Thermal uniformity analysis of SST data fields

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Introduction

- SST Uniformity fields:
  - ➔ NAVOCEANO Daytime VIIRS SST
  - ➔ NOAA ACSPO Daytime VIIRS SST
- NAVOCEANO Thermal Uniformity test:
  - ➔ Coherence of thermal gradient field
  - ➔ Correlation temperature/reflectance
- Modification of SST equations
- Evaluation, orbital overlap/buoy match-ups

SST Uniformity field

- Thermal Uniformity test included in NAVOCEANO SST Processing.
- Defined as difference between Max and Min in neighborhoods:
    - 2x2 pixels for SST processing with a 0.4°K threshold.
    - 3x3 pixels for Uniformity field

SST Uniformity field

- Thermal Uniformity test avoids contamination but also partially removes fronts
- Example: SST Uniformity fields on January 16, 2016 for the Gulf of Mexico,
  - Figure 1: NAVOCEANO SST
  - Figure 2: NOAA ACSPO SST
  - Note that in this example, ACSPO destriping step reduces the intrinsic noise.

SST Uniformity field

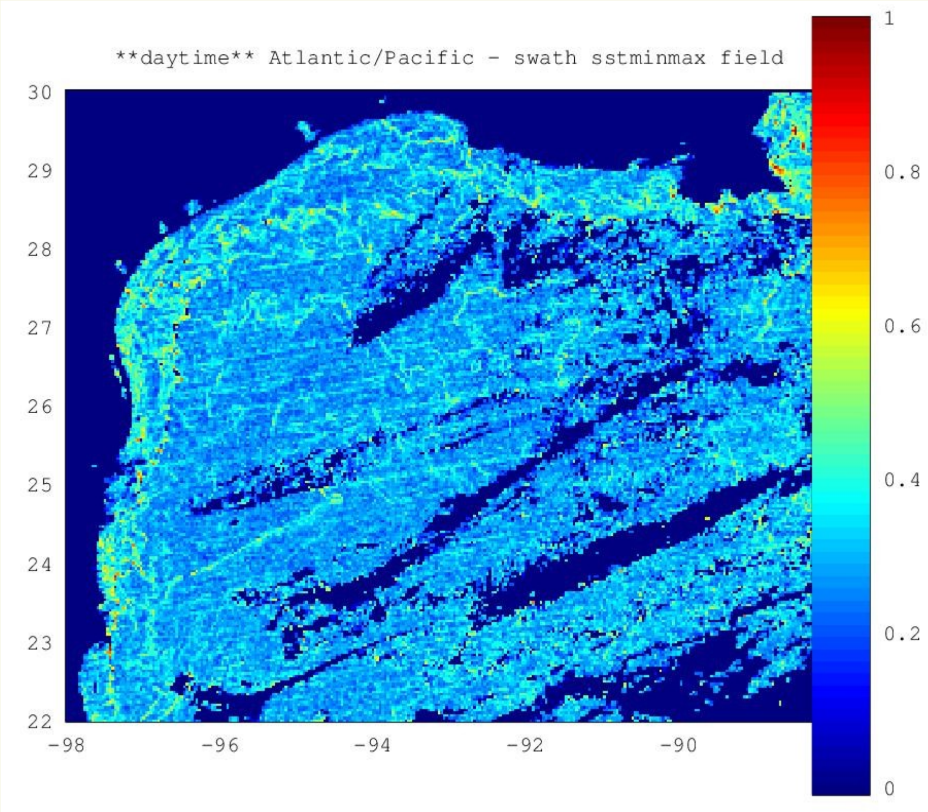


Figure 1: NAVOCEANO SST Uniformity

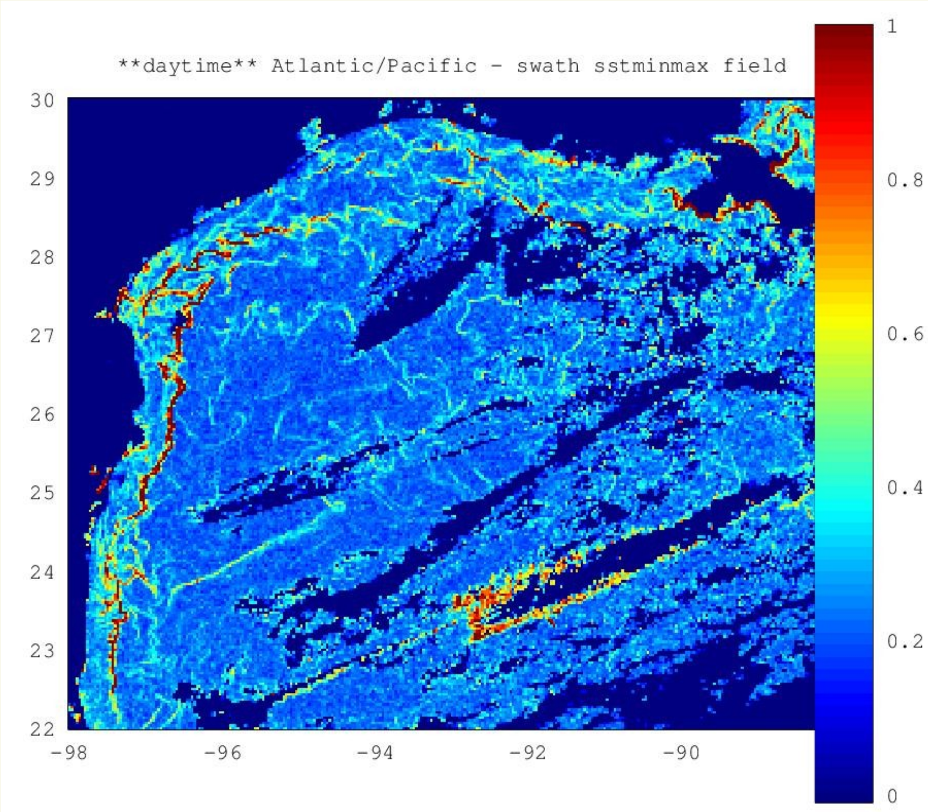
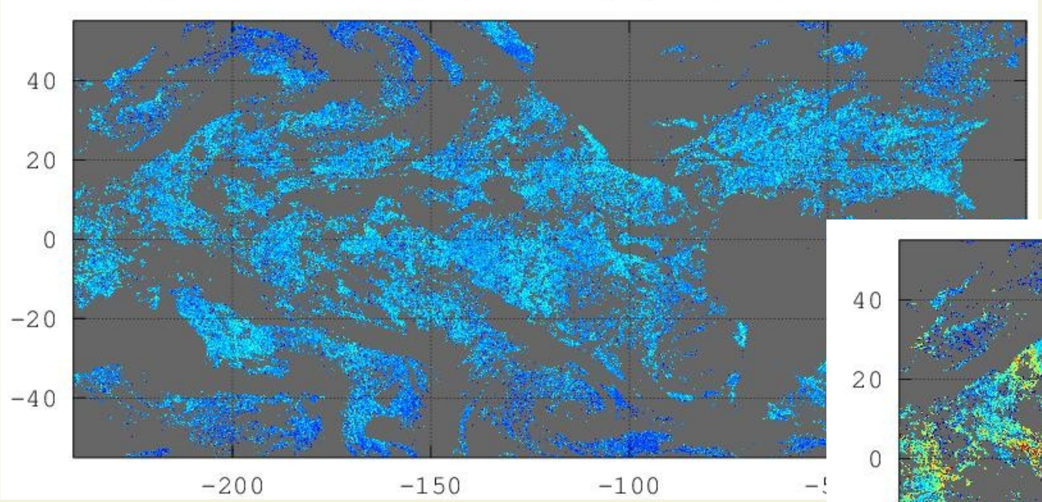


Figure 2: ACSPO SST Uniformity

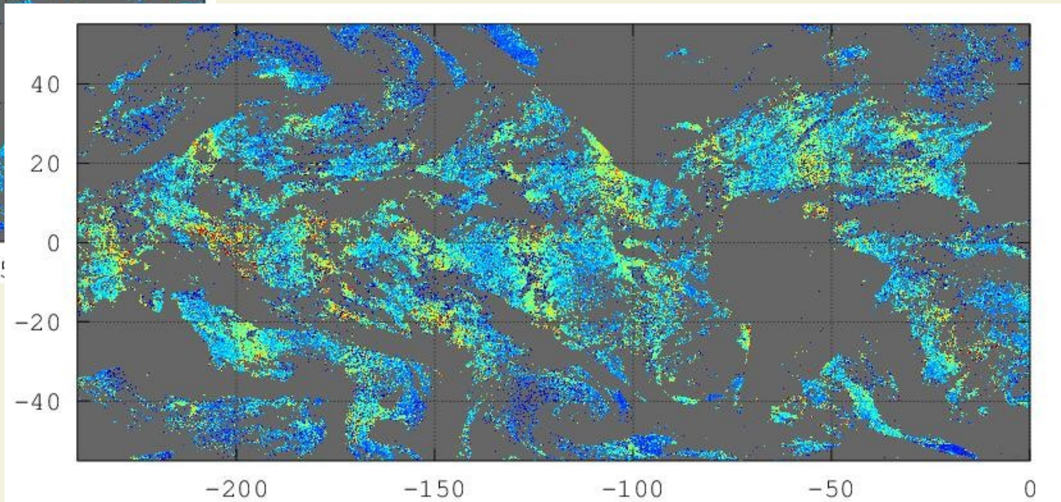
SST Uniformity field

- Global SST uniformity fields show pattern corresponding to VIIRS aggregation scheme.



