Toward high resolution ocean thermal fronts product from JPSS VIIRS

Irina Gladkova[1,2,3], Alexander Ignatov[1], Yury Kihai[1,2], Fazlul Shahriar [3], Boris Petrenko[1,2]

[1]NOAA STAR

[2]GST, Inc.

[3]City College of New York, NOAA/CREST

Why Fronts and who cares?

Why Fronts and who cares?

Marine animals seem to care a lot!

- Fish are particularly fond of ocean fronts where masses of warm and cold water meet, as these tend to contain large quantities of plankton.
- Mixing at the boundary between two water bodies can lead to elevated primary and secondary production.
- There are many published studies associating marine animals with fronts, including fish, seabirds, turtles, cetaceans, basking sharks.

Cetaceans know how to find fronts

Front detection: background

Finding ocean fronts in remotely sensed imagery is not new.

Existing approaches can be grouped as follows:

- derivative based edge detection (relies on locating gradient discontinuities in SST images that mark a sharp transition from cold to warm water);
- statistical/probabilistic edge discrimination and classification, (relies on statistical properties (bimodality) in the proximity of thermal front);
- surface fitting (assumes and relies on a smooth spatial variations in the position and strength of ocean fronts).

What's wrong with existing fronts detection algorithms?

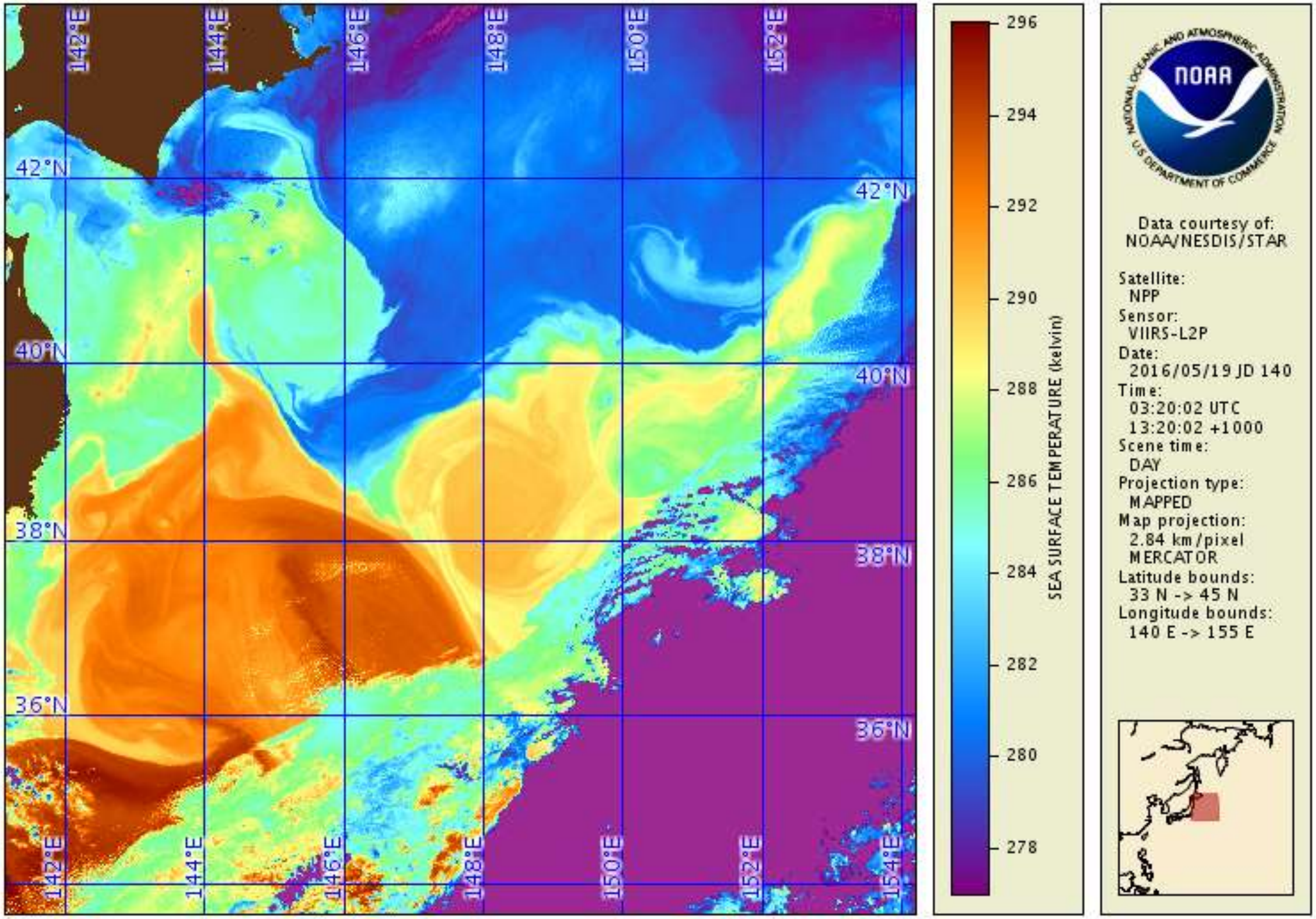
Application of front detection methods to instantaneous (observed) SST requires a reliable cloud mask, which not only masks out the clouds, but also does not have false cloud identifications.

Are current cloud masks reliable?

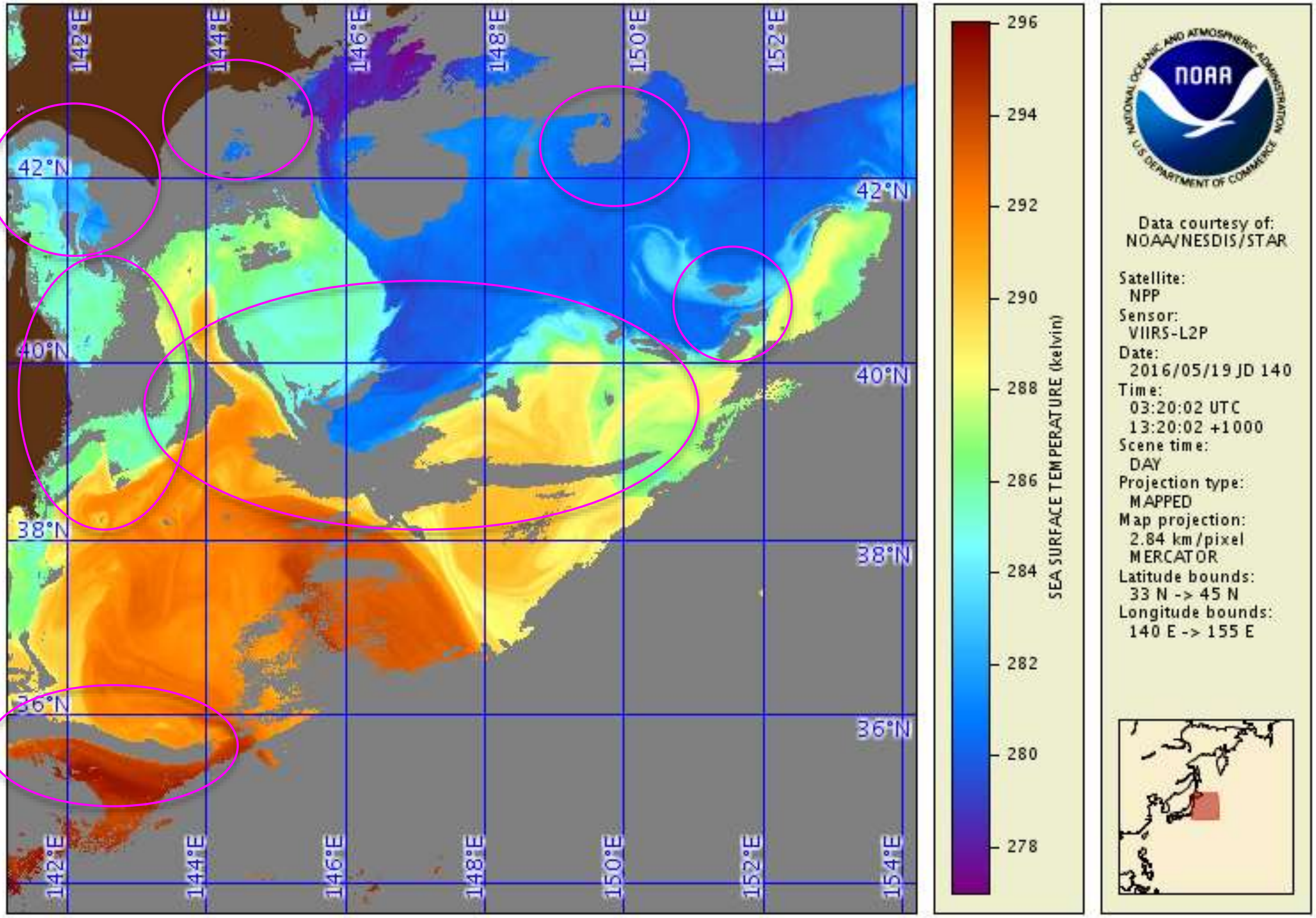
Globally – yes! Regionally – not quite so:

- Too many examples of misclassifications ("false alarms") in dynamic areas (currents, eddies, upwellings), costal zones, and sea-ice transitions
- Misclassifications are often persistent from one overpass to another
- They often may lead to data loss in interesting areas; and day/night inconsistency

