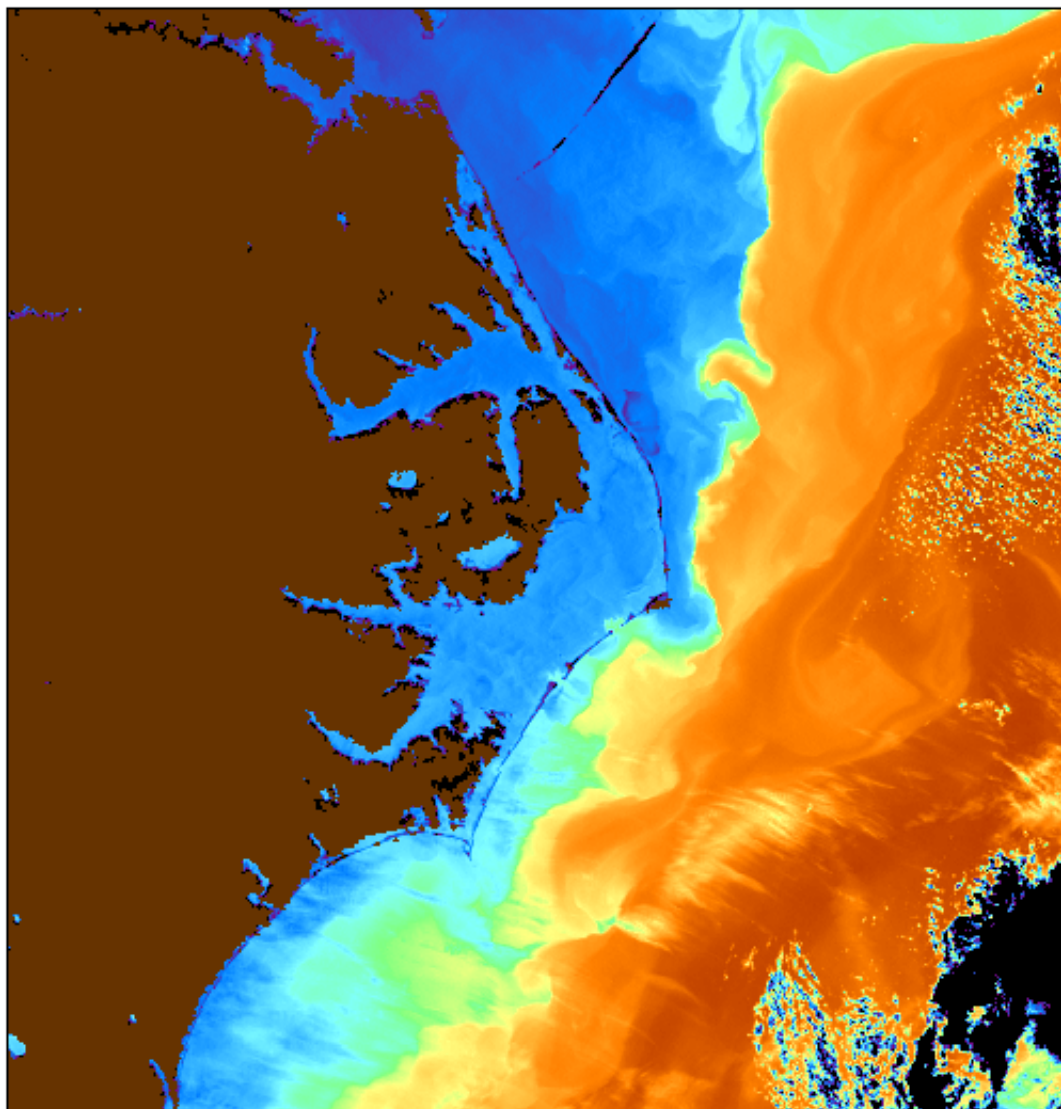

Longitude bounds:
55 W -> 48 W



Uruguay, 05/05/13 (night)



Pamlico Sound, 02/16/13 (night)