July 14, 2014

NAVOCEANO



ACSPO

Revised Uniformity Test

Recovery of Frontal Region

- Thermal Uniformity test on 3x3 pixel neighborhoods with 0.4°K threshold
- **When T3max – T3min > 0.4°K**
  with T3max/T3min being the maximum/minimum temperature in the 3x3 pixel window
- ➔Coherence of thermal gradient vector field
  ➔Correlation between temperature and reflectance field

Revised Uniformity Test

Coherence of thermal gradient vector field

- Differentiate between random variability of non-front regions and the more orderly vector field associated with fronts:

W is a 9x9 pixel window and (x,y) ∈ W

$$\text{coherence} = \frac{\| \, \text{mean}_w(\overrightarrow{\boldsymbol{grad}}(x,y)) \, \|}{\| \, \text{mean}_w(\, | \overrightarrow{\boldsymbol{grad}}(x,y) | \,) \, \|}$$

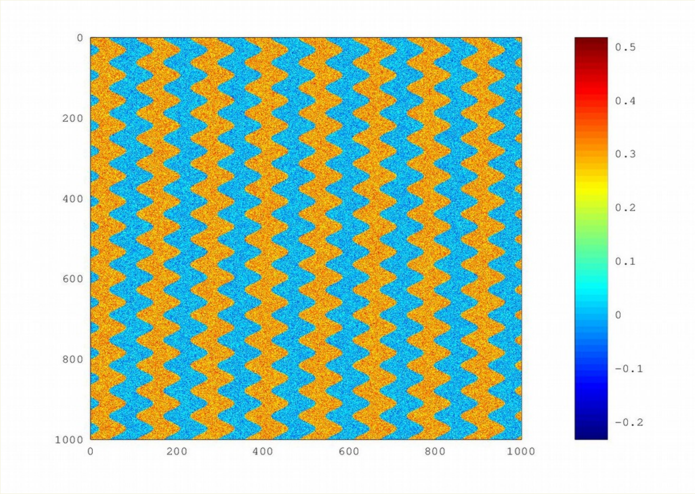
coherence ➡ 1 for uniform gradient distribution which leads to the following rule:

coherence < *f* ⇒ not a front (cloud)
Where *f* is a threshold to be determined

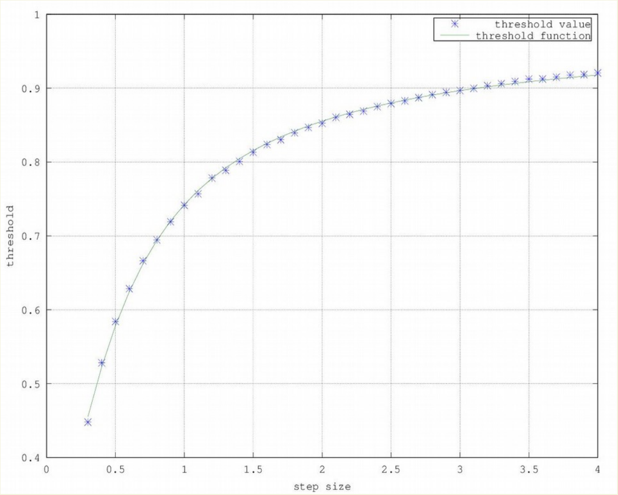
Revised Uniformity Test

Coherence of thermal gradient vector field

- In noise free environment, *f* can be selected as a constant.
- Synthetic fields help explore the dependence of *f* on front strength. The fields are made of repeating step functions (idealized fronts) to which Gaussian noise is added.
  - Step sizes vary from 0.3°K to 4°K
  - Standard deviation of noise is set 0.05°K
  - Probability of correct front detection is set at 95 percent



Example of synthetic field

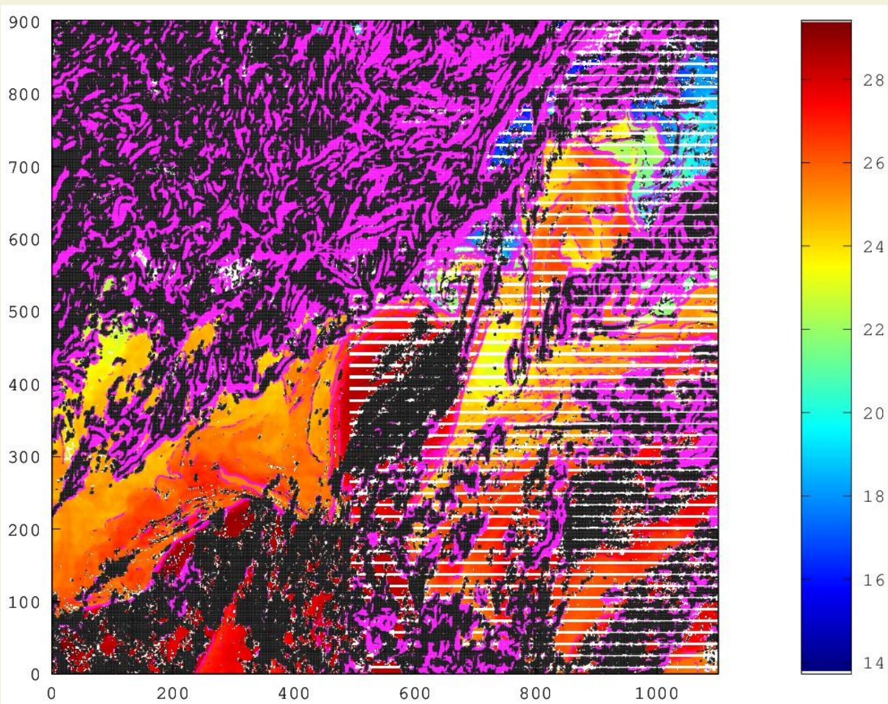


f as function of front strength

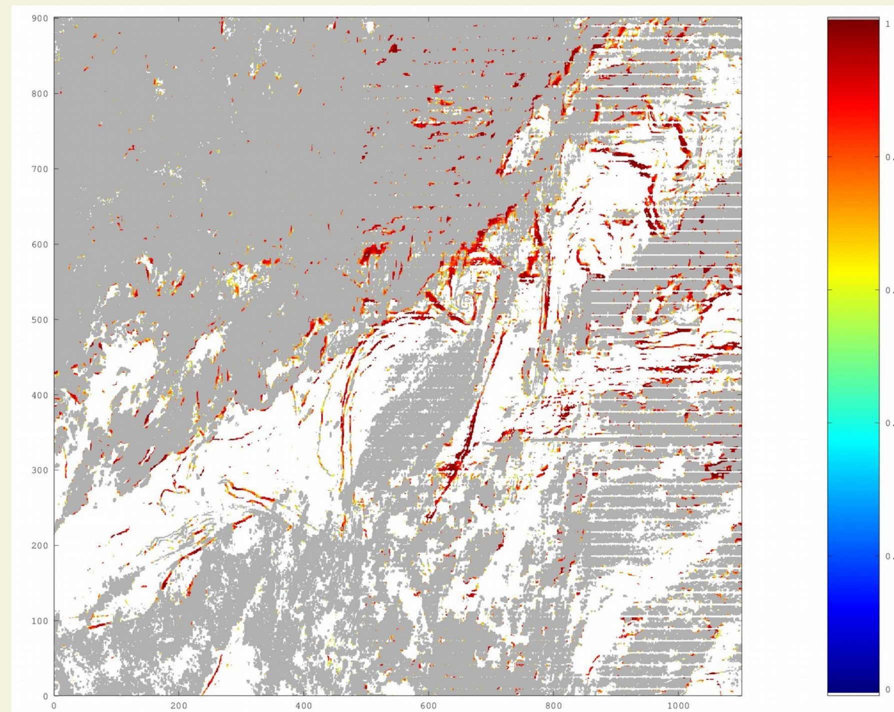
Revised Uniformity Test

Coherence of thermal gradient vector field

- Result of using fixed and variable thresholds



Fixed threshold (0.5): Frontal regions that passed are in magenta.



Variable threshold: Frontal regions that passed are in color.