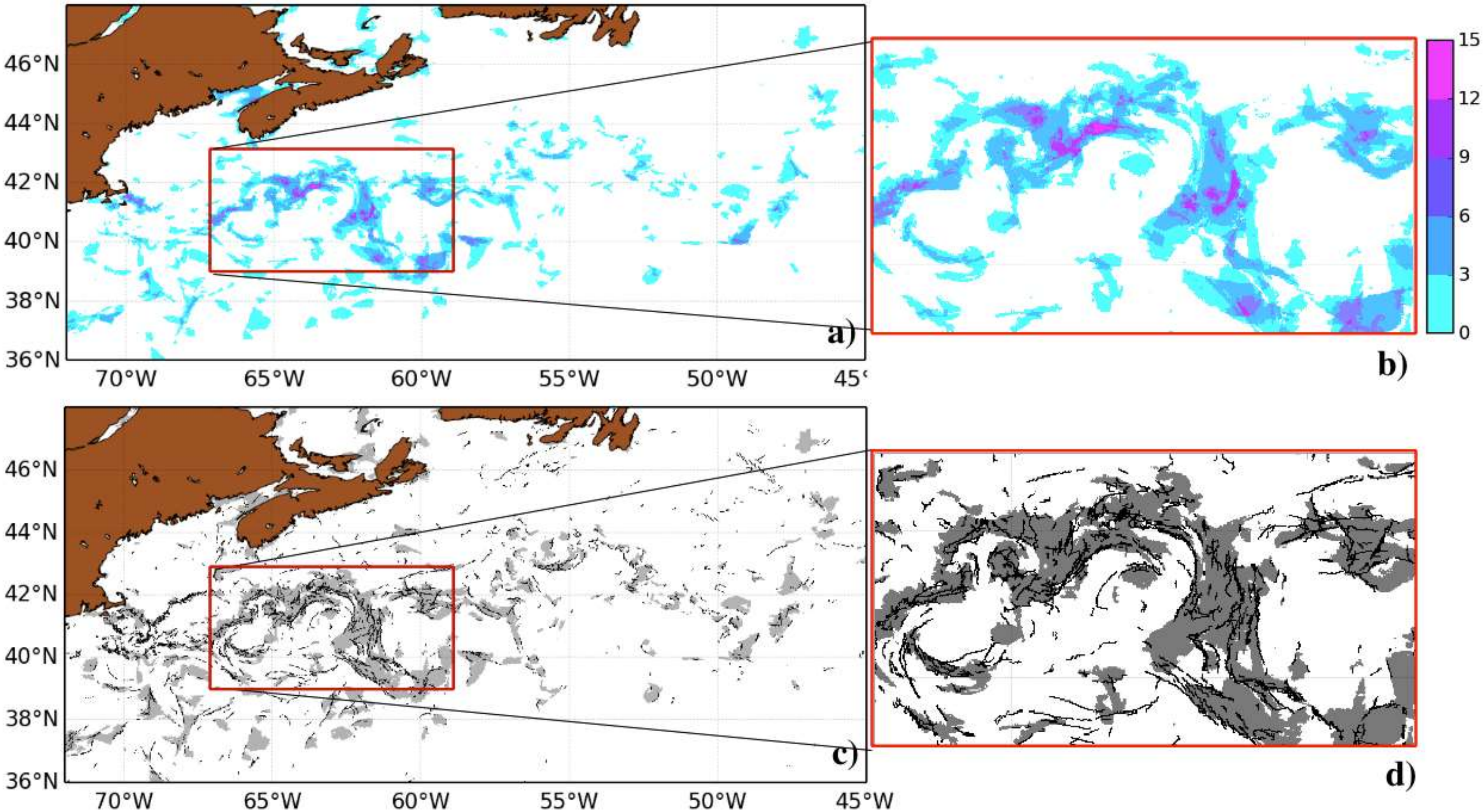
Example of misclassifications in dynamic regions (no cloud mask)



With current cloud mask (rendered in gray)



Persistent misclassifications near fronts



What can be done?

More often than not, false cloud identifications are persistently occurring in the dynamic regions with currents, eddies and upwelling; coastal areas and high latitudes.

One way to overcome the cloud masking misclassifications is to detect thermal fronts at the L2 swath level and incorporate in the cloud detection algorithm.

Objectives

1. **Improve clear sky identification in dynamic, coastal, and high-latitude areas of the ocean (to facilitate L3 and L4 improvements in these challenging regions, which are often missing in satellite data)**

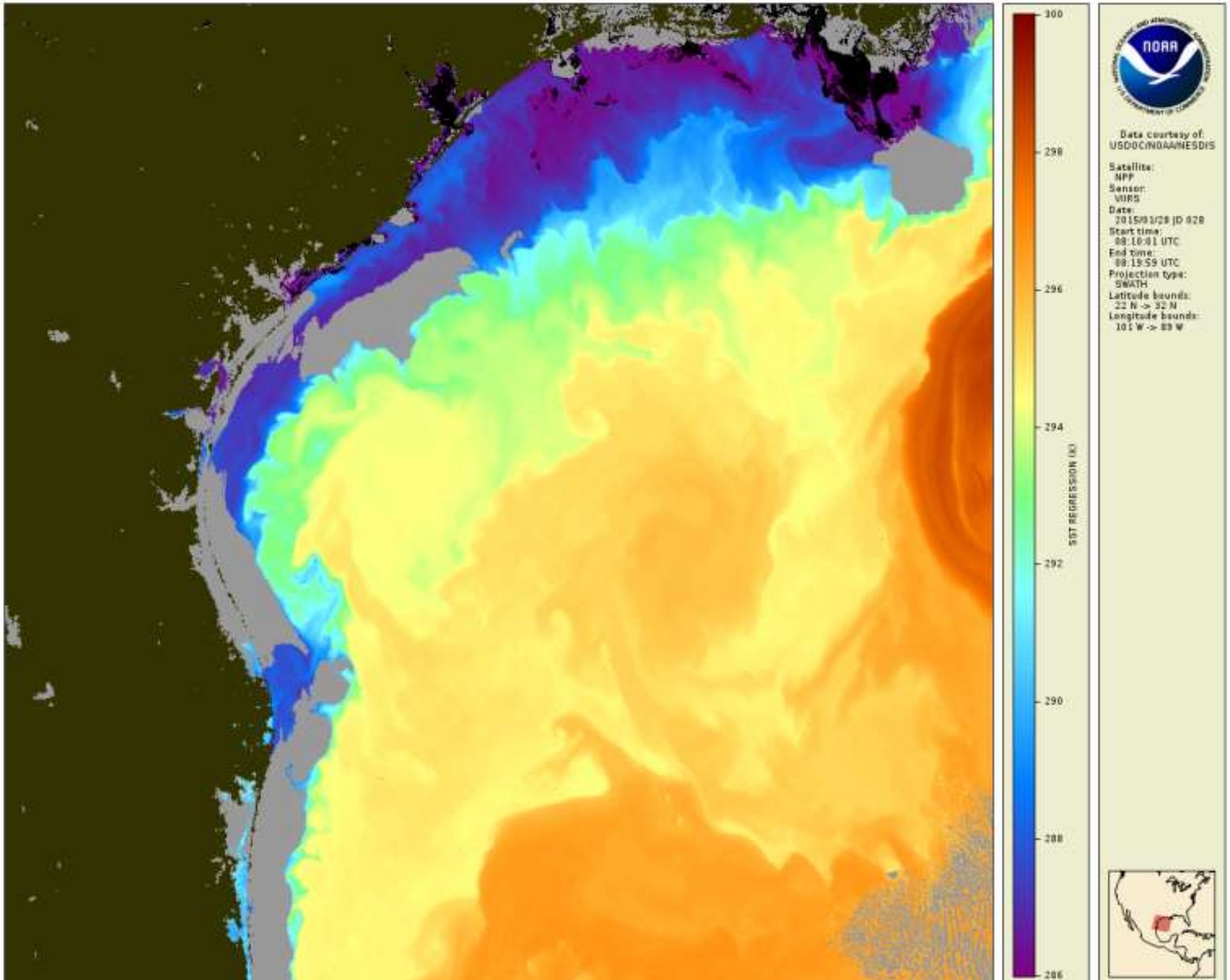
2. **Derive Ocean Fronts and save in L2and L3U ACSPO SST products**