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

Data courtesy of:
USDOC/NOAA/NESDIS

Satellite:
NPP

Sensor:
VIIRS

Date:
2013/02/16 JD 047


Start time:
11:50:00 UTC

End time:
12:00:00 UTC

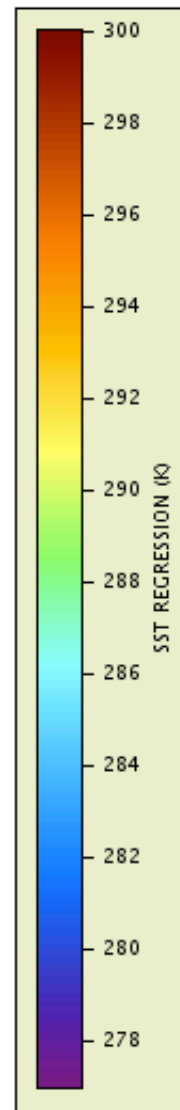
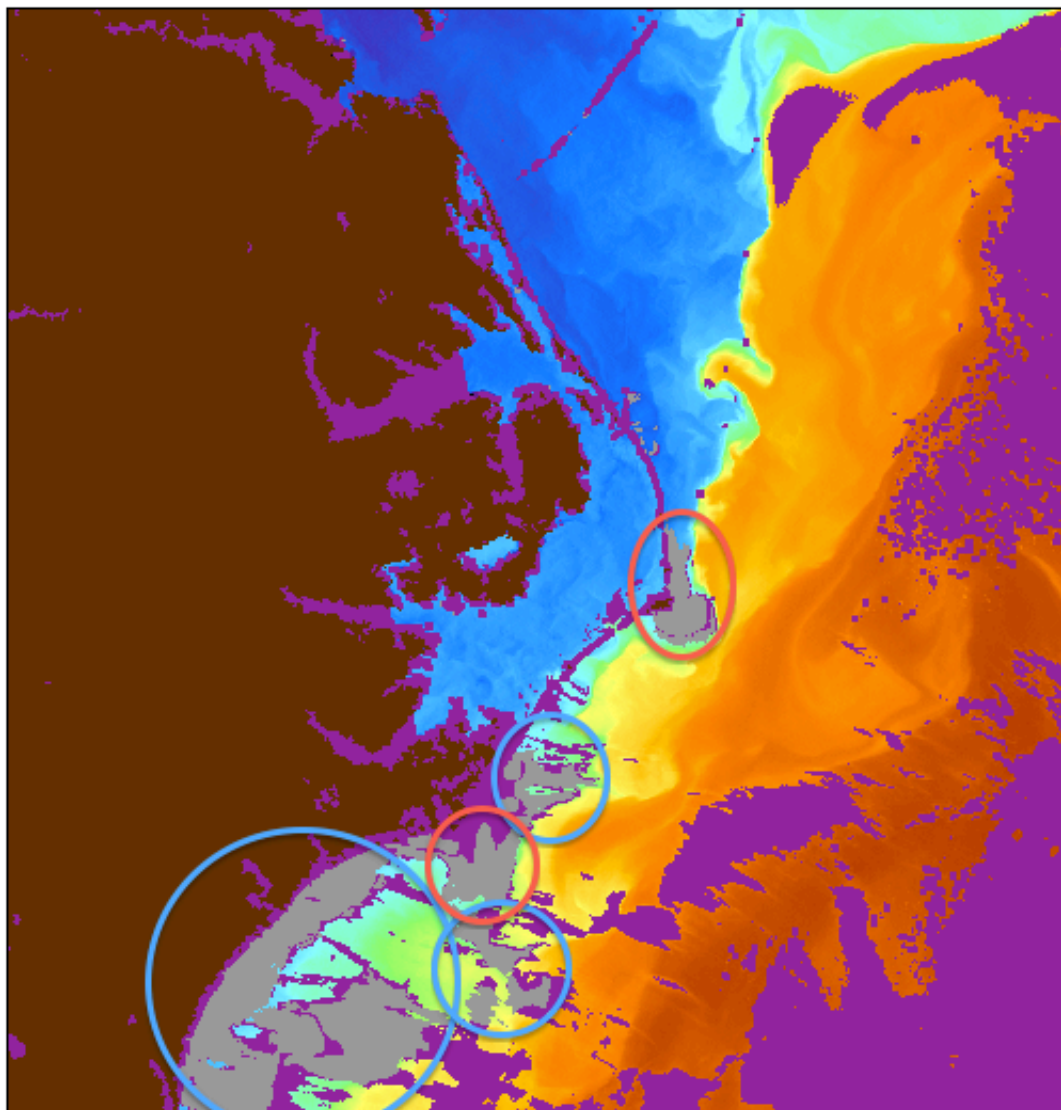

Projection type:
SWATH

Latitude bounds:
32 N -> 38 N

Longitude bounds:
79 W -> 72 W



Pamlico Sound, 02/16/13 (night)

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

Data courtesy of:
USDOC/NOAA/NESDIS

Satellite:
NPP

Sensor:
VIIRS

Date:
2013/02/16 JD 047


Start time:
11:50:00 UTC

End time:
12:00:00 UTC

Projection type:
SWATH

Latitude bounds:
32 N -> 38 N

Longitude bounds:
79 W -> 72 W



Future Work

- ☐ The algorithm presented here was initially designed as a supplementary step to the existing ACSPO Clear-Sky Mask
- ☐ We will consider redesigning the current ACSM, based on the new pattern recognition principles
- ☐ It will be first implemented and extensively tested with the VIIRS SSTs, and later extended to also include AVHRR and MODIS data
- ☐ We will also consider generating an ocean front product at the stage of cloud masking, and outputting in the SST files, as an additional layer