Revised Uniformity Test

Correlation of the thermal and reflective fields

- Performed when T3max – T3min > 0.4°K
- Correlation between:
  - brightness temperature at 10.763um (VIIRS M15) – *bt*
  - reflectance at 0.865um (VIIRS M7) - *r*

$$\mathrm{corr}(bt, r) = \frac{\mathrm{cov}(bt, r)}{\mathrm{stdev}(bt) * \mathrm{stdev}(r)}$$

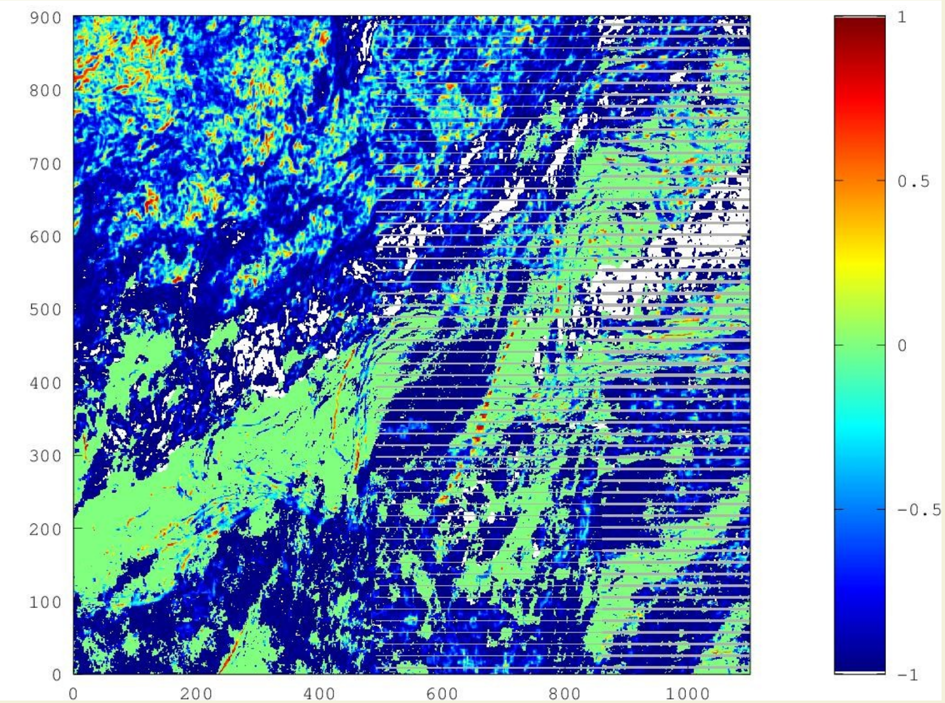
- Correlation is based on 7x7 pixel windows
- Negative correlation indicates cloud contamination leads to following decision rule:

$$\mathrm{corr}(bt, r) < -0.6 \Rightarrow \text{not a front (cloud)}$$

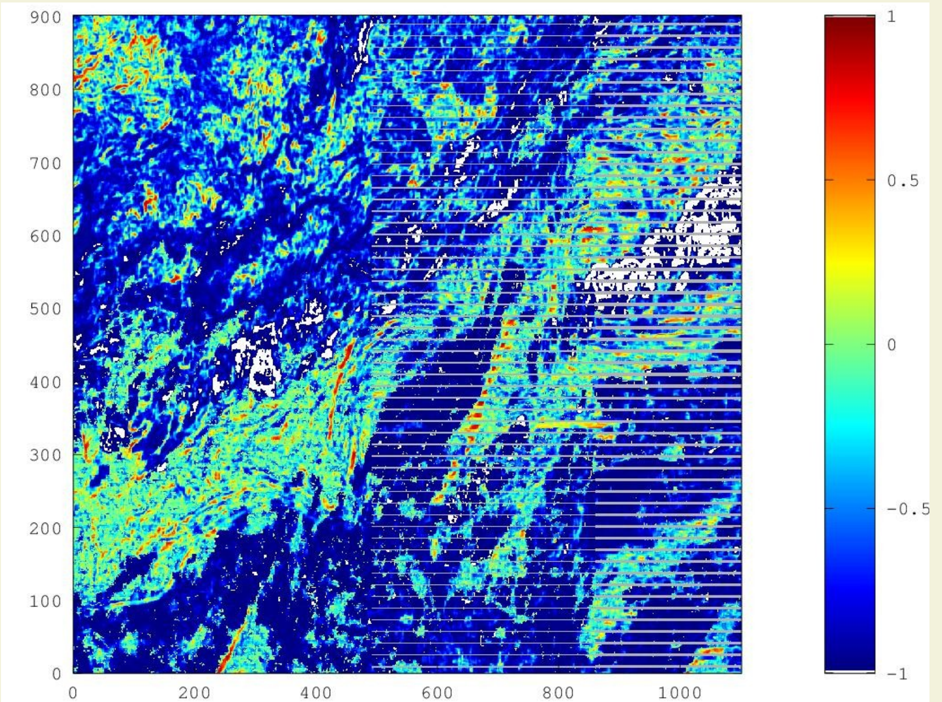
Revised Uniformity Test

SST versus Brightness temperature

- Thermal uniformity and associated tests operate on Brightness Temperature. Using SST produces noisier results:



Correlation of the brightness temperature and reflectance fields.
Orbital overlap std=0.34°K



Correlation of the SST and reflectance fields.
Orbital overlap std=0.37°K

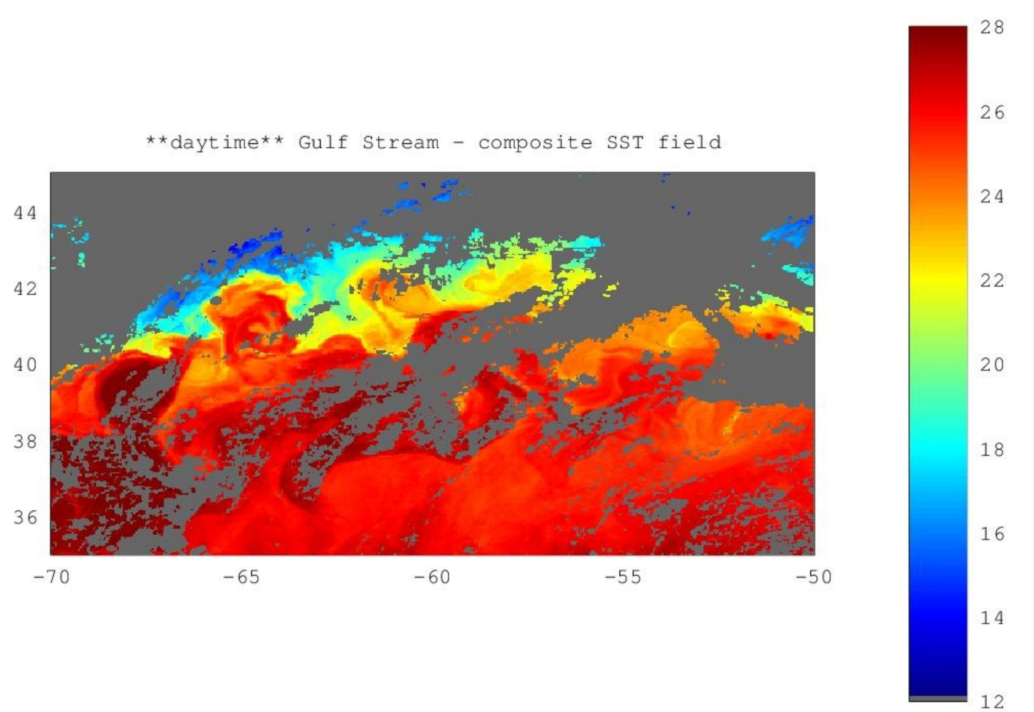
Revisited SST calculations

- The daytime NLSST or MCSST equations have the form:

$$SST = a * T_{11} + b * (T_{11} - T_{12}) \text{ where,}$$

a ~ 1 and b ~ 2.5 are semi constant variables

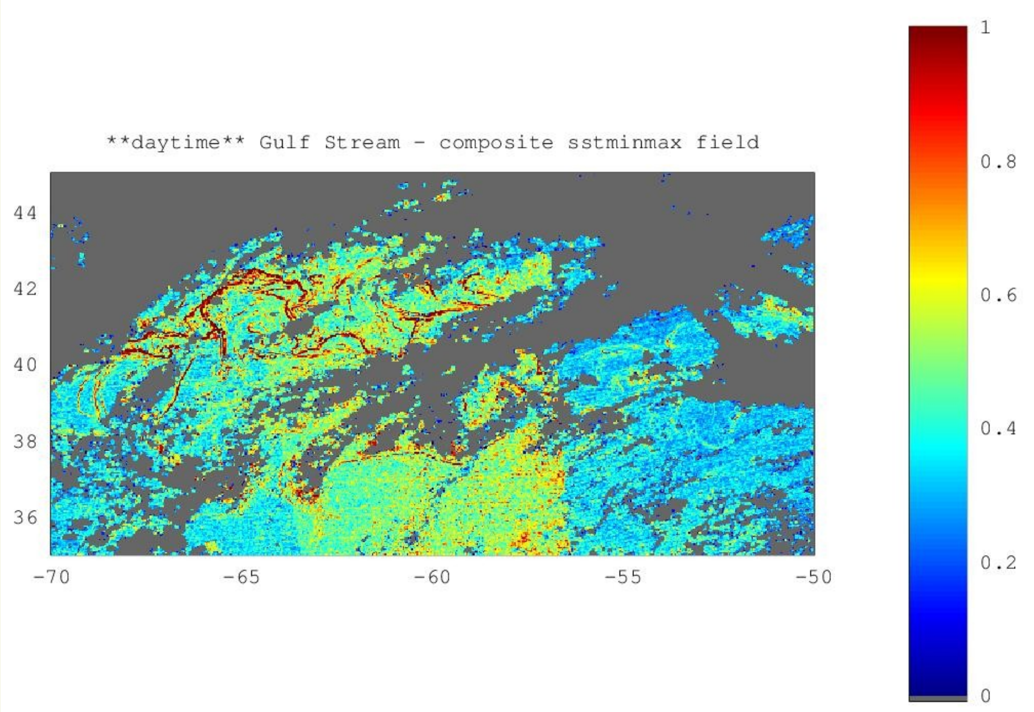
T_{11} and T_{12} are the brightness temperatures at 11μm and 12μm