Correcting current cloud mask

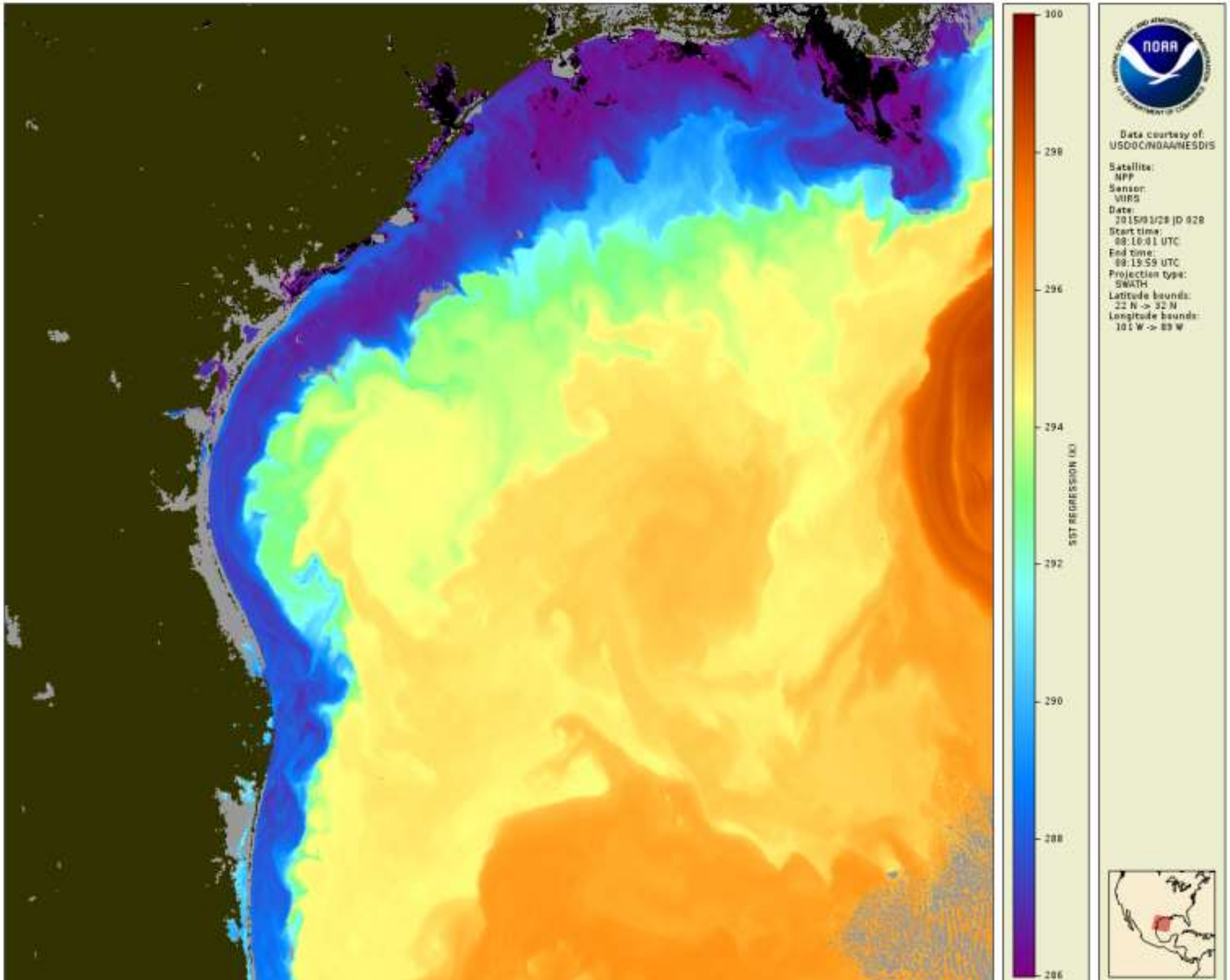
Pattern Test:

- **Find ocean thermal fronts**
- **Identify adjacent contiguous areas with uniform SSTs labeled cloudy by current mask**
- **Make ocean vs. cloud decision based on the statistics of the whole regions**

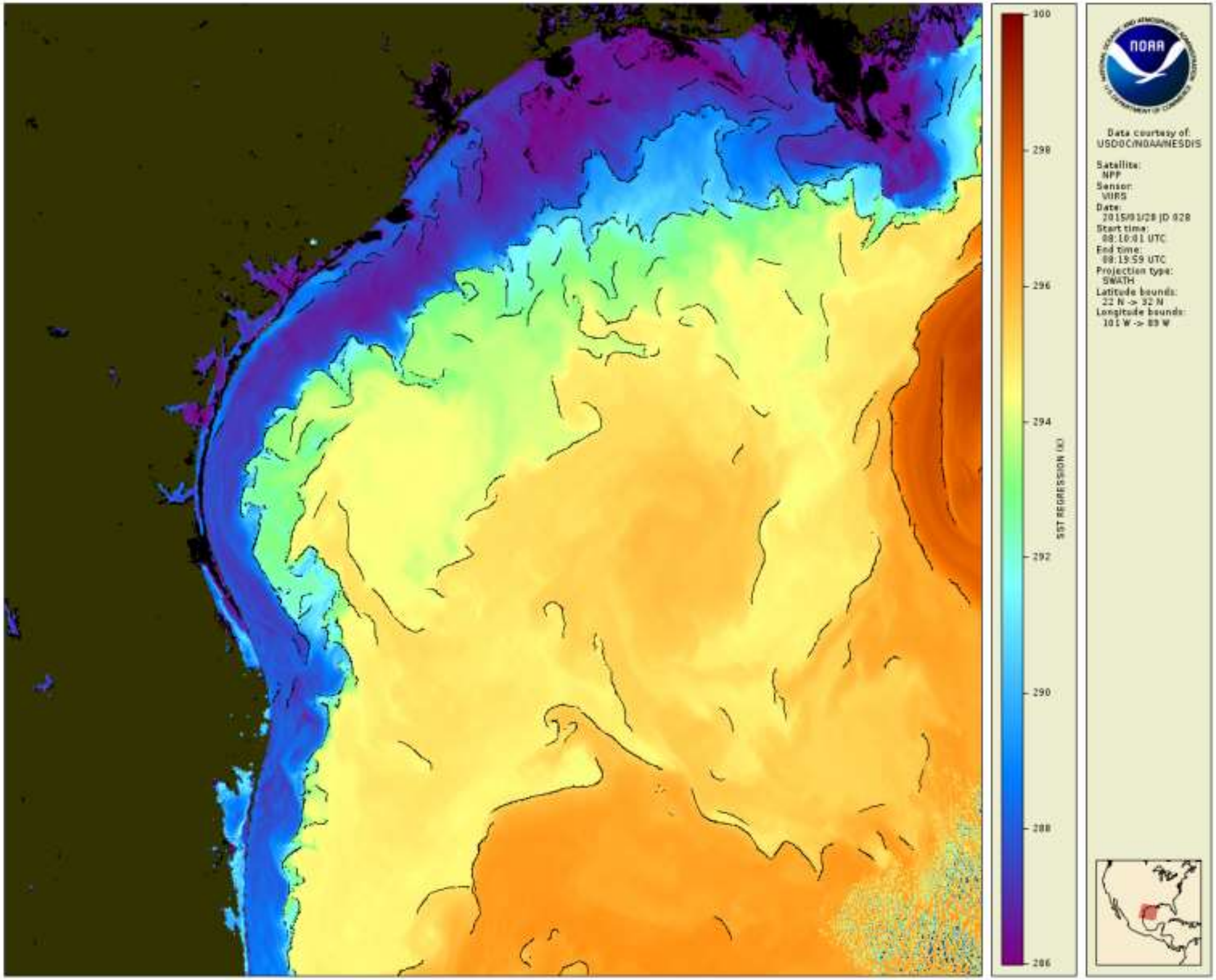
SST with current cloud mask overlaid



Corrected Cloud Mask



SST with thermal fronts overlaid



Thermal Front Identification Approach

Main Components of the Front Detection Step:

- Liberal thresholds to reduce search domain
- Directional Derivatives of thermal bands (11 and 12 micron)
- Log-enhancement of gradient magnitude
- Eigenvalues of Hessian
- Front Index (logistic function)
- Connecting fragments
- Bimodality check
- Thinning based on gradient field
- Hypothesis testing (accepting/rejecting fronts)

Algorithm is meant for real time ACSPO L1-to-L2 processing and has to be fast and efficient. It's implemented in C++ using standard functions from optimized openCV library.

Local behavior: 2nd order

The local behavior of a smooth 2D function can be analyzed using Taylor expansion.

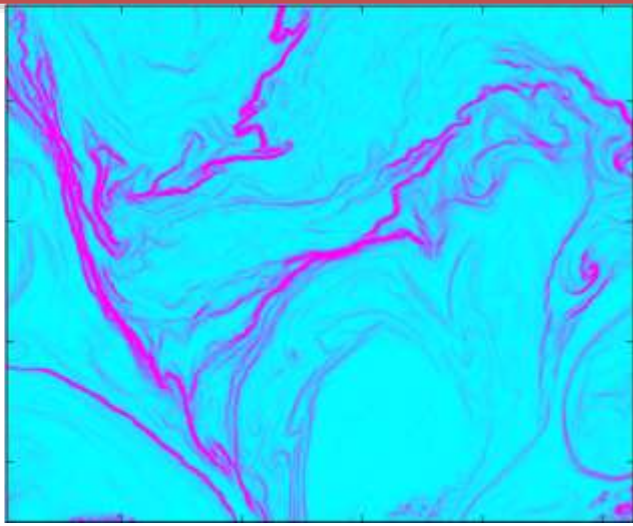
The 2nd order Taylor of the image I at a given point x_0 and scale s is:

$$L(\mathbf{x}_o + \delta\mathbf{x}_o, s) \approx L(\mathbf{x}_o, s) + \delta\mathbf{x}_o^T \nabla_{o,s} + \delta\mathbf{x}_o^T \mathcal{H}_{o,s} \delta\mathbf{x}_o$$

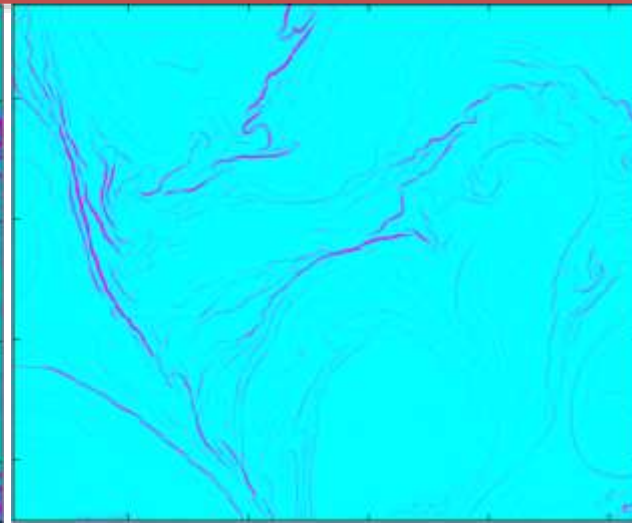
where $\nabla_{o,s}$ is the gradient and $\mathcal{H}_{o,s}$ is the Hessian matrix.