Daytime SST field on July 14, 2014

Revisited SST calculations

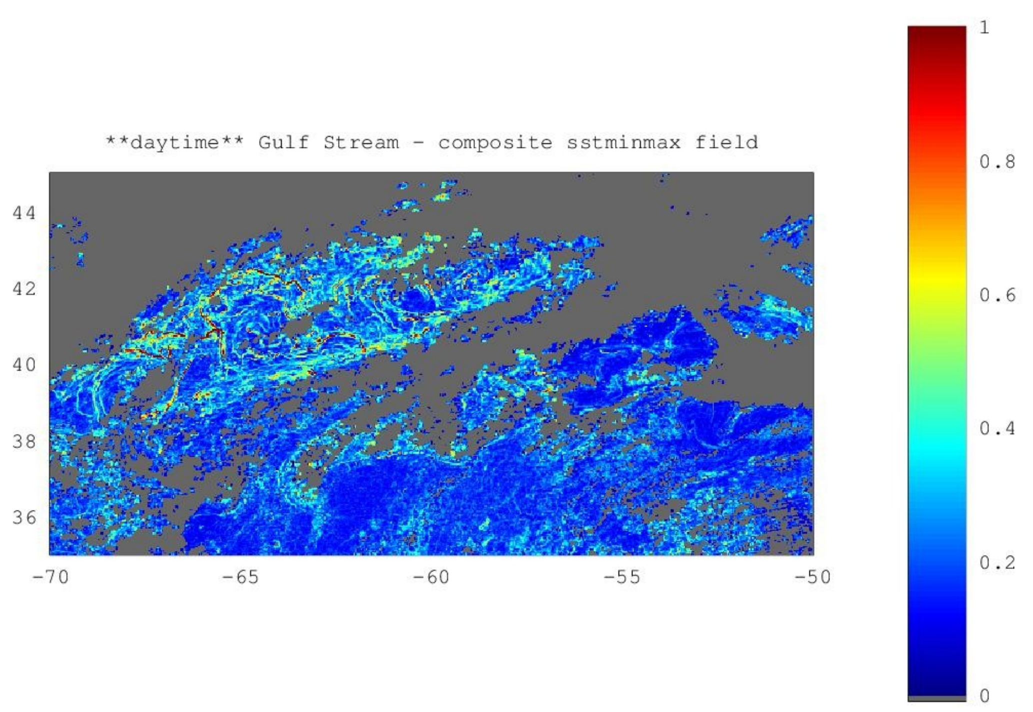
- The SST uniformity field highlight the noise in the SST data
- The noise which includes random noise and striping also corresponds to the VIIRS aggregation scheme.



Daytime SST Uniformity field on July 14, 2014

Revisited SST calculations

- The T_{11} uniformity field shows lower level of noise than SST
- The correction term of the SST equations, "b * (T_{11} - T_{12})", is responsible for increased noise.

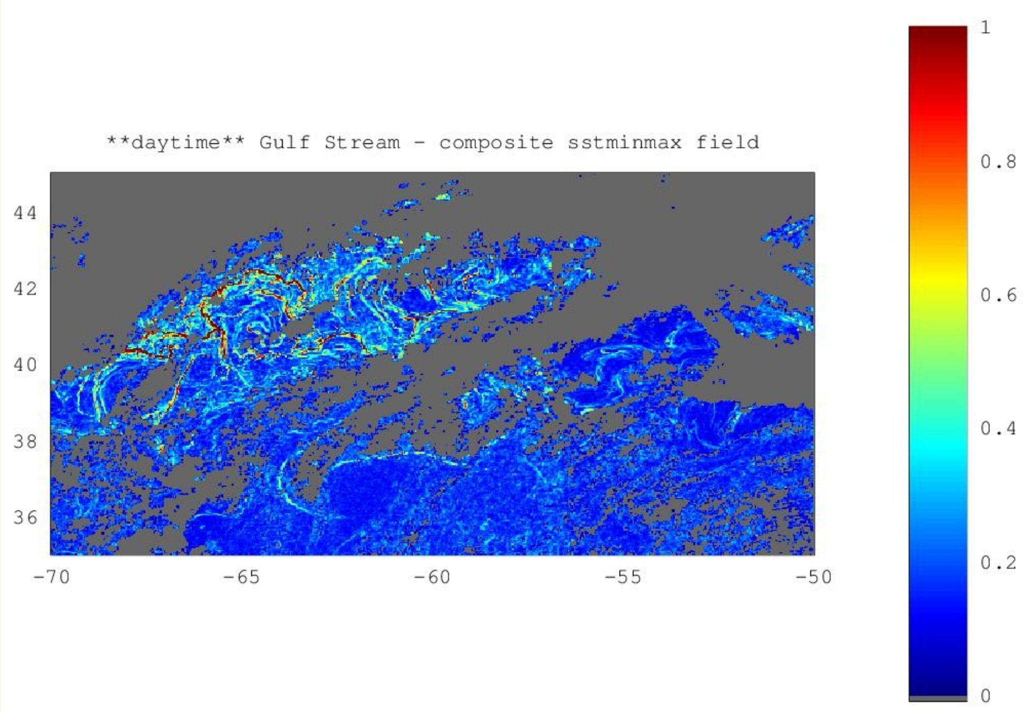


Daytime T_{11} Uniformity field on July 14, 2014

Revisited SST calculations

- Revisited SST uses an nxn pixel average of the correction term
- Keeps SST front strength to at least T_{11} level
- Reduces effects of random noise and striping

Example with n=7



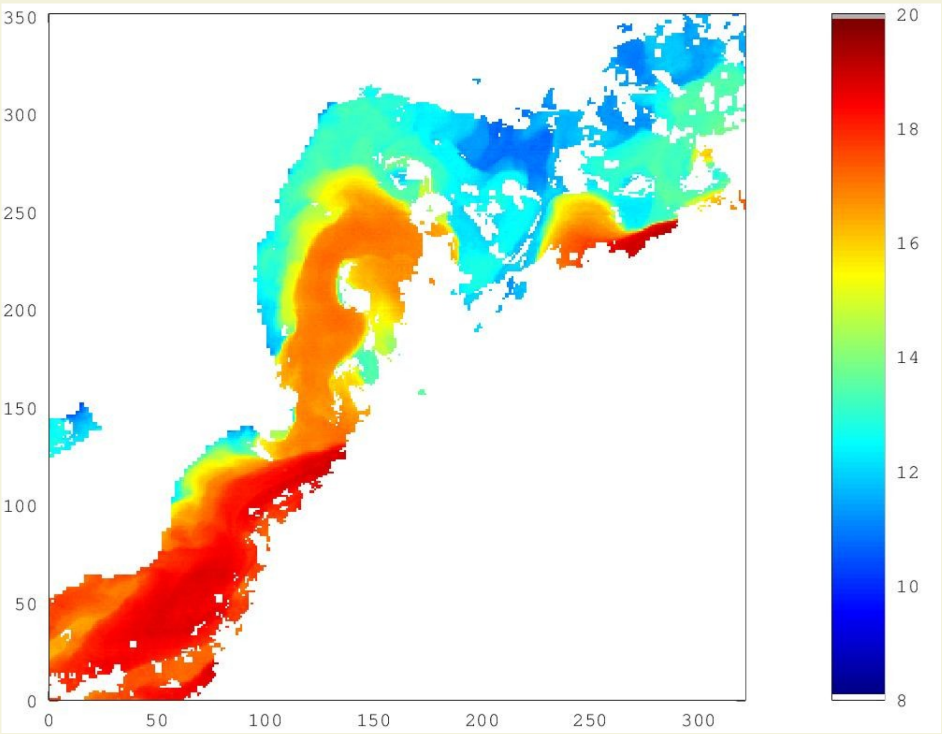
Daytime revisited SST Uniformity field on July 14, 2014

Comparative results

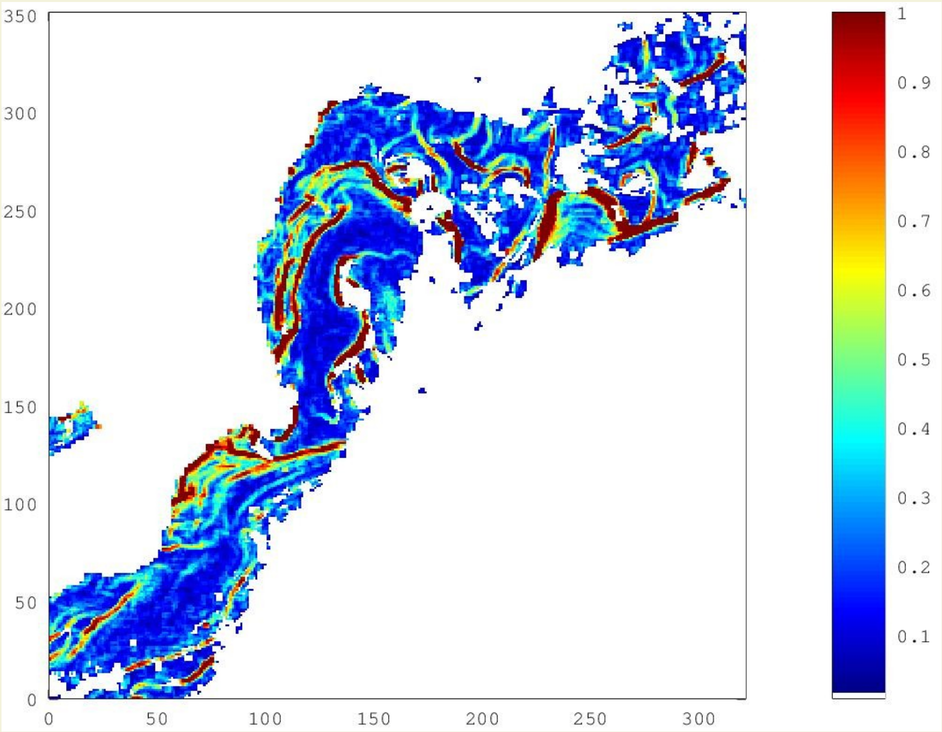
Case 1: East coast of Japan

January 16, 2016, 140E to 143E and 35N to 37N

- Updated NAVOCEANO SST processing



SST field



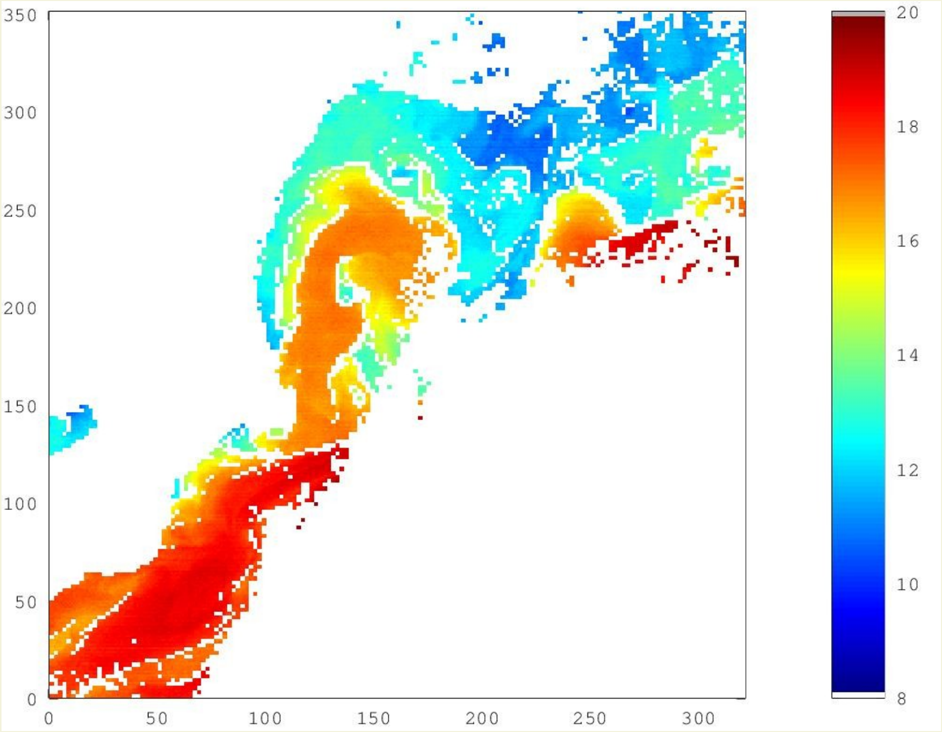
SST uniformity field

Comparative results

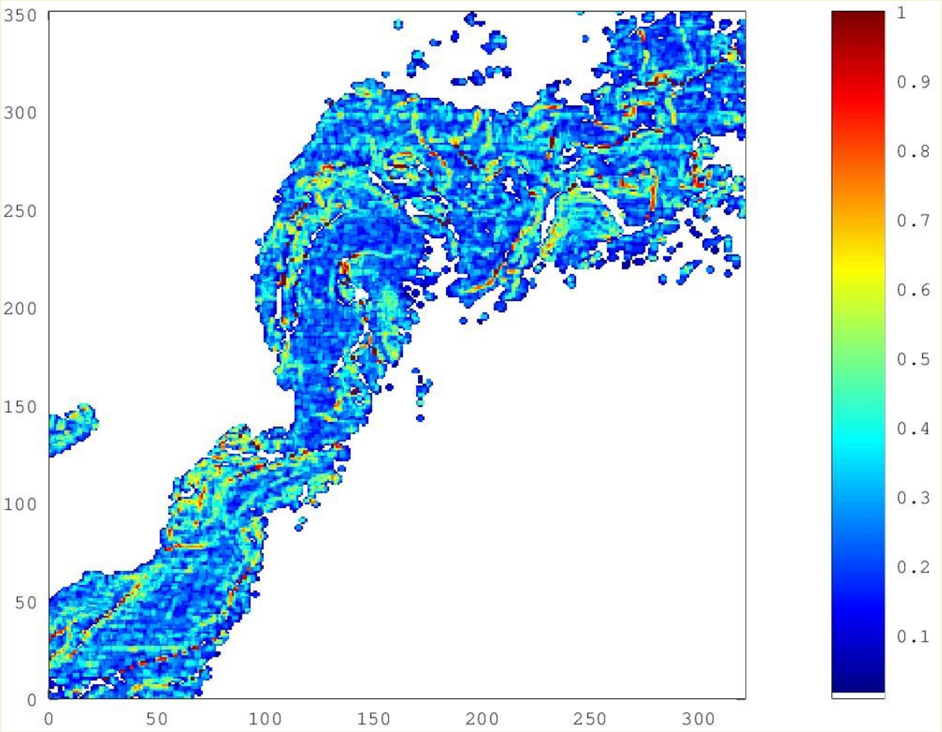
Case 1: East coast of Japan

January 16, 2016, 140E to 143E and 35N to 37N

- Original NAVOCEANO SST processing



SST field



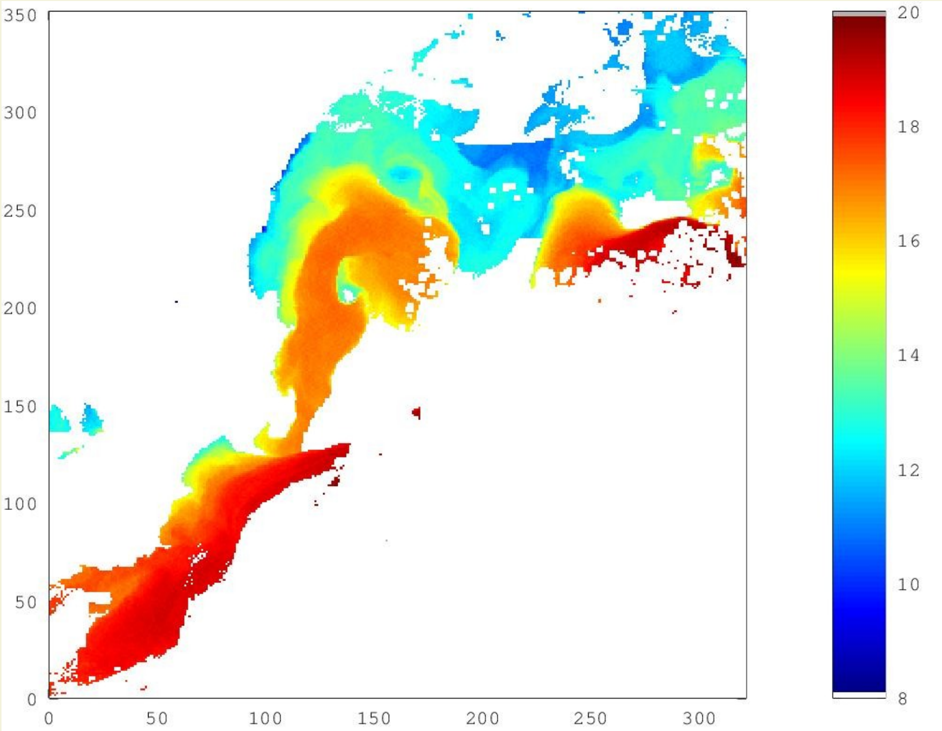
SST uniformity field

Comparative results

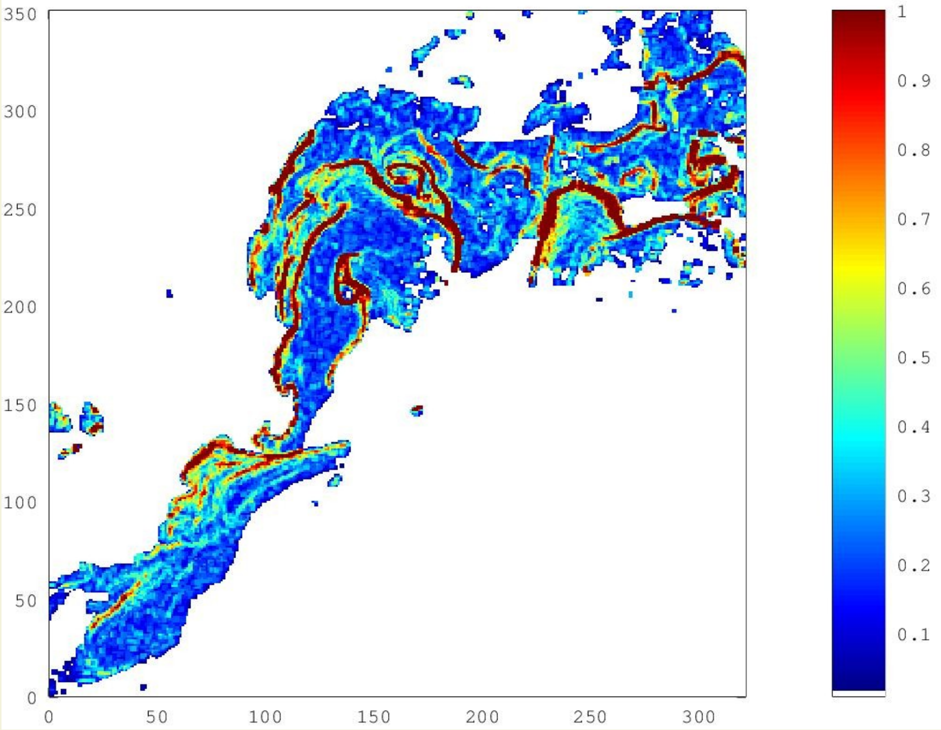
Case 1: East coast of Japan

January 16, 2016, 140E to 143E and 35N to 37N

- NOAA ACSPO SST processing (quality level 5 only)