- The gradient magnitude measures the (local) change in the intensity values.
- The Hessian measures the second order directional change.
- Eigenvalues of the Hessian allows (classification) and localization of the critical points.

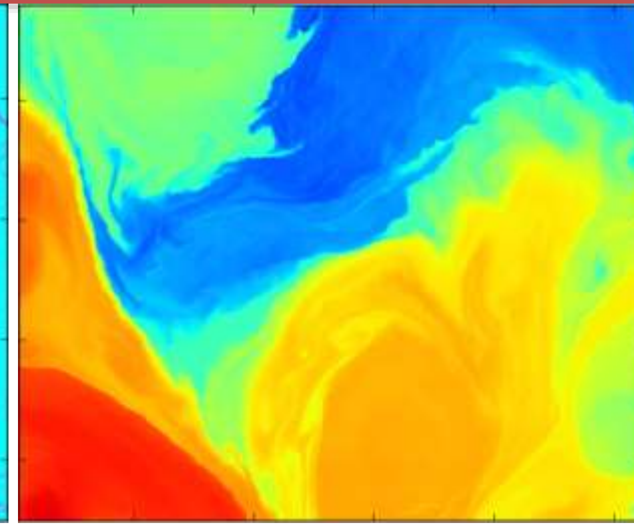
Local behavior: initial fronts



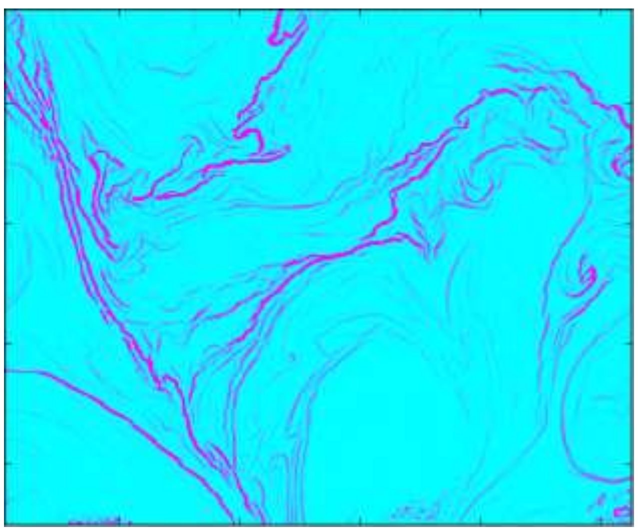
Gradient magnitude



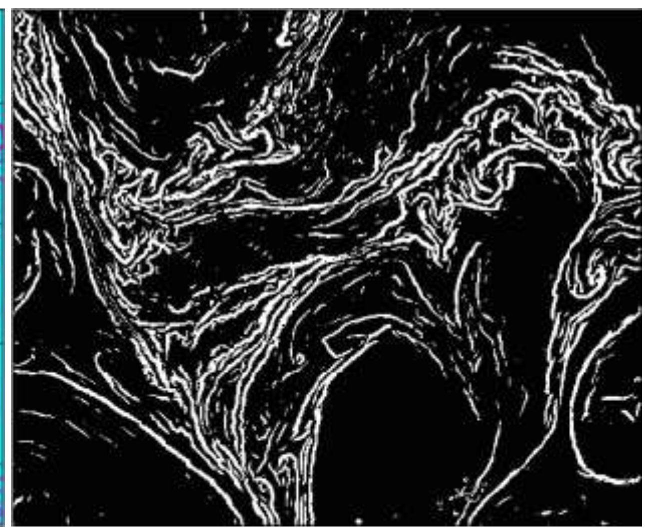
(Largest) Eigenvalue of Hessian