SST field



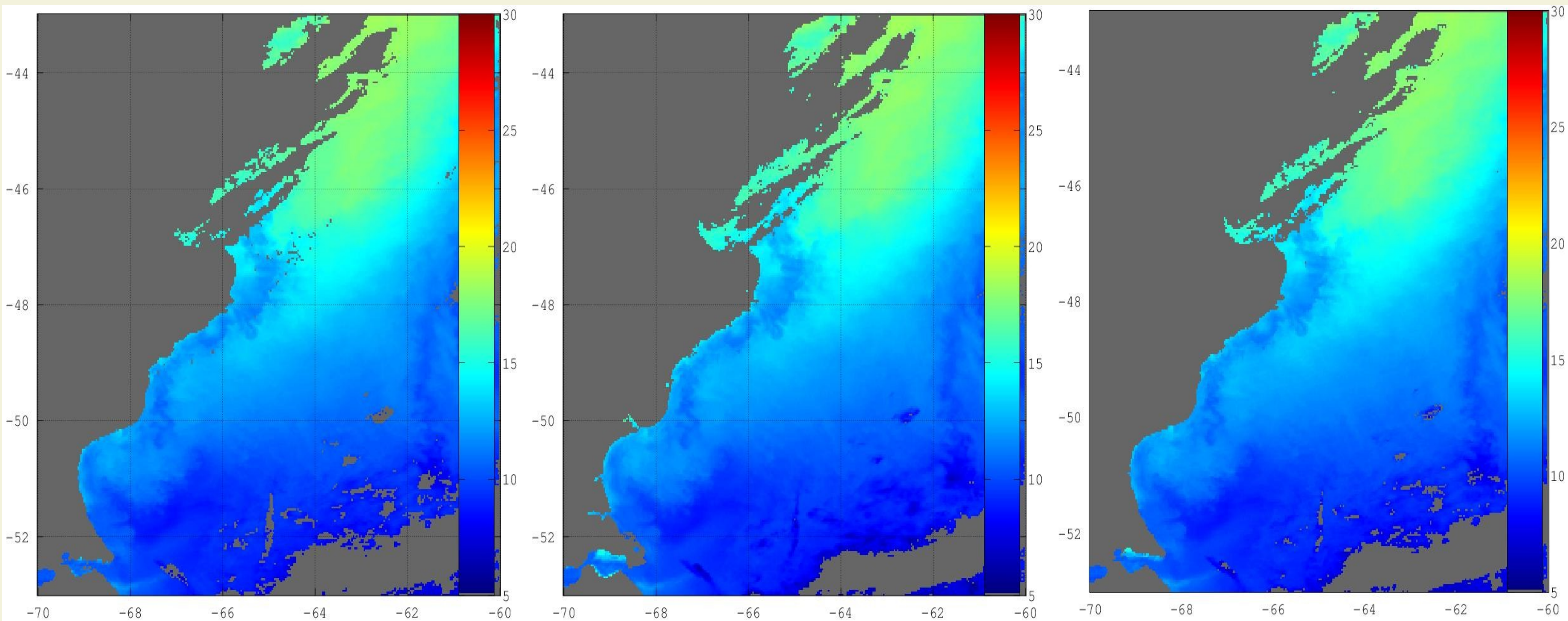
SST uniformity field

Comparative results

Case 2: East coast of Argentina

January 16, 2016, 70W to 60W and 53S to 43S

- SST fields



Updated NAVOCEANO

NOAA ACSPO

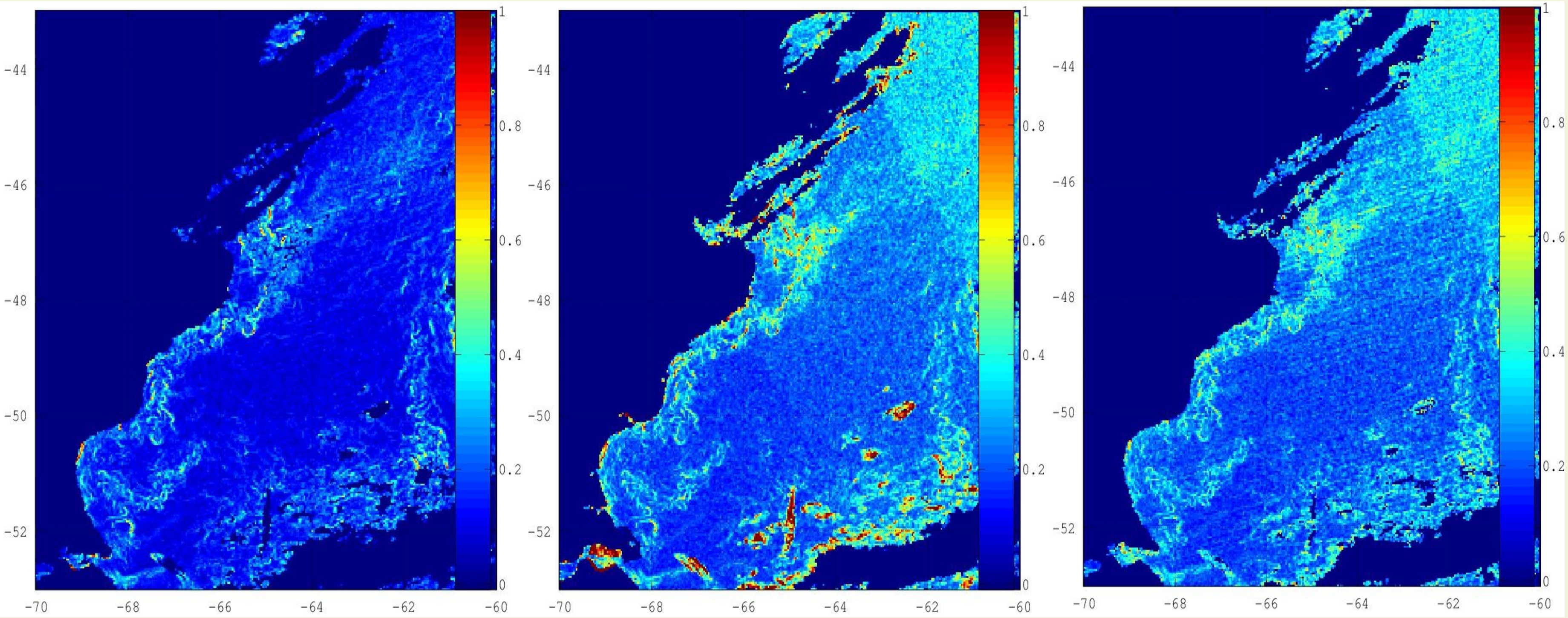
Original NAVOCEANO

Comparative results

Case 2: East coast of Argentina

January 16, 2016, 70W to 60W and 53S to 43S

- SST Uniformity fields



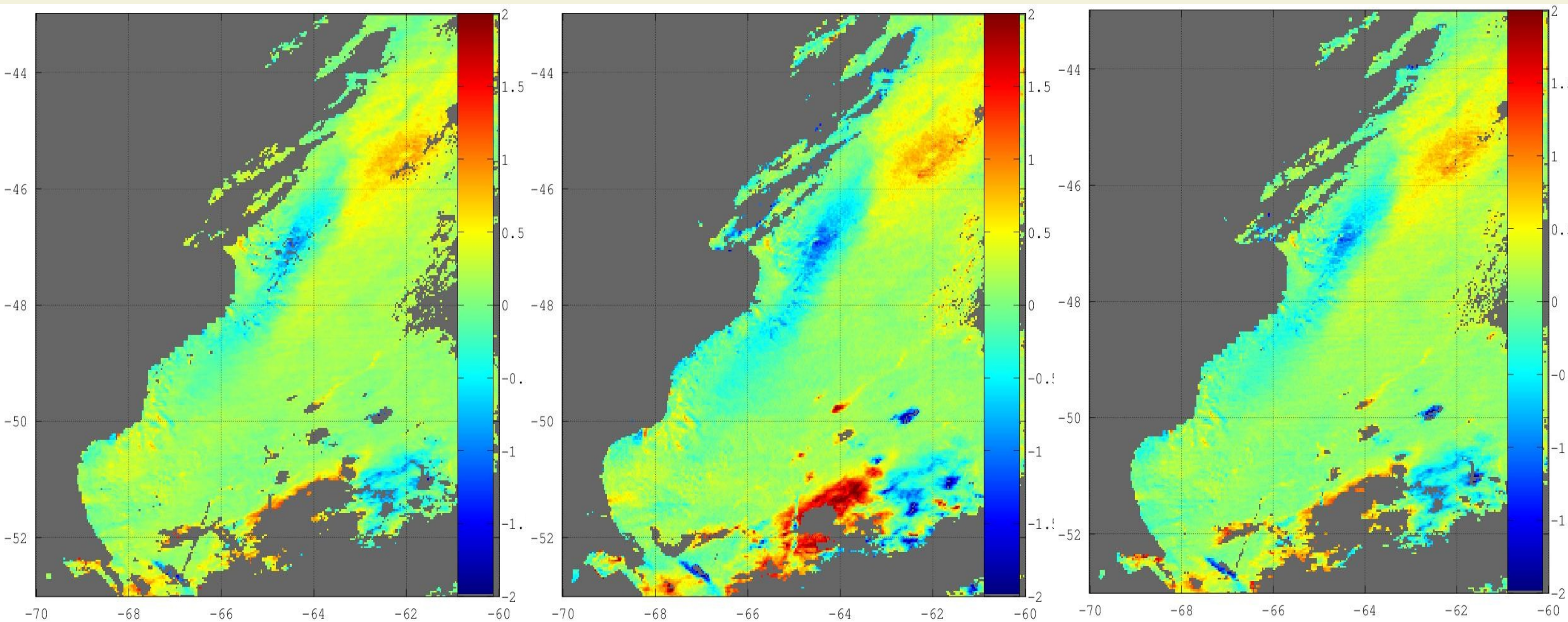
Updated NAVOCEANO NOAA ACSPO Original NAVOCEANO

Comparative results

Case 2: East coast of Argentina

January 16, 2016, 70W to 60W and 53S to 43S

- Orbital overlap: SST differences between 2 consecutive orbits.
- Warm and cold spots often indicate contaminated data in one orbit



Updated NAVOCEANO
Std=0.24°K

NOAA ACSPO
Std=0.34°K

Original NAVOCEANO
Std=0.28°K

Global results

Orbital overlap evaluation

- January 16, 2016 from 120E to 30W* and 55S to 55N
- Standard deviation from orbital overlap evaluation

method	Number of retrievals	Standard deviation
Updated	61 millions	0.43°K
Original	68 millions	0.40°K
ACSPO	75 millions	0.50°K

- NAVOCEANO updated processing despite recovering frontal regions, retains a low standard deviation in part because of a stricter uniformity test. It produces about 80 % of the number of ACSPO retrievals.