SST



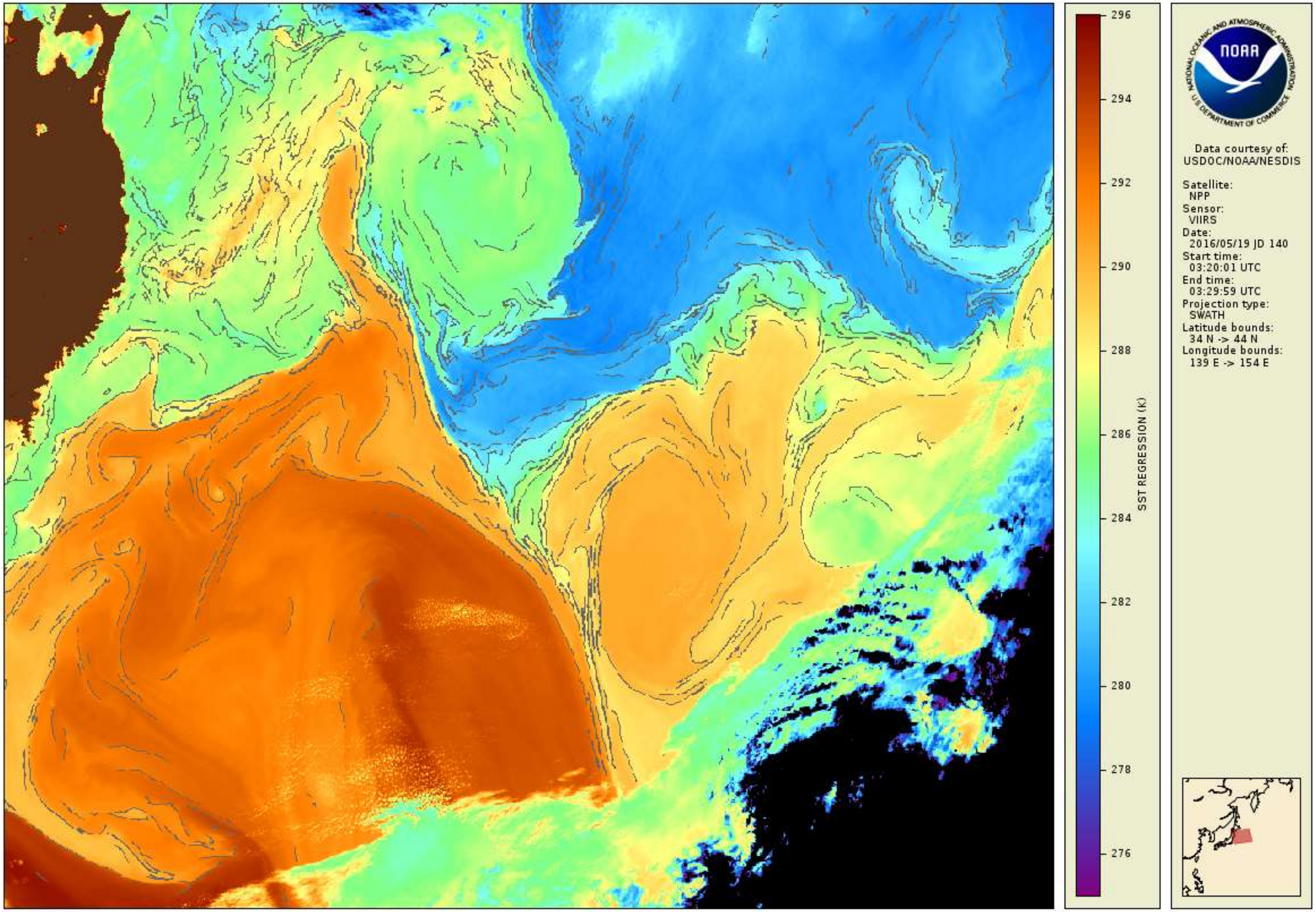
Front Index



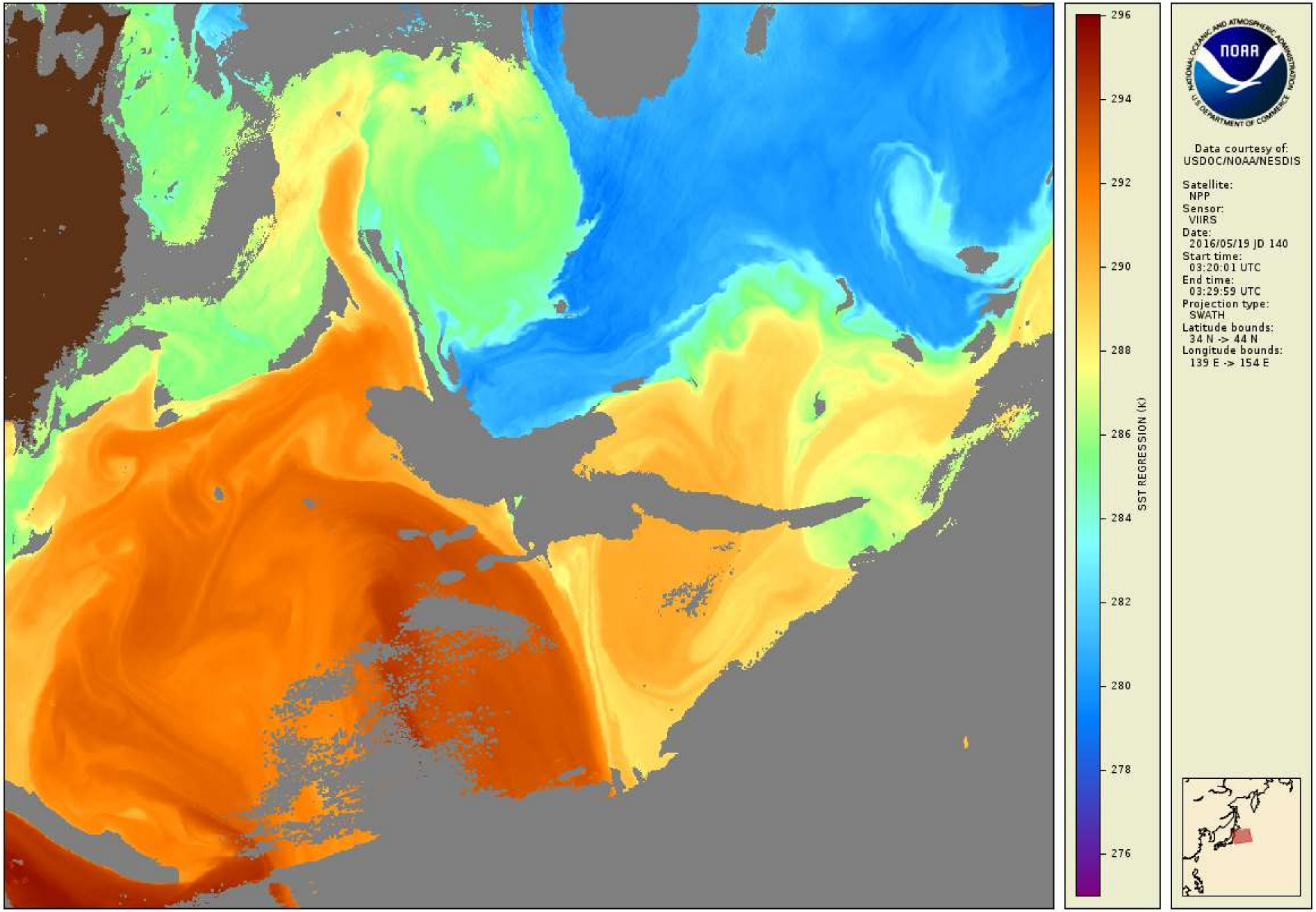
Initial Front locations

Front locations after thinning

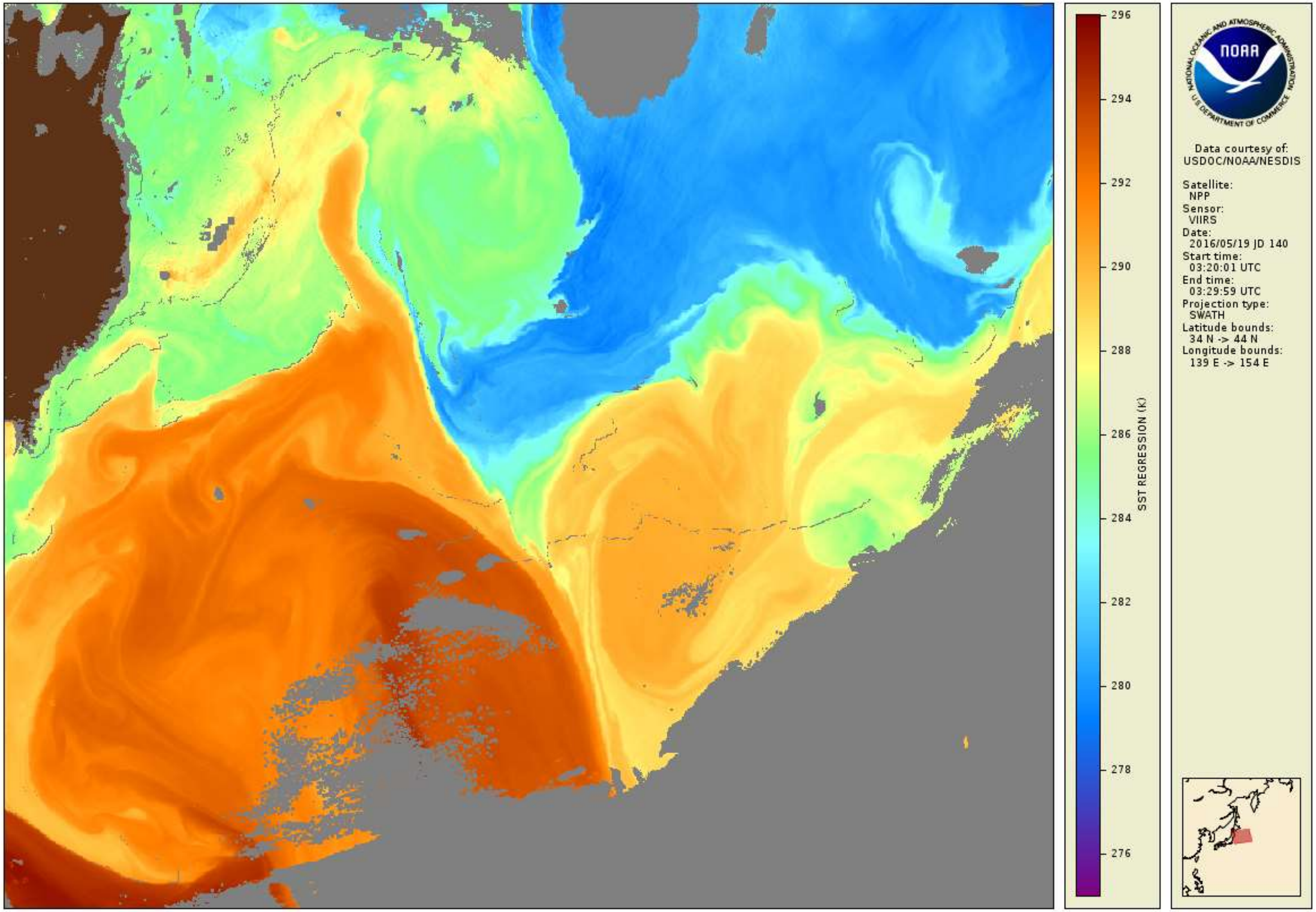
SST with thermal fronts overlaid



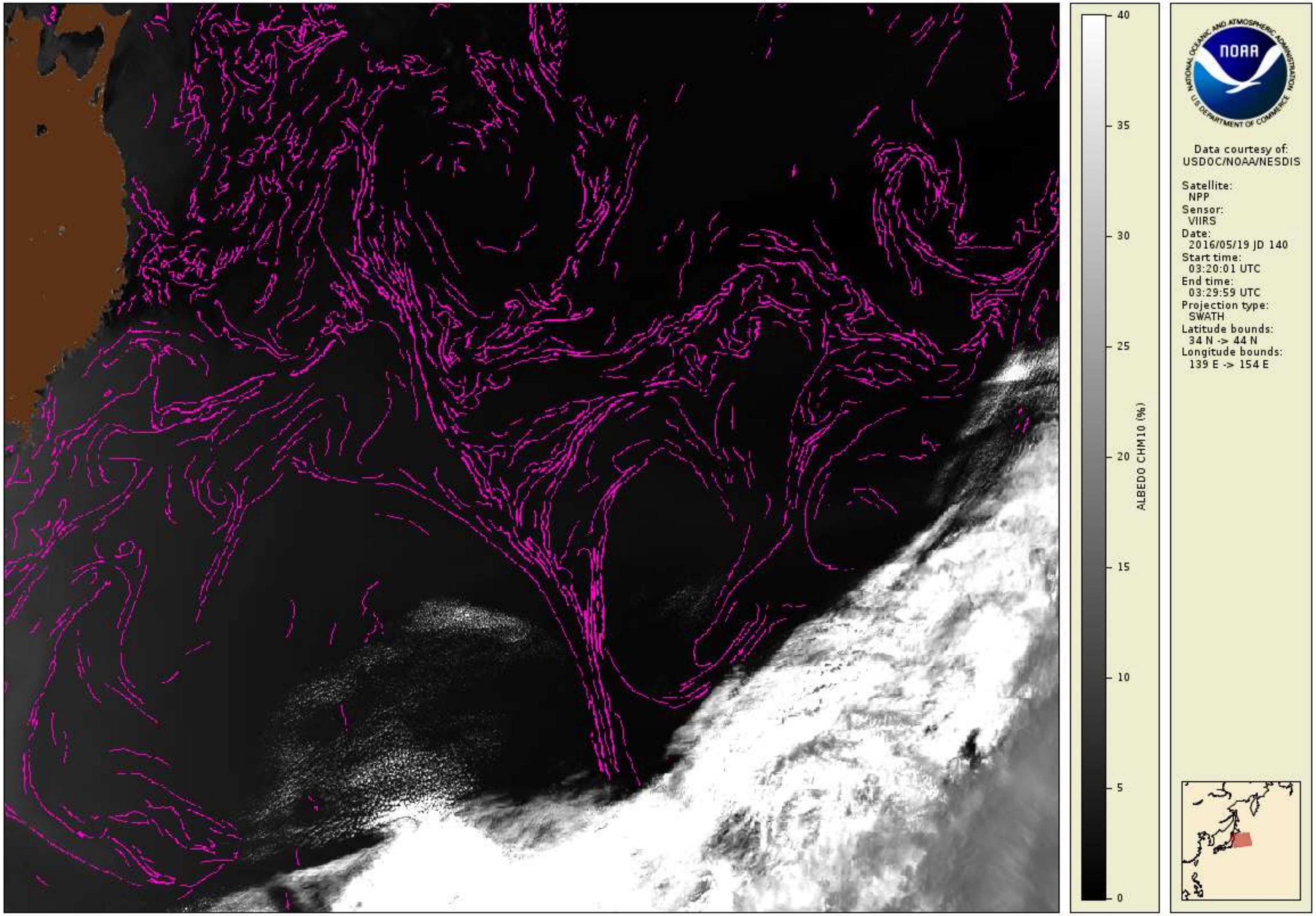
SST with current cloud mask



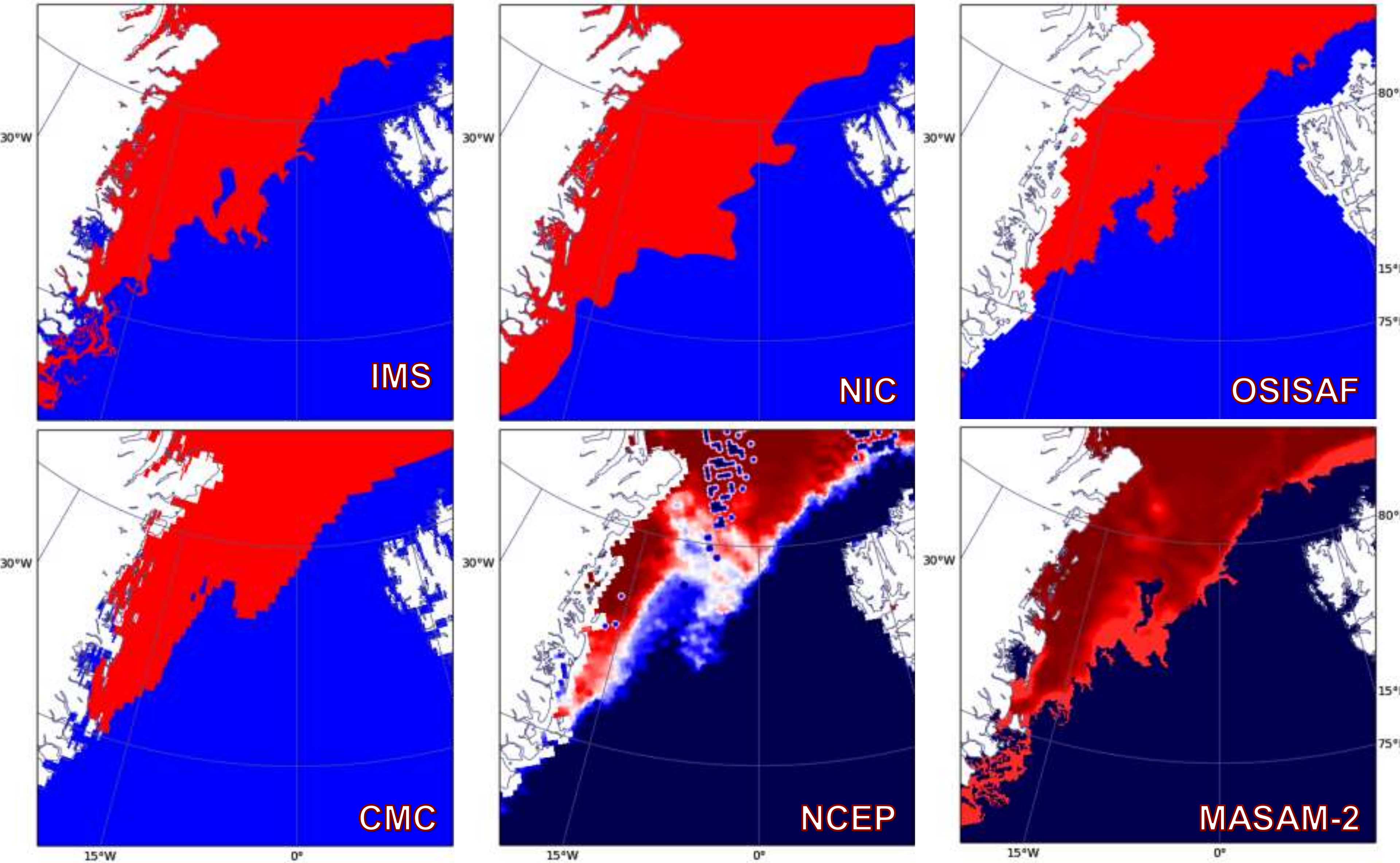
SST with corrected cloud mask



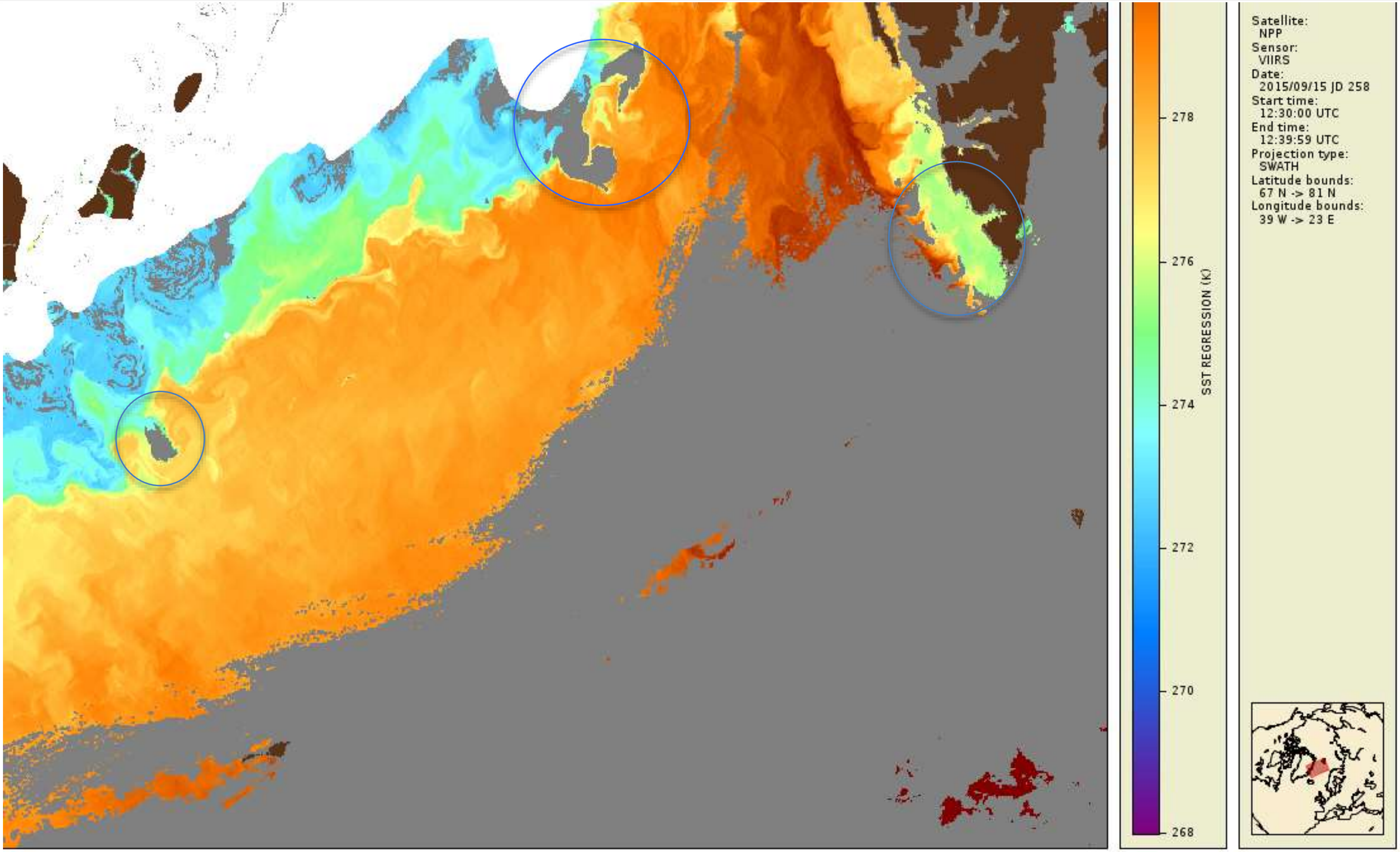