*ACSPO SST missing data between 30W and 0W

Global results

Orbital overlap evaluation

- NAVOCEANO original processing results in the lowest standard deviation because of its conservative cloud detection which often discards frontal regions. It produces about 90% of ACSPO retrievals.
- ACSPO processing is not as strict with cloud contamination but produces the largest number of retrievals and good coverage of frontal regions at the cost of a higher standard deviation.

Buoy match-ups

- Evaluation through buoy match-ups is preliminary. Early results indicate a standard deviation of 0.45°K for the updated and original NAVOCEANO SST (all categories), and 0.47°K for ACSPO SST (quality level 5 only).

Conclusion

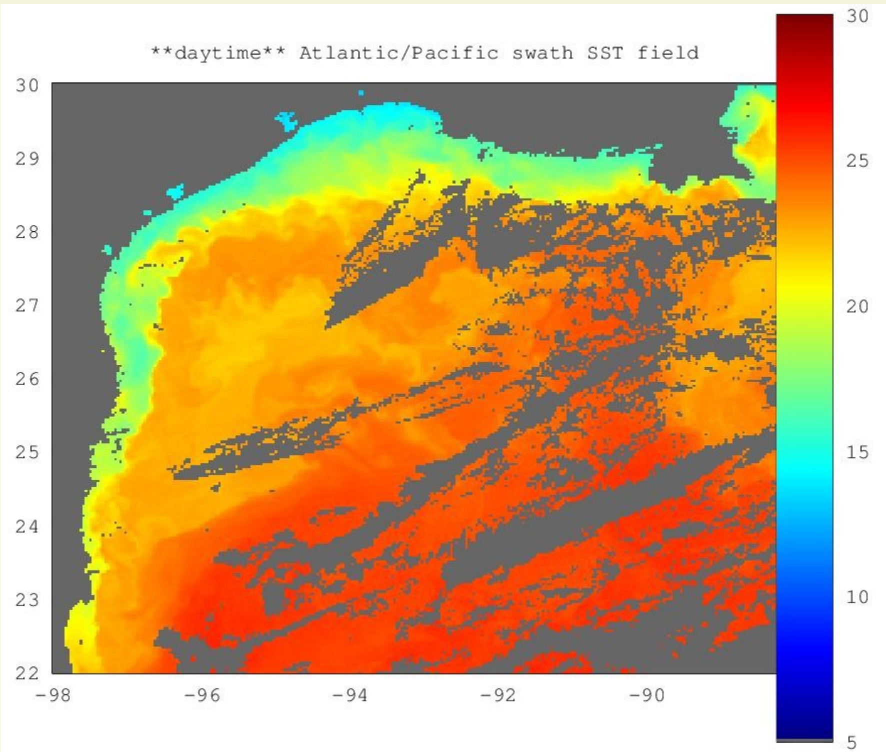
- The updated NAVOCEANO SST processing successfully improves the coverage of frontal regions while maintaining strong cloud detection.
- The uniformity and associated tests perform better with brightness temperature than SST. This may have implications for SST edge detection.
- Replacing the standard correction term in the daytime SST equations by an nxn pixel average can drastically reduce the effect of random noise and striping while keeping the strength of the fronts in the resulting SST field to at least that of the level of the fronts in the brightness temperature field.

Comparative results

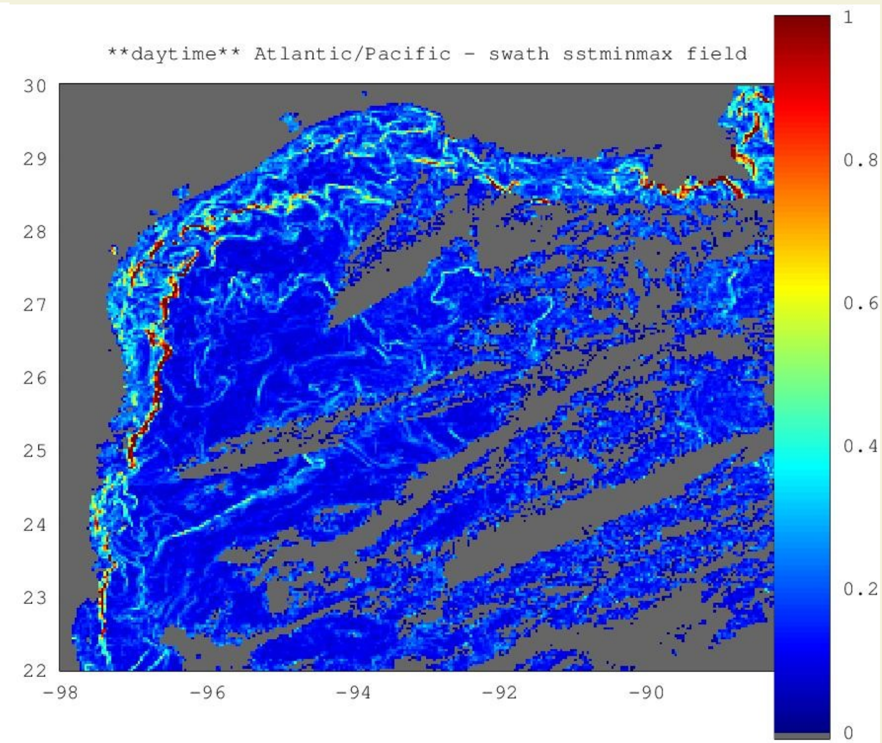
Case 3: Gulf of Mexico

January 16, 2016, 98W to 88W and 22N to 30N

- Updated NAVOCEANO SST processing



SST field



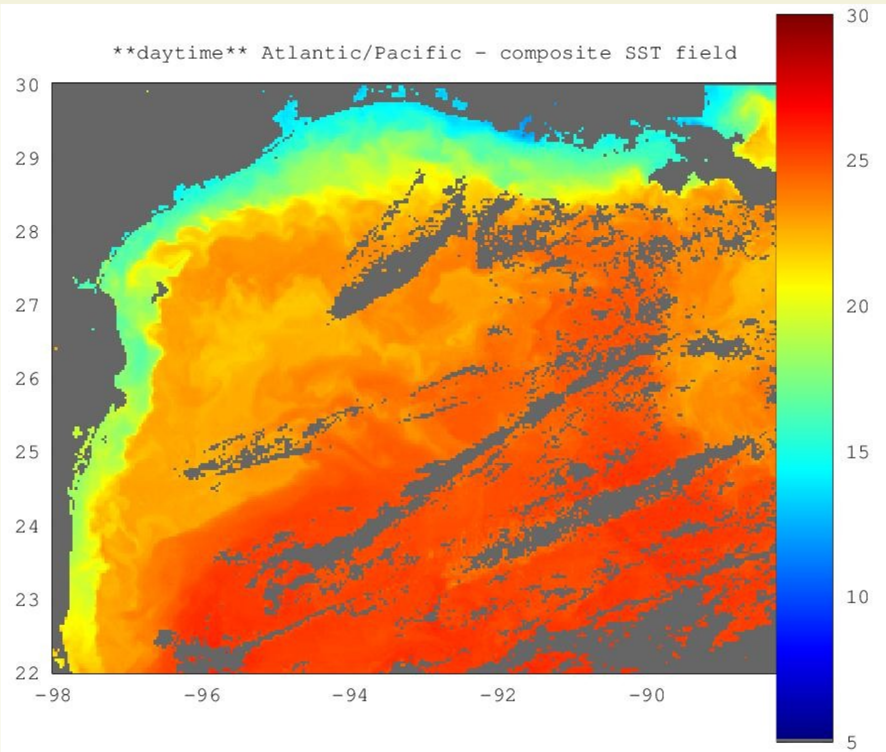
SST uniformity field

Comparative results

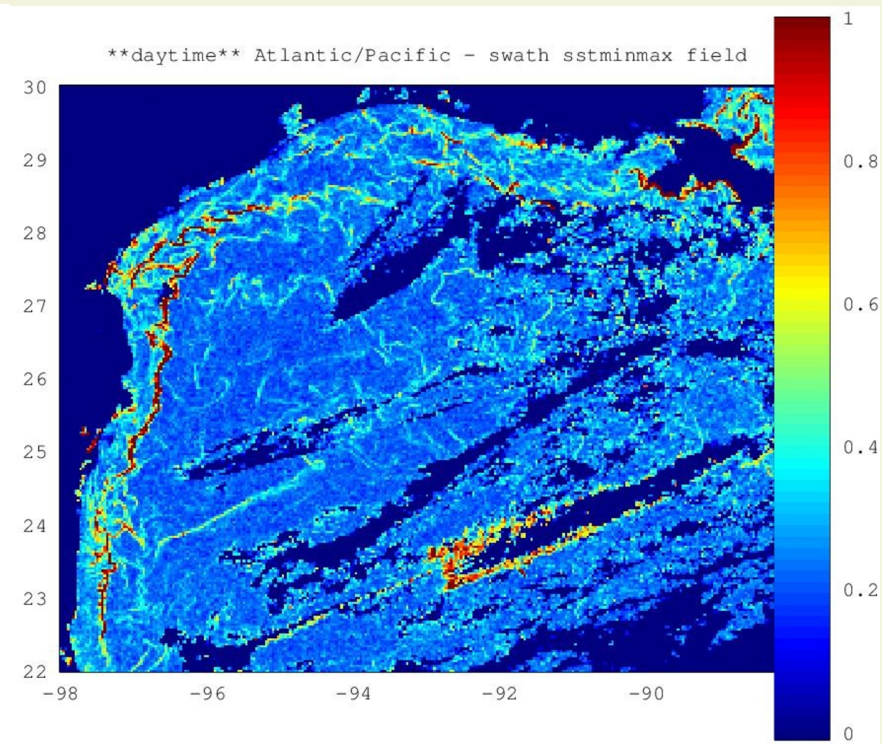
Case 3: Gulf of Mexico

January 16, 2016, 98W to 88W and 22N to 30N

- NOAA ACSPO SST processing



SST field



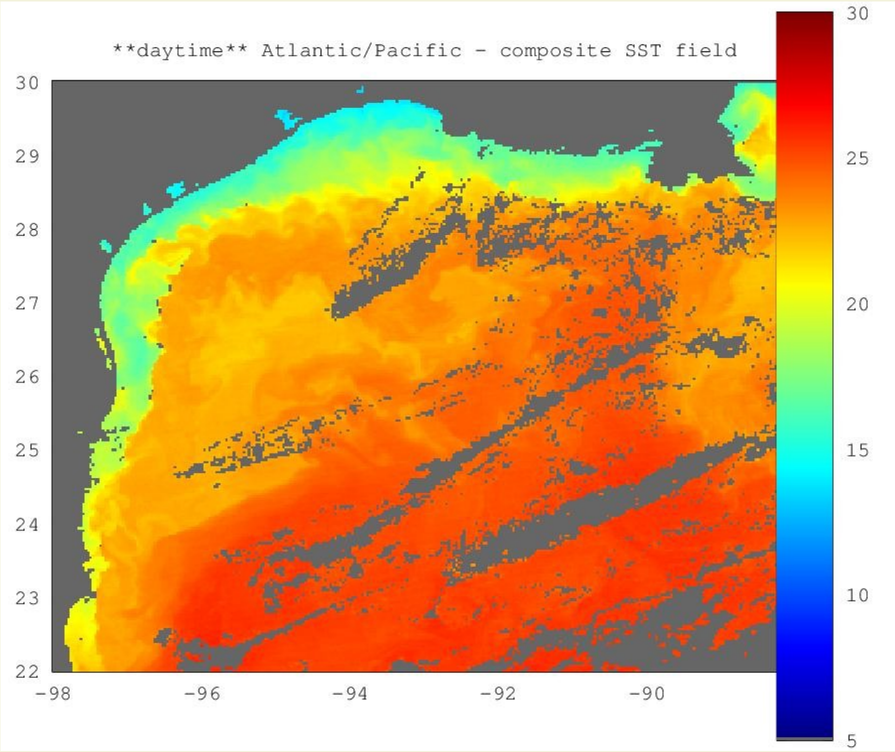
SST uniformity field

Comparative results

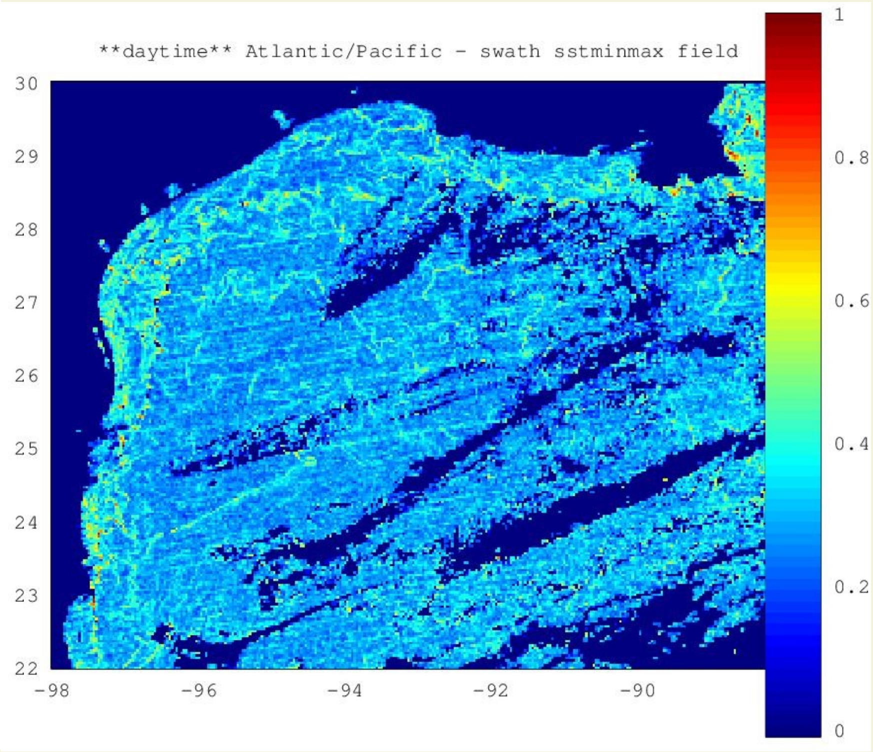
Case 3: Gulf of Mexico

January 16, 2016, 98W to 88W and 22N to 30N

- Original NAVOCEANO SST processing



SST field



SST uniformity field