Albedo with thermal fronts overlaid



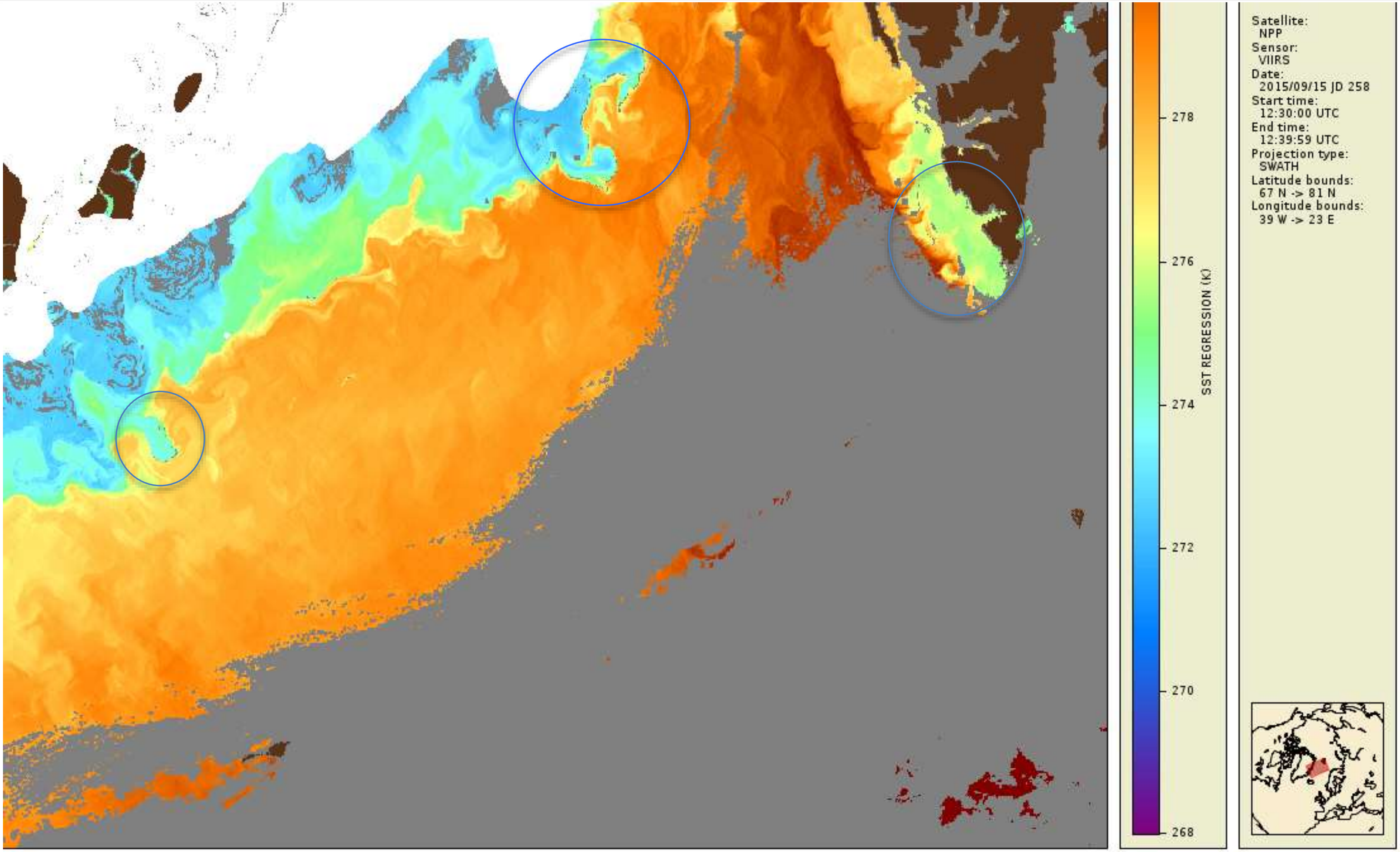
Next question is: How reliable is sea ice mask?



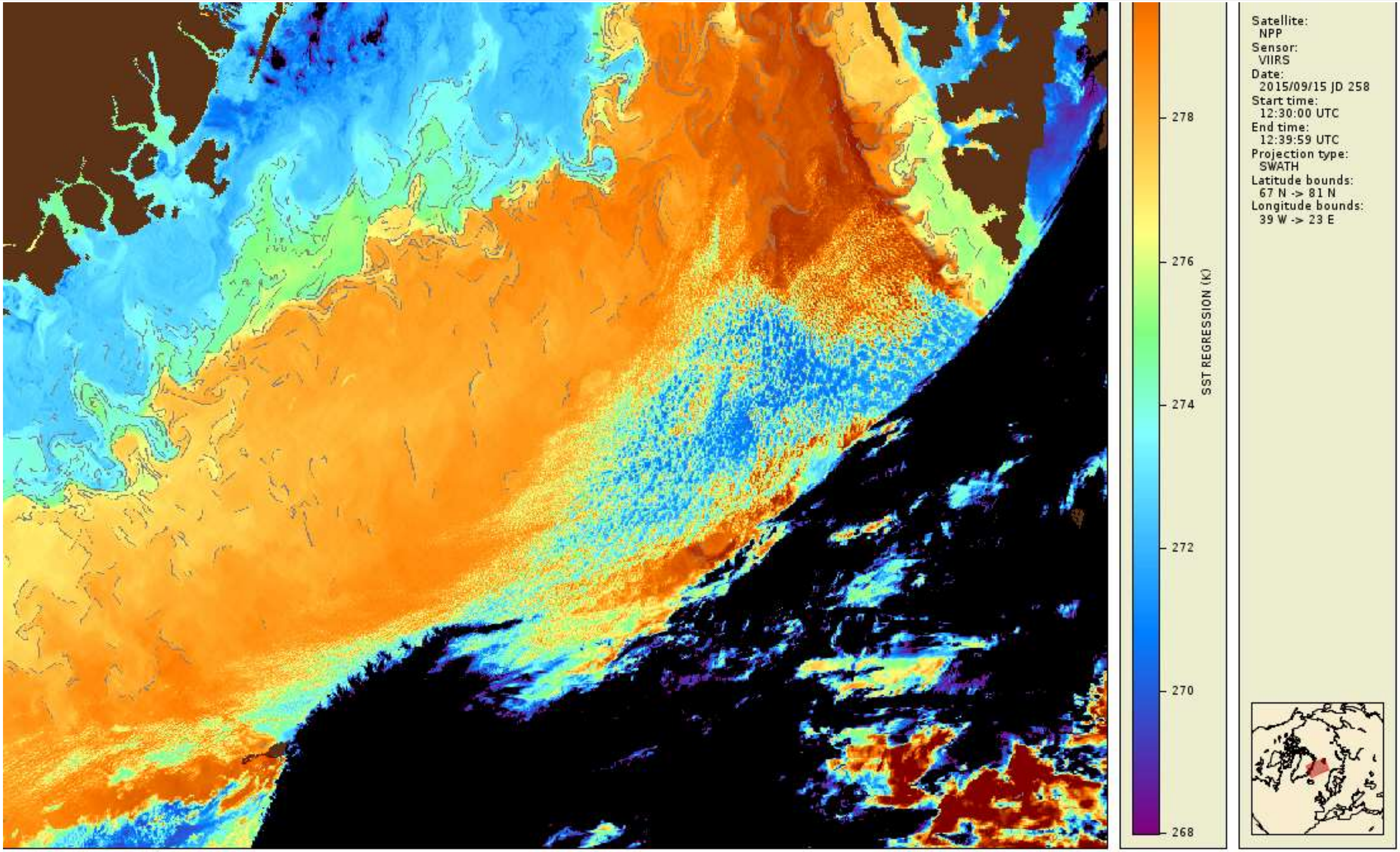
SST with current cloud mask



SST with corrected cloud mask



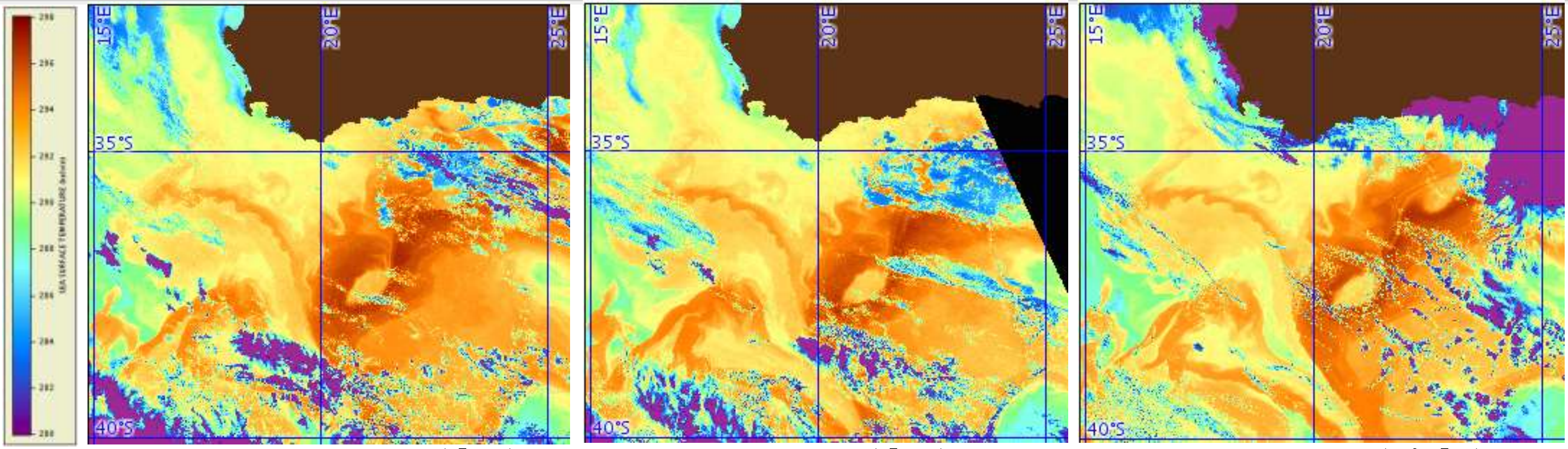
SST with thermal fronts overlaid



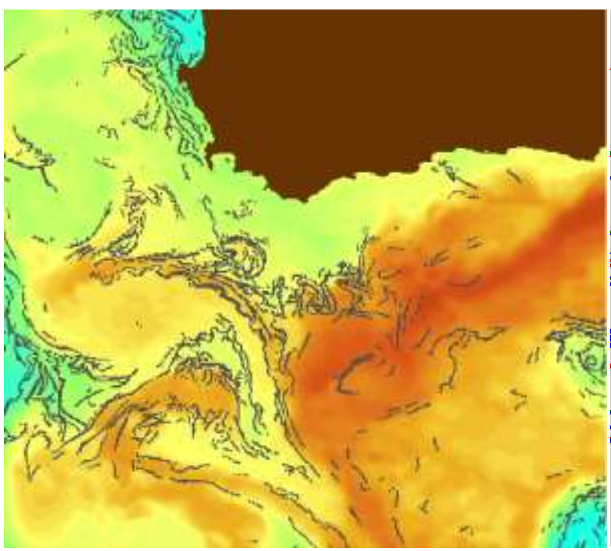
Initial comparisons with L4

- Initial comparisons of L2 fronts with fronts computed on MUR 1km L4 product have been performed;
- Thermal fronts for MUR SST were computed using ArcGIS implementation of SEID algorithm and superimposed with VIIRS SST imagery;
- To facilitate the comparison, ACSPO VIIRS SST and fronts were re-projected to same grid as MUR;
- MUR product in general seems to capture high resolution ocean features
- However in dynamic areas, the fronts are captured better in the original L2 projection.

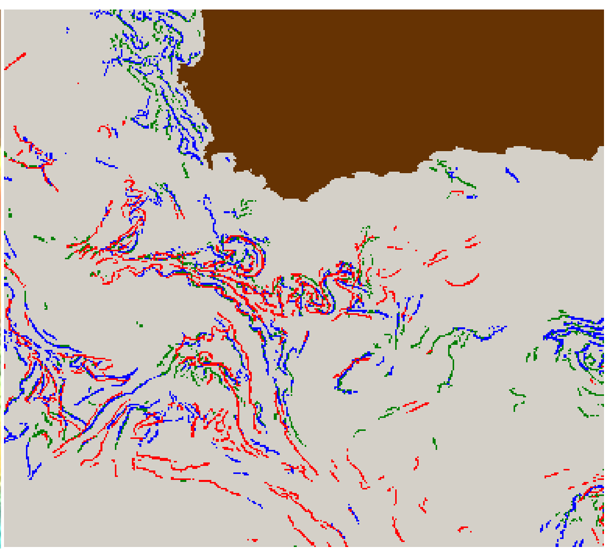
Agulhas, October 18, 2015



3 overpasses: 11:40UTC (day) 13:20UTC (day) 23:00UTC (night)



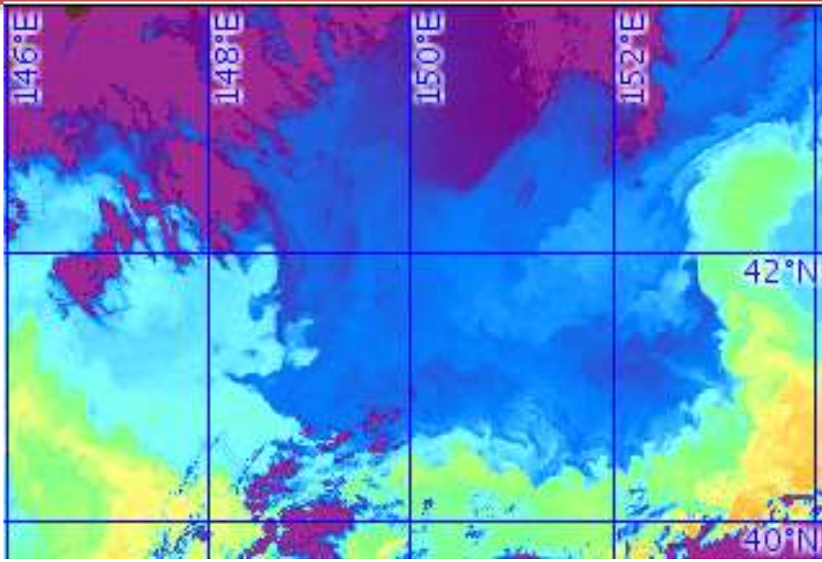
L4 MUR with L2 fronts



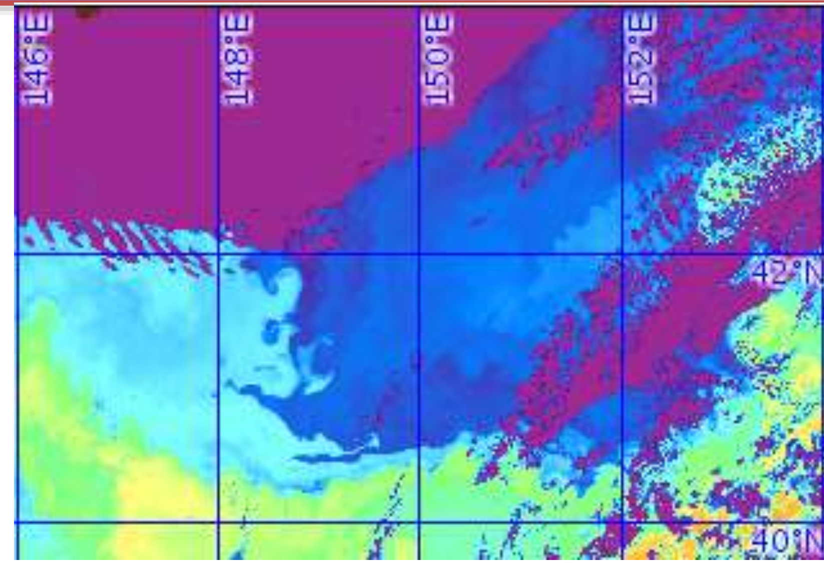
L2 fronts for each overpass

Cloud Mask has false cloud identifications, partially masking dynamic region. Fronts computed from1km MUR L4 daily (not shown) do not agree with L2 fronts in this case.

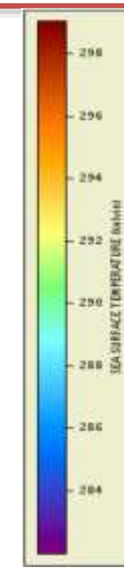
Kuroshio, October 18, 2015

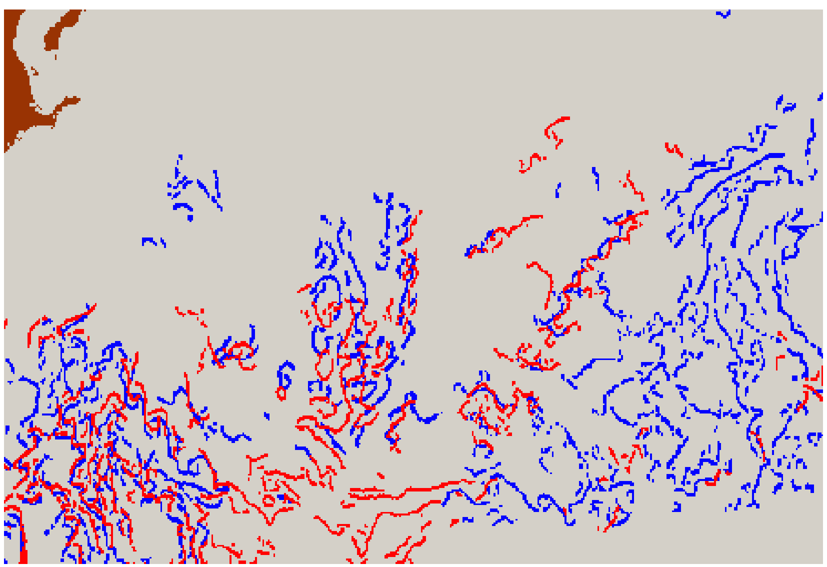


3:40UTC (day)

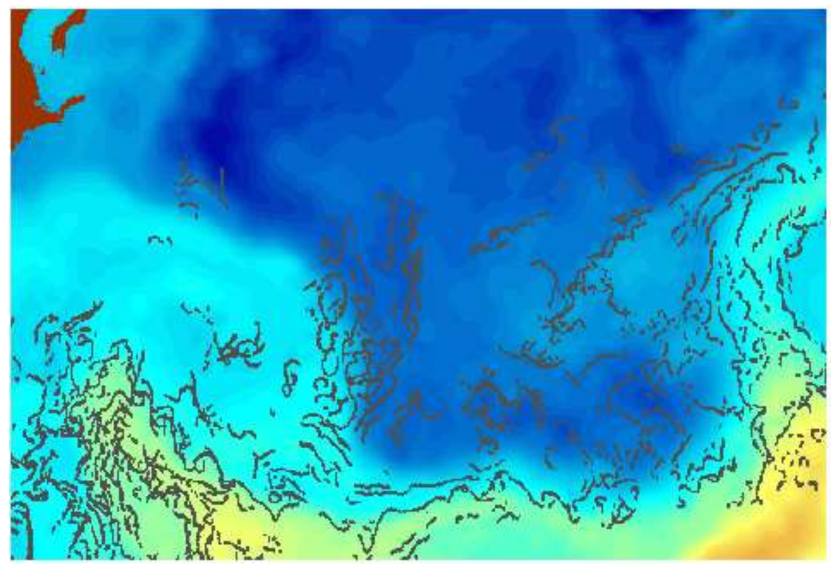


15:50UTC (night)





L2 fronts from 2 overpasses



L4 MUR with L2 fronts

Summary and Future Plans

- **Pending implementation of the bow-tie deletion & correction algorithms with VIIRS and MODIS (ACSPO v2.50), finalize the Ocean Fronts Algorithm and document**
- **Comprehensively test/evaluate the improved ACSPO clear-sky mask**
- **Implement pattern recognition and thermal front detection algorithms in ACSPO v2.60**
- **Work with L4, fisheries, marine biologists and other users to evaluate the effect on their analyses**